Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy

Volume 13 Article 32

January 2010

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Chapter 31

ENCLOSING DIOXINS CONTAMINATED SEDIMENTS BY GEOTEXTILE TUBES

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ABSTRACT

In 2002, Japan enacted environmental standards for dioxins contaminated sediment. A nationwide sediment dioxins survey of public waters found sediment exceeding environmental standards in some rivers: a problem requiring countermeasures. The Eco-tube is a permeable geotextile container with soft and high water content sediment deposited in rivers, lakes, and marshes. It promotes dewatering of the sediment, and the filtering function of the tubes c[§]an purify the drain and enclose toxic substances such as dioxins. After dewatering, they are used to build embankments by taking advantage of their tensile strength. This report describes a trial execution of Eco-tubes that enclose dioxins contaminated sediment. The trial followed preliminary testing: measuring the quantity and turbidity of the drain by pressurized filtering test to examine the geotextile's filtering performance and select the coagulant. Next, 0.2m^3 tubes of the selected material were filled with sediment and used for laboratory experiments based on the actual execution, confirming the dewatering speed and filtering effectiveness of the method. The trial applied 2 patterns (5 cases) based on the test results.

(1) Filling high density tubes with sediment already containing coagulant. (2 cases) (2) Filling tubes with sediment and adding coagulant into drain. (3 cases) Results: (1) Drain of 130pg-TEQ/g dioxins contaminated sediment becomes 2.4pg-TEQ/l. (2) Drain including the 960pg-TEQ/l dioxins went down 0.42pg-TEQ/l by adding coagulant. Pattern (2) was much easier to execute, and more effectively reduced turbidity of the water. The tube height fell to 1/2 to 1/7 of maximum height in about 5 months. These findings confirmed that Eco-tube enclose dioxins contaminated sediment and reduce the volume of sediment by dewatering.

Keywords: geotextile, dioxins, contaminated soil

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1. INTRODUCTION

In Japan, several dioxins contaminated sites have drawn. The proper disposal of dioxins contaminated sediments and soil have become a major problem in recent years. Considering these conditions, the Japanese government made a law called the Law Concerning Special Measures against Dioxins. The Eco-Tube that has been developed jointly by the Public Works Research Institute and private companies as a measure to enclose dioxins contaminated sediments. This method was used to promote dewatering and lower the volume of dioxins contaminated sediments. This report presents the results of field executions and various laboratory experiments.

1.1 The Eco-Tube

The Eco-Tube involves packing a water-permeable geotextile tube with soft and high water content soil such as dredged sediments from rivers, lakes, and marshes (Mori et al. 2002a). Fig. 1 shows the configuration of the Eco-Tube. The Tube after dewatering can also be used as embankments using reinforcement of the geotextile. The water drained from the tubes has low turbidity, because soil particles are retained inside the tubes thanks to the filtration function of the permeable material used to make the tubes. Mori et al. (2002b, 2002c) suggested the utilizing a geotextile tube to trap toxic substances such as dioxins and heavy metals. And also Lawson (2006) given an Example of enclosing contaminated sediment by geotextile tube.

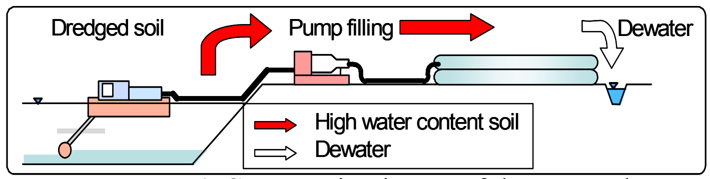

Figure 1. Construction image of the Eco-Tube

Nowadays there are 3 methods adopted for preventing the spread of contamination and each has some problems.

The following are problems of concern regarding past technologies adopted as methods of preventing the spread of contamination by bottom sediments polluted with dioxins. 1) Sand covering method and in-situ stabilization: Increase in the volume is accompanied. And because they are not purification technologies that make the dioxins harmless, contaminated soil may be exposed by construction work. 2) Dredging removal with sediment purification: Soil burning methods, chemical methods, etc. are used, but these are all expensive and time-consuming. 3) Dredging removal with stabilization: Because dredging removal produces a large quantity of surplus water, when the environmental standard is exceeded, purifying the drainage may become very expensive. And the stabilized soil has increased volume, so ensuring a site for disposal of the treated soil is a problem.

