Environmental Geotechnics, Sêco e Pinto (ed.) © 1998 Balkema, Rotterdam, ISBN 90 5809 006 X

Sedimentation and consolidation of lake-bottom deposits with an organic flocculant

Y. Sugawara & H. Akagi
Waseda University, Tokyo, Japan

H. Komine
Central Research Institute of Electric Power Industry, Chiba, Japan

ABSTRACT: In closed water environments such as lakes or marshes, soil and organic materials deposit at the bottom. In order to solve problems of land smells or water pollution, bottom deposits have been dredged or stabilized with cement. Recently, the reuse of lake-bottom deposits for agricultural compost has been planned, but an efficient flocculation and dewatering method for high water content lake deposits is necessary for this to be implemented. In this study, a series of sedimentation experiments and consolidation tests on lake-bottom deposits dredged from a closed water environment lake were carried out using an organic flocculant. It is shown from the experimental results that an optimum volume of flocculant does exist for efficient sedimentation and that the addition of flocculant improves the dewatering characteristics of lake-bottom deposits.

1 INTRODUCTION

In closed water environments such as lakes and marshes, soil and organic materials deposit at the bottom. They are often responsible for bad smells and water pollution problems. In order to solve these problems, the bottom deposits have been dredged or stabilized with cement. However, it has become difficult to find a disposal place for dredged materials. It is important to reuse these dredged materials for a variety of purposes, e.g. ceramic materials or construction materials. Because the bottom deposits generally contain an abundance of organic matter, it is assumed that these dredged bottom deposits would be suitable for reuse as an agricultural compost.

Lake-bottom deposits generally have a high water content and are dispersed after being dredged. An efficient flocculation and dewatering method is therefore necessary for its utilization. In the case of usual treatments of a slurry or suspension, organic and inorganic flocculants are often used together. However, the high valency metallic ions contained in an inorganic flocculant are assumed to be harmful to vegetation, which is problematic if dredged materials are to be used as an agricultural compost. In contrast, an organic high polymer flocculant has been used as a soil improvement agent in agriculture.

Consequently, an organic high polymer flocculating agent (polyacrylamide) was adopted as flocculant in this study. A series of sedimentation experiments and consolidation tests were carried out on lake-bottom deposits dredged from a closed water environment lake using an organic high polymer flocculant.

2 EXPERIMENTAL PROCEDURE

2.1 *Samples and Flocculating agent used*

The lake-bottom deposit samples used in this study were dredged from the three different places at TEGANUMA lake, Abiko city, Chiba, Japan(Fig.1). TEGANUMA lake is a closed water environment whose COD (chemical oxide demand) value is the highest in Japan. The physico-chemical properties of the dredged bottom deposit samples are listed in Table1. Samples No.1 and No.2 were used in the sedimentation experiments, and sample No.3 was used in the consolidation test.

Figure 1. The location of TEGANUMA lake

The flocculating agent used in this study was a mixture of polyacrylamide (nonionic) and acetate (anionic) solutions. The concentration of each flocculating agent solution was 0.1% by weight. The mixing ratio of the acetate solution was one-fifth of that of the polyacrylamide solution.

2.2 *Sedimentation Experiments*

In the sedimentation experiments, the dredged lake-bottom deposits were mixed with distilled water. The polyacrylamide and acetate solutions were added to a suspension of dredged lake-bottom deposits. The time-dependent variations of the sedimentation face (the interface between solid sediments and water phase) and the absorbancy (optical density) of the water phase were measured. The additive volume of two types of flocculating agents were varied, and changes in the sedimentation rate and absorbancy of the water phase were observed.

The relationship between the absorbancy value and the SS (suspension solid) concentration of soil particle suspension was obtained by preparing suspensions of several known concentrations and measuring their absorbancy values (Fig.2). It can been seen in Figure 2 that the absorbancy value increases as its SS concentration increases. The water contents of the sample suspensions at the beginning of the sedimentation experiments were 372.0(%) (sample No.1) and 554.3(%) (sample No.2), respectively.

