A DEWATERING TEST OF DREDGED SOIL WITH HIGH WATER CONTENT (PART 3)

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1. INTRODUCTIONS In order to transport, dispose and recycle dredged soil with high water content, it is very effective to dewater the soil. A vacuum-induced consolidation method for dewatering quickly the soil, which is poured into a container such as a bag and a soil bin, was proposed and the availability of the method was investigated (Umezaki et al. 2003, 2004 & 2005).

In this paper, a series of dewatering tests using small sizes of soil bin and actual vertical drains were carried out. Based on the results, influence of distance between drains and new methods to reduce water content further and to remove easily soil adhered on drain surface are discussed.

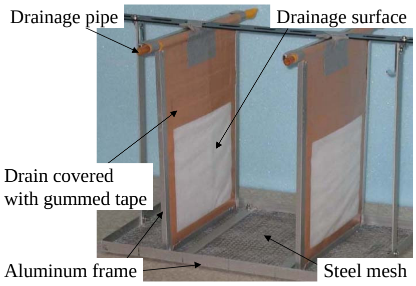

Photo 1 An example of vertical drains (Case 2(a) & 2(b))

2. DEWATERING TEST Soil sample was obtained by dredging the bottom of Ube Port in Ube City, Yamaguchi, Japan. The physical properties of the soil are as follows: ρ_s=2.614 g/cm^3, w_L=79.8%, w_p=31.9%, I_p=47.9, CF=43.0%, MF=29.3% and SF=13.3%, where CF is the clay fraction, MF is the silt fraction, and SF is the fine sand fraction. The soil was fully mixed at initial water content, w_0=289.9-295.5%, which is about 3.6-3.7 times w_L. This assumed the consistency of muddy water.

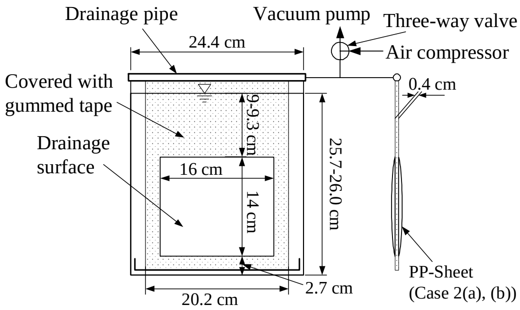

Figure 1 Conditions of dewatering test

Photo 1 shows an example of vertical drains used here. A miniature vertical drain with $b\approx$20.2 cm wide by $h\approx$27.0 cm high by $d\approx$0.45 cm thick is made from an actual prefabricated drain, which is called C-Drain. The drain is reinforced with aluminum frame not to bend. The bottom edge of the drain is sealed with gummed tape and the top edge is fixed to drainage pipe with ϕ_1=1.0 cm of outer diameter. One end of pipe is sealed and another end is connected to a vacuum pump, as shown in **Figure 1**. The both surfaces of the drain are covered with gummed tape as shown in **Figure 1**, in order to set drainage area of one side to $14\text{cm}\times16\text{cm}$. The area of drainage surfaces of one drain is $14\text{cm}\times16\text{cm}\times2$=0.0448 m^2. After the drains were placed in the soil bin, the dredged soil was poured into the soil bin. Initial height of the soil is h_0=25.7-26.0 cm and the soil layer of 9-9.3 cm thick from the soil surface acts as airtight layer as shown in **Figure 1**. The soil sample was added during the test in order to ensure the thickness of the airtight layer. The soil bin tests were carried out for 2 or 3 hours. **Table 1** shows test cases, where M_0 is initial soil mass poured into the soil bin. In Cases 1(a) and 1(b), 6 and 2 drains were arranged, respectively, in order to investigate influence of distance between drains. In Cases 2(a) and 2(b), drainage surfaces were covered with polypropylene sheet (PP-Sheet). After release of vacuum pump, the PP-Sheet was expanded by air pressure of 9.8 kN/m^2, in order to remove the soil adhered on drain surfaces. In Case 2(b), after vacuum pressure was applied for 2 hours in muddy water, the drains were picked out from the soil bin and vacuum pressure was applied for further 1 hour in air. During all tests, mass of dewatering, ΔM, height of the soil surface, h, and vacuum pressure, p_v, were measured.