The Eco-Tube promotes the dewatering and the lower the volume of contaminated sediments. Therefore it can be used as a low cost method of prevent pollution diffusion.

2. LABORATORY EXPERIMENTS

2.1 Purpose of the Experiments

It is preferable that the water drained from the tubes satisfy wastewater standards (dioxin concentration: 10pg-TEQ/1) without further treatment. Laboratory experiments were done in order to select tube material and coagulant that can satisfy wastewater standards. Advance experiments confirmed that if the turbidity was 20NTU or less, the dioxin concentration was below the wastewater standard, so the turbidity was used as an indicator of the wastewater standard.

2.2 Experiment Samples

Table 1 shows the results of the physical and chemical properties of the experiment specimens. Dioxin concentration was 130pg-TEQ/g that was below the bottom sediment environmental standard (150pg-TEQ/g).

Table 1. Properties of Bottom Sediment

Density of soil particles ρ_s(g/cm^3)		2.533
Water content w(%)		156
Grain size distribution	Gravel (%)	0
	Sand (%)	22
	Silt (%)	51
	Clay (%)	27
	Maximum grain size (mm)	2
Consistency	Liquid limit w_L(%)	78
	Plastic limit w_P(%)	45.9
	Plastic index I_P	32.1
Classification of geomaterials for Engineering purposes		Sandy silt (High liquid limit)
pH		6.67
Ignition loss L_i(%)		8.9
Dioxins (pg-TEQ/g)		130

2.3 The Pressure Filtration Test

2.3.1 Purpose of the Test

It is important that tubes used to enclose contaminated soil reduce the turbidity of water drained from the tubes at the same time as they do not break, discharging the enclosed material. The pressure filtration test was done as an experiment intended to select the tube materials that can be applied to this experiment, because the tube material varies in filtration

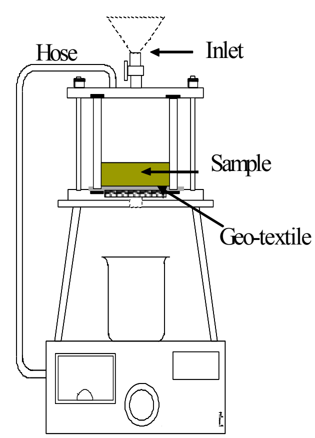

Figure 2. Pressure Filtration Tester

performance and strength according to its standard and its maker. Figure 2 shows the pressure filtration test equipment.

2.3.2 Test Conditions

Table 2 shows the specifications of the tube materials used for the tests and Table 3 shows the test conditions. Tube material was selected considering safety (turbidity capture performance, strength) and cost, and with ① coefficient of permeability in a range of 10^{-2} to 10^{-4}, ② aperture diameter of the tube material within 0.2mm, and ③ elongation of the tube material within 40% (in order to prevent the decline of filtration performance by expansion of the apertures by tension). And the cover factor is an index of the percentage of the tube material surface that is fiber surface: a value dependent on the fiber density and fiber thickness.

Table 2. Tube Material Specifications

Geo-textile	Type A	Type B	Type C
Mass ［g/m^2］	210	260	530
Thickness ［mm］	0.35	0.37	0.69
Tensile strength ［N/cm］	720,720	500,450	740,1470
Elongation ［%］	13,13	40,25	17,13
Ripping Strength ［N］	640,640	150,150	920,1090
Hydraulic conductivity ［cm/s］	1.5×10^{-3}	1.2×10^{-3}	2.6×10^{-4}
Cover factor	1644	2314	2033

※Strength values ; vertical, lateral

Table 3. Pressure Filtration Test Cases

Case	Geo-textile	Flocculant	Water content (%)
1	Type A	-	500
2		PAC	500
3		Anion	500
4		Cation	500
5		PAC + Cation	500
6		Low cation	500
7	Type B	-	300
8			500
9			700
10	Type C	-	300
11			500
12			700

2.3.3 Experimental Results

2.3.3.1 Comparison of Turbidity of Water Drained from the Tube Material

The turbidity of the drainage was compared under conditions such that the water content of the specimen is 500% and coagulant is not added. Figure 3 shows the results. It shows that the turbidity varies by tube material: B < A < C. Beginning thirty minutes after the start of the test, the turbidity in all experimental cases had fallen below 20NTU that is the drainage standard index.