The procedure for the sedimentation experiments was as follows:

1) To take 30 ml of lake-bottom deposits in a 100 ml measuring cylinder and increase the volume to 50 ml with the addition of distilled water.

2) To add a specified volume of polyacrylamide into 1) and shake the measuring cylinder upside-down 10 times.

3) To add a specified volume of acetate into 2) and shake the measuring cylinder upside-down 10 times.

4) To increase the volume of the sample suspension to 100 ml with the addition of distilled water.

5) To shake the measuring cylinder upside-down 10 times and then to let it rest quietly on a horizontal table.

6) To take the scale reading of the measuring cylinder at the sedimentation interface at fixed time intervals.

7) To extract a part of the upper water phase and to measure its absorbancy value at the end of sedimentation experiment.

2.3 *Consolidation Tests*

The oedometric consolidation tests for the dredged lake-bottom flocs obtained from sedimentation tests

Table 1. Physico-chemical properties of the sample used.

sample	No.1	No.2	No.3
density ρ_s (Mg/m^3)	2.46	2.47	2.59
liquid limit w_L (%)	96.7	105.5	58.5
plastic limit w_p (%)	71.6	76.7	41.9
plasticity index I_p	25.1	28.8	16.6
CEC* (meq/100g)	337.1	355.9	200.8

* Cation Exchange Capacity

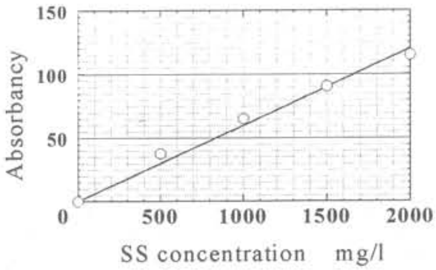


Figure 2. The relation between absorbancy and SS concentration

were carried out using both samples with and without a flocculating agent under incremental loading sequences. At the beginning of consolidation tests, the water contents of the sediment samples were 104.6(%) (with flocculant) and 105.1(%) (without flocculant), respectively.

The consolidation test procedure for the sediment sample with flocculant was as follows:

1) To take 300 ml of lake-bottom deposits in a 1000 ml measuring cylinder.

2) To add 60 ml of polyacrylamide into 1) and shake the measuring cylinder thoroughly.

3) To add 12 ml of acetate to 2) and shake the measuring cylinder thoroughly.

4) To increase the volume of the sample suspension up to 1000 ml with the addition of distilled water.

5) To retrieve the accumulated bottom substances floc and put them into the oedometer ring.

6) To begin the incremental loading on the samples in the oedometer.

3 EXPERIMENTAL RESULTS AND DISCUSSION

3.1 *Sedimentation Experiments*

Figure 3a shows the time-dependent variations of the sedimentation face of sample No.1 suspensions with different additive volumes of flocculants. The settling rate of the sedimentation interface increased as the additive volume was increased up to 8 ml. When the additive volume became more than 8 ml, the settling

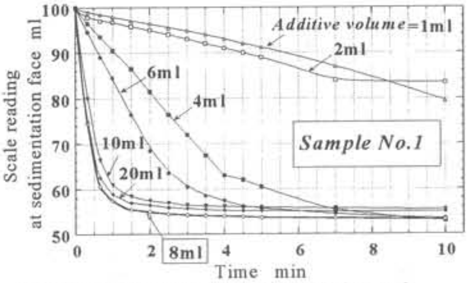


Figure 3a. Time-dependent variations of sedimentation face (sample No.1)

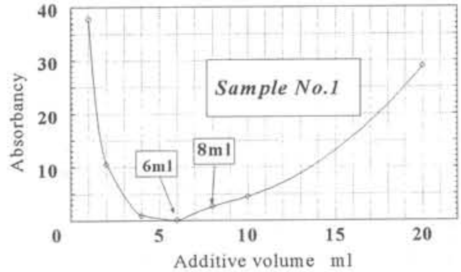


Figure 3b. The relationship between absorbancy and additive volume (sample No.1)