Table 1 Test cases

Cases	Drain	Distance between drains	Duration of test	w_0 (%)	M_0 (kg)
1(a)	C-Drain	6 cm	3 hrs in muddy water	292.8	27.32
1(b)	C-Drain	17.8 cm	3 hrs in muddy water	289.9	28.36
2(a)	C-Drain +PP-Sheet	17.8 cm	2 hrs in muddy water	293.2	28.20
2(b)	C-Drain +PP-Sheet	17.8 cm	2 hrs in muddy water + 1 hr in air	295.5	28.20

3. TEST RESULTS AND DISCUSSIONS **Figures 2(a)–2(c)** show changes of h, p_v and ΔM^* with time, where ΔM^* is mass of dewatering per unit surface area of drain. The thicknesses of the airtight layer are always kept over 6 cm during all tests, so that the values of $p_v\approx-93\text{kN/m}^2$ are kept until end of all tests. The changes of ΔM^* are almost same in all cases except Case 2(b). It is clear that there are hardly both influences of changing distance between drains and covering the drain surface with PP-Sheet on changes of h, p_v and ΔM^*, when the distance is longer than the total thickness of soil adhered on both surfaces of drain, d_s=2.0-2.8 cm (see **Photo 2**). **Table 2** shows test results, where M_d and M_S are wet mass and dry mass of dewatered soil per unit surface area of drain, and $\overline{w}$ is mean water content of dewatered soil, respectively. The values of

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$\overline{w}$ in Cases 1(a), 1(b) and 2(a) are almost equal in spite of duration of dewatering. On the other hand, the values of M_d and M_S in Case 2(a) are smaller than those in Cases 1(a) and 1(b), because the duration of dewatering in muddy water in the former is shorter than those of the latter. In Case 2(b), after drains picked out from soil bin, $p_v \approx -93\text{kN/m}^2$ is kept until 150 minutes. Due to occurrence of cracks on the surface of dewatered soil, p_v decreases to about -43kN/m^2 as shown in **Figure 2(b)**. The change of ΔM^* in Case 2(b) is almost same as those in the other cases before crack occurs. The change of ΔM^* after crack occurs becomes smaller than those in the other cases. The value of M_S in Case 2(b) is almost same as that in Case 2(a) and that of $\overline{w}$ in Case 2(b) is smaller than those in the other cases as shown in **Table 2**.

Figure 3 shows relationships of $\overline{w}$ to p and p', respectively, where p is consolidation pressure and p' is effective stress. NCL* is the line which is determined by extrapolating test result obtained from one-dimensional consolidation test using incremental loading (JIS A 1217). The values of $\overline{w}$=99.0-107.2% in Cases 1(a), 1(b) and 2(a) are corresponded to those of p'=0.39-0.95 kN/m^2 on NCL* and they are much smaller than consolidation pressure, p_1=93 kN/m^2. In these cases, degrees of consolidation, $U_p = (p'/p_1)\times 100\%$, are below about 1% and dewatering due to vacuum consolidation (VC) hardly progresses during 2 or 3 hours. When the value of U_p becomes 100%, that of $\overline{w}$ is corresponded to about 60%. However, it takes very long time to reach $U_p \approx 100\%$. On the other hand, the value of $\overline{w}$ after 3 hours in Case 2(b) is $\overline{w}$=75.5% which is smaller than w_L, and it is corresponded to those of p'=15.4 kN/m^2 and $U_p \approx 17\%$. Moreover, the value of w where cracks occurred in Case 2(b) is w=70% and it is corresponded to those of p'=29 kN/m^2 and $U_p \approx 31\%$. In this case, the soil becomes the unsaturated condition due to through-flow drying. Therefore, dewatering effect is enhanced further by applying p_v in air.