2.3.3.2 Comparison of Coagulants

It confirmed the results for each type of coagulant using tube material A and 500% water content specimen. Figure 4 shows the results. The drainage turbidity fell according to the coagulant, in the order low cation type > PAC + cation type > cation type > PAC > anion type.

2.3.3.3 Comparison of Water Content

Tube materials B and C were used to study the impact of varying the water content between 300%, 500%, and 700%. The results are shown in Figure 5. It confirms that as the water content rose, more water was drained and its turbidity was lower.

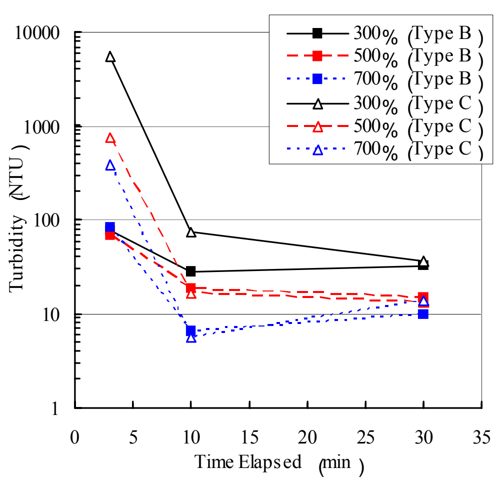

Figure 3. Comparison of Tube Materials

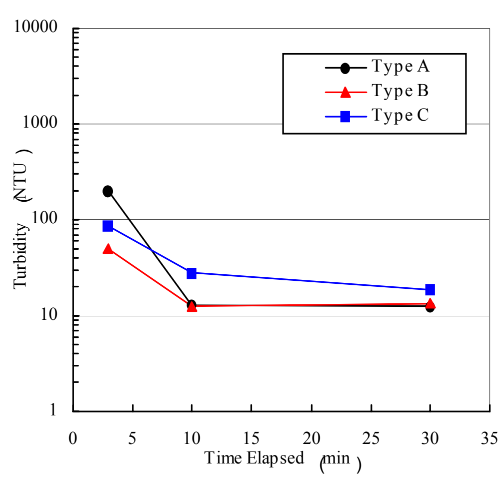

Figure 4. Comparison of Coagulants

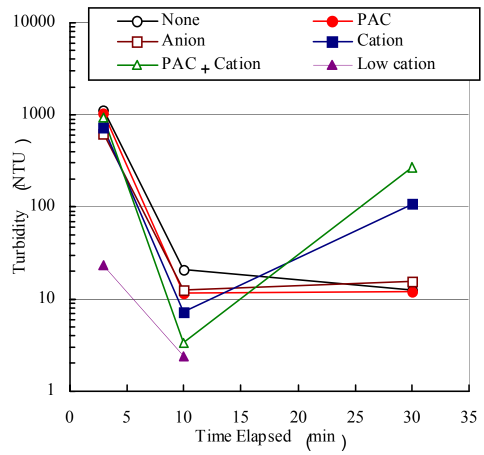

Figure 5. Comparison of Water Contents

2.4 Two-hundred Liter Tube Filling Experiment

2.4.1 Purpose of the Experiment

Two-hundred liter tubes were used for filling experiments to confirm the turbidity capture capacity during actual execution.

2.4.2 Experiment Method

An electric pump was used to fill tubes with specimen with its water content adjusted to 500%. Water drained from the tubes was sampled at periodically to measure the quantity of drainage and its pH. The drainage was collected in 5 liter batches and the turbidity was measured. Table 4 shows the experiment conditions.

Table 4. Experimental case

Case	Geo-textile	Flocculant	Water content (%)
1	A	-	500
2		PAC	
3		PAC + Cation	
4		Low cation	
5	B	PAC	
6		Low cation	
7	C	PAC	

2.4.3 Experiment Results

2.4.3.1 Comparison of Turbidity of Water Drained from the Tubes

A specimen prepared by mixing PAC as the coagulant with bottom sediment was used to fill the tubes and the turbidity of drainage form the tubes was measured. The results are shown in Figure 6. They reveal that the turbidity fell in the sequence: tube material B>C>A. This result differs from the results of the pressure filtration test described in the previous part of this report, but they show that the larger the cover factor, the lower the turbidity.