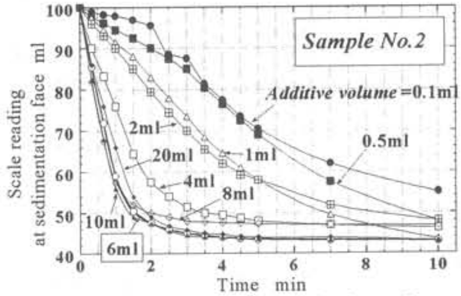


Figure 4a. Time-dependent variations of sedimentation face (sample No.2)

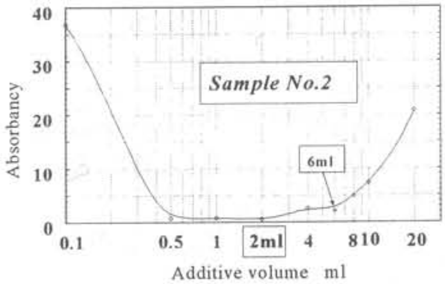


Figure 4b. The relationship between absorbancy and additive volume (sample No.2)

rate tended to decrease slightly with further increases in the additive volume. Figure 3b demonstrates the relationship between the absorbancy (optical density) of the water phase and the additive volume of flocculant. The absorbancy value decreased as the additive volume was increased up to 6 ml. The absorbancy reached a minimum value at 6 ml and then increased again with further increases in the additive volume.

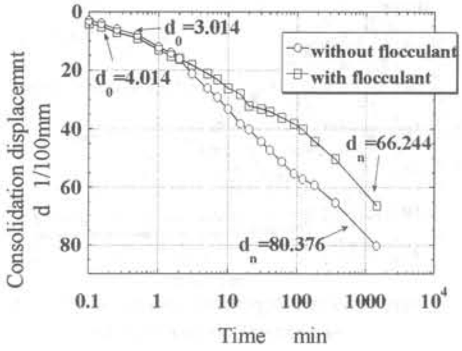
Similar relationships for sample No.2 suspensions are shown in Figure 4a and Figure 4b. A similar tendency as that observed for the sample No.1 suspensions was identified in the variations of the settling rates for sedimentation interfaces and the absorbancy of the water phase with changes in the additive volume of flocculant. The settling rate tended to decrease as the additive volume became more than 6 ml and the absorbancy became a minimum value at 2 ml.

It was found from the sedimentation experimental results that there were optimum additive volumes of flocculating agent for both settling rate and the absorbancy, but that these volumes were not the same. When the additive volume of flocculant was small, the dispersed clay particles in the lake-bottom deposits remained in suspension due to poor flocculation. Consequently, the settling rate for the sedimentation interface was small and the absorbancy of the water phase was large. When the additive volume was too large, the clay particles were dispersed due to the excess addition of flocculant. Therefore, the settling rate for the sedimentation interface was decreased and the absorbancy increased again.

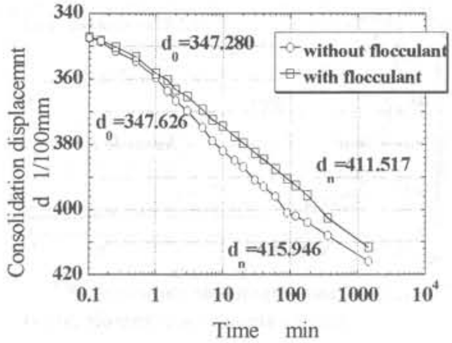
3.2 *Regulations for discharge during the dewatering process*

According to Japanese regulations with regard to the discharge from the dewatering process of dredged materials, the SS concentration of the discharge shall be less than 200 (mg/l) or 600 (mg/l). From Figure 2, it can be seen that the absorbancy value of the sample suspension is approximately 10 at 200 (mg/l) of SS concentration, which is the lower limit for Japanese regulation for SS concentration. It is possible to reduce the absorbancy value of the water phase discharged from the dredged lake-bottom deposits below 10, if the flocculant is added properly, as shown in Figures 3b and 4b.