The left side of **Photo 2** is dewatered soil adhered on vertical drain at end of the test in Case 2(b). By applying air pressure into the drain on the right side in **Photo 2**, the soil can be removed instantaneously and hardly remain on the drain.

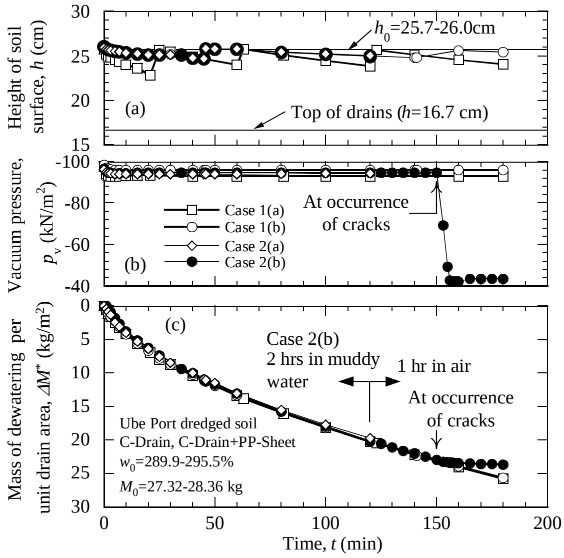

Figure 2 Changes of h, p_v, ΔM^* and $\overline{w}$ with time

Table 2 Test results

Cases	M_d (kg/m^2)	$\overline{w}$ (%)	M_S (kg/m^2)
1(a)	32.6	107.2	15.7
1(b)	32.1	99.3	16.1
2(a)	24.7	99.0	12.4
2(b)	23.9	75.5	13.6

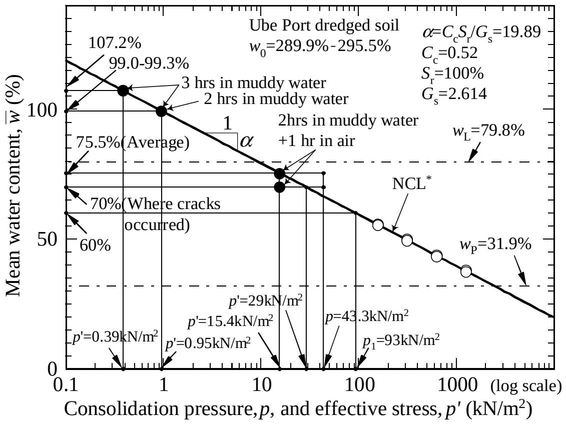

Figure 3 $\overline{w}$ -p and $\overline{w}$ -p' relationships

Photo 3 shows dewatered soil which is removed from the drain in Case 2(b). The soil is hard, so it does not bend when it is lifted by hand.

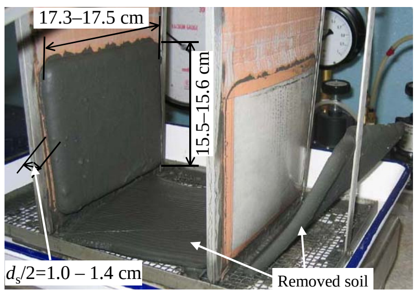

Photo 2 Removal of soil from drain in Case 2(b)

5. CONCLUSIONS The soil bin tests for dewatering the dredged soil with M_0= 27.32 - 28.36kg and w_0=289.9-295.5% which is about 3.6-3.7 times w_L were carried out for 2 or 3 hours. The main conclusions obtained in this paper are as follows.

(1) There is hardly influence of the distance between drains on the amount of dewatering, when the distance is longer than about 3 cm.

(2) Using a new method in which vacuum pressure is applied in muddy water for 2 hours and in air for further 1 hour, the dredged soil can be dewatered below w_L. The dewatered soil is enough condition to transport by dump truck.

(3) Using a new method in which air pressure is applied into the PP-Sheet, the dewatered soil adhered on drains can be easily removed. Therefore, using this new method, the dewatered soil can be efficiently brought together.

Photo 3 Dewatered soil in Case 2(b)

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