2.4.3.2 Comparison of Coagulants

Specimens prepared by adding and mixing low cation type, PAC, and PAC + cation type as the coagulant with bottom sediments were used to fill tubes. The tubes used were made of tube material A. Figure 7 shows the results. The turbidity of the drainage fell in the sequence: low cation type > PAC + cation type > PAC > no coagulant. But although the turbidity was low immediately after drain, when it had been left alone for a few hours, all drainage was colored yellow. This is assumed to be an effect of oxidation of iron that was leached out. Figure 8 shows the relationship of the quantity of drainage with the time. From the result of Figure 7 and 8, no clear relationship of the drain speed and turbidity was observed.

2.4.3.3 Adding Coagulant to the Drainage

A tube made of tube material C was filled with bottom sediment (without the addition of coagulant), and then PAC and low cation type coagulants were added to the drainage. Figure 9 shows the results. The turbidity rose in the sequence PAC < low cation type < no coagulant. Looking at the quantity of coagulant that was added, in the case of PAC, up to 10mg/l, the more that was added, the lower the turbidity, but above that level, very little change was seen. With the low cation type, clear characteristics were not confirmed. And unlike the case where the tube was filled with bottom sediment after coagulants were added to it (2), the drained wastewater was not colored even when the drainage was left standing for several days.