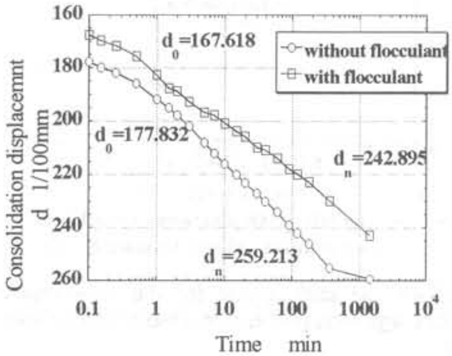
The turbidity of the water phase discharged from flocculating sediments with the organic flocculant has been found to be generally greater than that of the discharged water phase, when using an inorganic flocculant. From these experimental results, however, it was found that the turbidity of the discharged water phase using an organic flocculant is much lower than that required by Japanese regulations. The water phase obtained from the suitable addition of an organic flocculant to the suspension of the dredged lake-bottom deposits can therefore be discharged from the treatment plant.



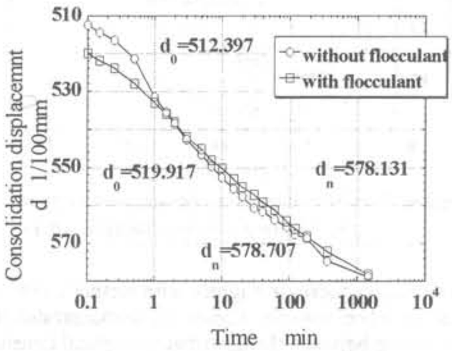
(a) p=10 kN/m^2



(c) p=160 kN/m^2



(b) p=40 kN/m^2

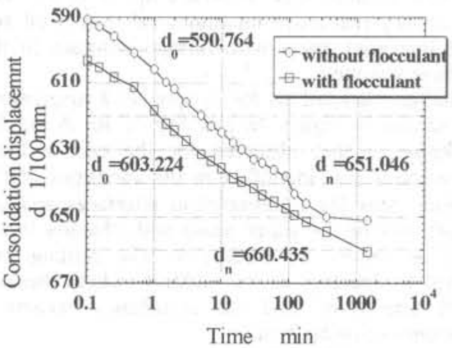


(d) p=640 kN/m^2

3.3 *Consolidation Tests*

Figures 5 illustrate the time-dependent variations in the consolidation displacements from the oedometric consolidation tests using the accumulated flocs both with and without flocculating agent under different consolidation pressures. It was found from a series of these oedometric consolidation tests that as the consolidation pressure increased, the magnitude and the rate of the consolidation displacement became greater for the sample with flocculant than for the sample without.

Table 2 shows a comparison of the permeability coefficients of the accumulated flocs calculated from the consolidation test results. The permeability coefficients of the sample with flocculating agent was found to be larger than that of the sample without flocculant.



(e) p=1280 kN/m^2

Figures 5. Time-dependent variations of consolidation displacement for sediment with and without an organic flocculant

Table 2. Comparision of the permeability coefficients.

mean consolidation pressure p (kN/m^2)	k (m/sec) without flocculant	k' (m/sec) with flocculant	k'/k
5. 0	2.88×10^{-9}	1.95×10^{-8}	6. 8
1.4×10	1.02×10^{-8}	2.00×10^{-8}	2. 0
2.8×10	6.29×10^{-9}	1.98×10^{-8}	3. 2
5.6×10	3.12×10^{-9}	8.77×10^{-9}	2. 8
1.1×10^{2}	1.55×10^{-9}	1.54×10^{-9}	1. 0
2.2×10^{2}	8.15×10^{-10}	7.53×10^{-10}	0. 9
4.4×10^{2}	6.14×10^{-10}	4.43×10^{-10}	0. 7
8.8×10^{2}	3.55×10^{-10}	1.20×10^{-9}	3. 4