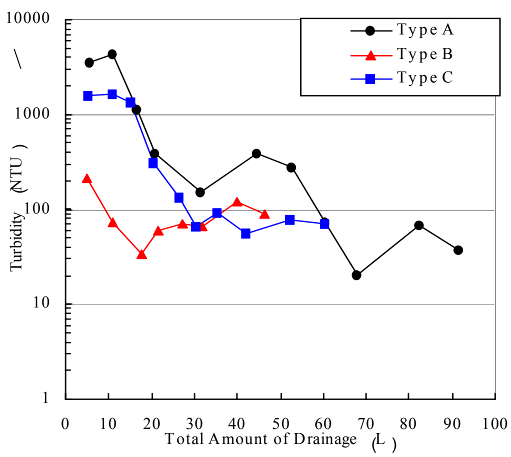

Figure 6. Comparison of Tube Materials

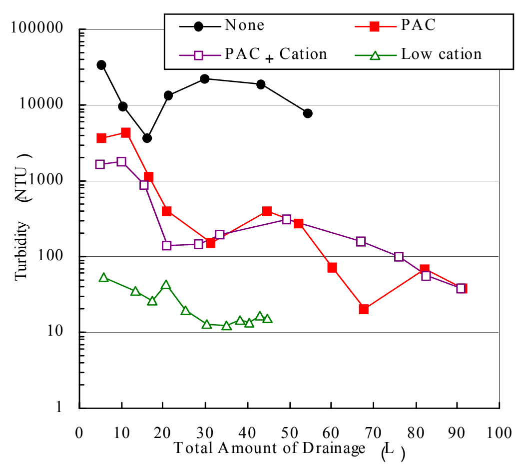

Figure 7. Comparison of Coagulants

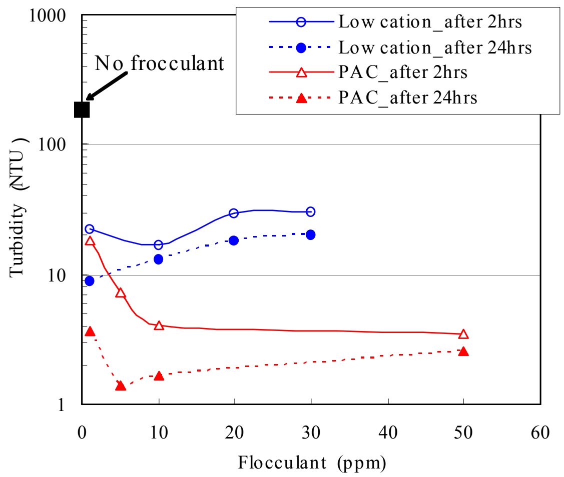

Figure 8. Drain Speed

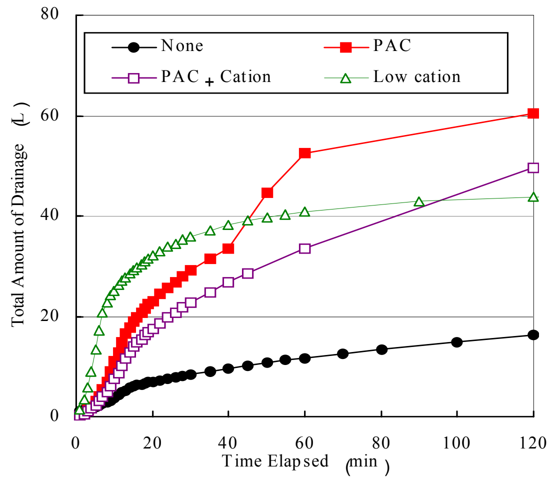

Figure 9. Quantity of Coagulant Added

2.5 Summary of the Laboratory Experiments

The results of the pressure filtration experiments and the 200 liter tube filling experiment show that when the coagulant was directly mixed with the bottom sediment and when it was mixed with the drainage, the turbidity was most effectively lowered by the low cation coagulant and the PAC respectively. And mixing the coagulant with the drainage was easier than mixing the coagulant uniformly with the bottom sediment. The results of the pressure filtration experiment and the 200 liter tube filling experiment differed partially depending on the tube material. So it is vital to select the tube material not only by performing a pressure filtration experiment before the actual execution; but by also performing a filling experiment using a smaller tube such as a 200 liter tube.

3. ONSITE EXECUTION

3.1 Outline of the Execution

The Eco-Tube was applied to approximately 15m^3 of dredged bottom sediment. The execution was performed by applying two patterns with differing coagulant addition methods based on the results of the laboratory experiments. Figure 10 is a flow chart of the execution. The water drained from the tubes was stored temporarily in a tank where its dioxins concentration was measured, and if it was confirmed that it satisfied the wastewater standard (10pg-TEQ/1), it was released. Photo 1 shows a view of the execution and Figure 11 shows a section of the tube installation. The tube material was tube material B in Case 1 and tube material C in Case 2. In Case 2, the bottom sediment was filled in the tube by the pattern shown in Table 5 in order to confirm the impact of differences in the quantity filled and the water contents of the specimen.

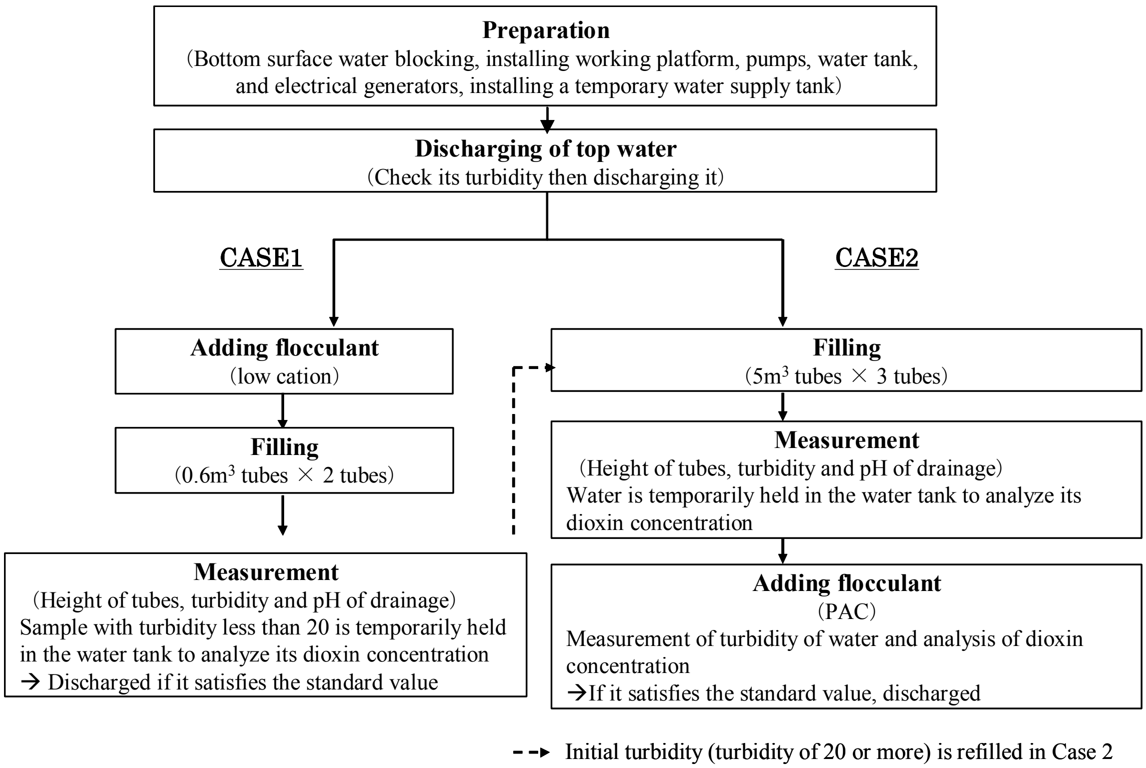

Figure 10. Execution Flow Chart

Table 5. Case 2 Experiment Pattern

CASE	Height of Tubes / Quantity filled	Water content condition
CASE2-1	70cm / 5.0m^3	High
CASE2-2	60cm / 4.3m^3	High
CASE2-3	48cm / 3.7m^3	Low

Photo 1. View After Execution

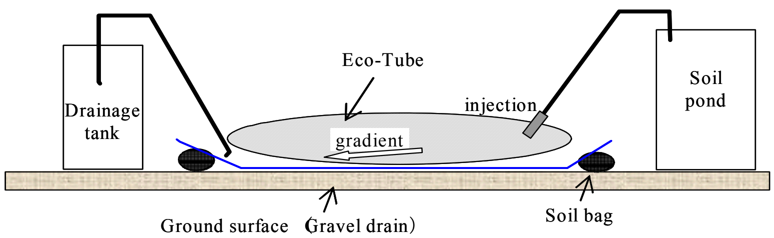

Figure 11. Cross Section of Tube Installation

3.2 Items Measured and Measurement Results

The turbidity and pH of the water drained from the tubes and the height of the tubes were measured from the start of execution. The height and water content of the tubes, and the cone penetration resistance were surveyed continually in order to confirm the way the bottom sediment changed after it was placed in a tube.

3.2.1 Turbidity of the drainage

Figure 12 shows the results of the measurements of the turbidity of the drainage. In Case 1, the turbidity fell below 20NTU that is the control standard at about 60 minutes after the start of filling (about 30 minutes after the pump stopped operating). And the dioxins concentration of the drainage stored in the water tank was 2.4pg-TEQ/l (SS: 13mg/l). It was, therefore, the drainage standard is satisfied confirmed except the initial turbidity that occurred until the mud membrane is formed in a tube and filtration function became effective (here, this refers to drainage with turbidity of 20NTU or more) is removed.

In Case 2, as shown by Photo 1, the turbidity remained almost unchanged without any decline in Case 2-2. And in Case 2-1 where the conditions of the specimen filled was almost the same, the turbidity fell to about 20NTU that is the control standard as shown in Figure 12. This difference is assumed to be based on the quantity filled. In Case 2-2, it was confirmed that air was trapped at a location far from the inlet, and water with high turbidity continued to be drained from this part. As a result of collecting drainage in Case 2 in a water tank, adding PAC as the coagulant, letting it settle, then measuring the dioxins concentration, drainage that was 960pg-TEQ/l (SS: 2020mg/l) before addition of the coagulant fell to about 0.42pg-TEQ/l (SS: mg/l).

3.2.2 Tube Height

Figure 13 shows change of tube height over time. In all cases, the tube height fell as dehydration reduced its quantity. In Case 1, it fell to about 1/3 in both cases. And in Case 2-1, Case 2-2, and Case 2-3, it fell to about 1/7, 1/6, and 1/2 respectively.

3.2.3 Water Content

Specimens inside the tubes were sampled and their water content measured at about 40 days after filling and at about 150 days after filling. Figure 14 shows the results. In all cases, no significant change was found between 40 days and 150 days after filling. The water content of the specimens of soil that filled the tubes was wide, ranging from 100% to 400%, but 150 days later it ranged from 50% to 90% in all cases. For this reason, it was confirmed that the water content declined to a stipulated level regardless of the water content conditions of the filled specimens.

3.2.4 Cone Penetration Resistance

Like the measurements of the water content of the specimens, the cone penetration tests were done at 40 days and at 150 days after filling. Figure 15 shows the results. At 150 days after filling, in almost all cases, strength became more than 200kN/m2. In Case 2-2 and Case 2-3, the strength after 150 days was lower than it was after 40 days. This is assumed to be an impact of differences between test locations.