Table 3. Comparison of the time required for dewatering by filter-press (hr)

mean consolidation pressure p(kN/m^2)	Cv (m^2/sec) (without flocculant)	**t (hr) (without flocculant)**	Cv (m^2/sec) (with flocculant)	**t (hr) (with flocculant)**
5.0	5.08×10-7	**2.9**	4.17×10-6	**0.4**
1.4×10	1.47×10-6	**1.0**	3.18×10-6	**0.5**
2.8×10	1.78×10-6	**0.8**	5.85×10-6	**0.3**
5.6×10	1.83×10-6	**0.8**	5.27×10-6	**0.3**
1.1×10^2	1.70×10-6	**0.9**	1.74×10-6	**0.8**
2.2×10^2	1.75×10-6	**0.8**	1.79×10-6	**0.8**
4.4×10^2	2.14×10-6	**0.7**	1.81×10-6	**0.8**
8.8×10^2	2.52×10-6	**0.6**	1.06×10-5	**0.1**

3.4 *Trial design calculation for filter-press system*

The dredged lake-bottom deposits may be dewatered in the plant system using a filter-press to reduce the volume or to decrease the water content. In this section, the trial design calculation for the filter-press system is performed to obtain the time interval required for dewatering.

Because the dewatering phenomena in the filter-press system are similar to the consolidation phenomena of saturated clay, the following equation can be used for the calculation of the required time interval for dewatering:

$$\frac{c_v t}{H^2} = \frac{T_v}{36} \times 10^{-8} \qquad (1)$$

in which c_v is the coefficient of consolidation obtained from the consolidation test (m^2/sec), t is the time interval required for dewatering (hr), H is one-half of the filter thickness (mm), and T_v is the time factor. Assuming that the filter thickness is 50 (mm) and the degree of consolidation is U=90%, then H = 25 (mm) and T_v= 0.848. The calculation results are listed in Table 3.

It can be seen in Table 3 that the time interval required for dewatering the materials with flocculant is shorter than that for materials without flocculant. Therefore, the suitable addition of flocculating agent is expected to improve the dewatering efficiency of a filter-press system. For example, the required time interval for dewatering in the filter-press system is reduced from approximately 0.8 (hr) to 0.3 (hr) with the addition of flocculant. It should be possible to use a filter-press system to reduce the flocculated sediment volume of lake-bottom deposits.

Based on the results of this study, it is plausible that dredged lake-bottom deposits can be reused as agricultural compost materials, because the flocculation and dewatering efficiency can be improved by the addition of an organic high polymer flocculant.

4 CONCLUSIONS

It can be concluded from the sedimentation experiments and the consolidation tests for the suspensions of dredged lake-bottom deposits with or without flocculant that:

(1) Optimum additive volumes of flocculating agent exist for the settling rate and absorbancy of sedimentation interface.

(2) It is possible to reduce the absorbancy value of the water phase discharged from dredged lake-bottom deposits below 10 with the proper addition of an organic flocculant.

(3) The permeability coefficient of the sample with flocculating agent is larger than that of the sample without flocculant.

(4) The suitable addition of organic flocculating agent is expected to improve the dewatering efficiency of a filter-press system.

It is therefore plausible to reuse dredged lake-bottom deposits as agricultural compost materials, because the flocculation and dewatering efficiency is expected to be improved by the addition of an organic high polymer flocculant.

It is acknowledged that a part of this study was financially assisted by Chemical Grout Corp.

REFERENCE

Abiko city agency 1994. *Annual reports on environmental issues*: 26-28. (in Japanese)