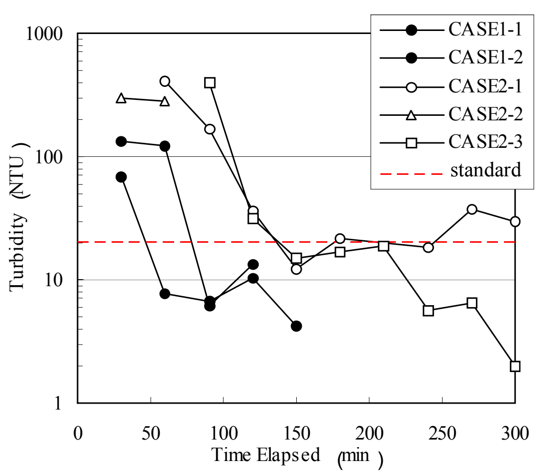

Figure 12. Turbidity of drainage

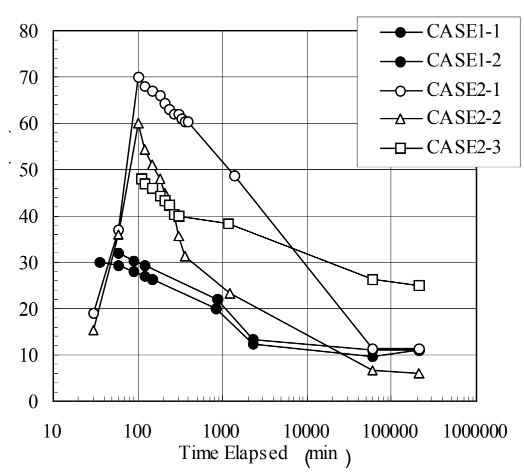

Figure 13. Tube Height

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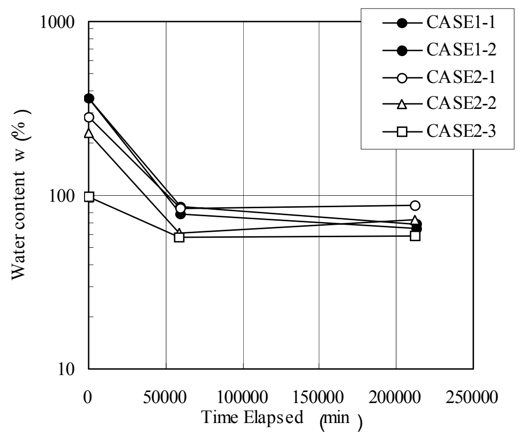

Figure 14. Water Content

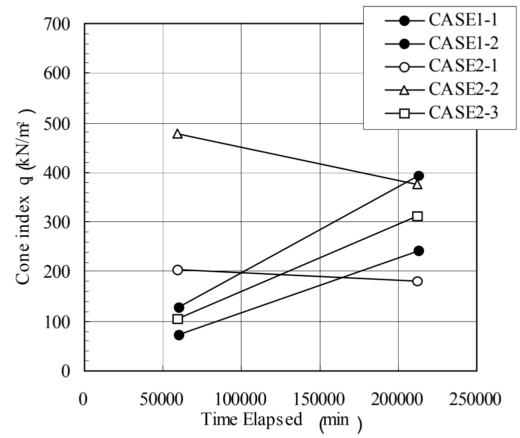

Figure 15. Cone Insertion Resistance

3.3 Summary of the Onsite Execution

The results of the execution reveal that there are cases where the mud membrane that was expected to form on the interior of the tube during the early stage of dehydration cannot form and the filtration function cannot be fully performed, because of differences in the quantity of bottom sediment and its water content. In this way, in cases where the water drained from the tube does not satisfy the control standards, coagulant should be added to the water that is drained from the tube to remove turbidity from the drainage.

4. CONCLUSIONS

The results of the laboratory experiments and the onsite executions have confirmed that the Eco-Tube encloses dioxin contaminated sediment and dehydrates bottom sediment reducing its quantity, and have also confirmed that it is effective as a contamination spread prevention method that will cover the shortcomings of the sand covering method, the stabilization method, and the dredging removal methods that are the conventional ways of preventing the spread of contaminants from bottom sediment that has been contaminated by dioxins.

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