Ⅲ - B225

Drainage ability of soil-cement columns in Ariake clay

Saga University, M., N. Miura
SM., ○S. L. Shen
M., K. Koga
Shinwa Techno Co.Ldt., M., R. Nakamura

1.Introduction Lime column, due to its low compressibility and high permeability, can be also used as an vertical drain besides its direct strengthening to soft clay (Broms and Boman, 1977). However, in present engineering practice due to difficulty to decide the drainage effect parameters, this kind of drainage effect is seldom taken into consideration. This paper discusses the drainage effects of SDM (slurry double mixing) columns in Ariake clay via an *in-situ* construction test.

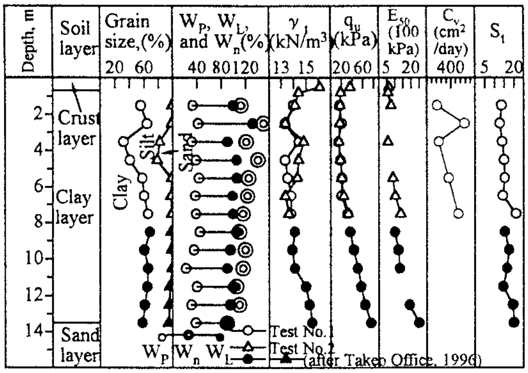

Fig.1. Geotechnical profiles and soil properties at in-situ

2.Test construction procedure

Geotechnical profiles and field construction: Total 12 large scale soil-cement columns were constructed in July, 1996, by a new developed improvement machine called SDM method at Ashikari inside the bank of Rokkaku river to study the effect to the surrounding ground during construction. The improvement chemical agent was cement slurry with W/C ratio of 100% and amount of 140kg/m^3. The improvement ratio in area was 50% and installation speeds were 0.7 and 1.0m/min. Fig.1 shows the geotechnical profiles and soil properties at the construction site. Fig.2 plots the plan and section of constructed columns and test instrumentation.

Test procedure: Tests on surrounding ground were field measurement of pore pressure, strength tests, tests of physical properties. To measure the pore pressure generation and dissipation, 4 piezometers were set in the middle among columns, with 33cm to column surface and with the depth of 1.5, 3.5, 5.5 and 7.0m, respectively. The cone test and boring of samples were taken two times (1~3 and 35~43days after construction) at three different locations, A, B, C, with a distance to column of 6.5cm, 20cm and 33cm, respectively (Fig.2).

3.Test results and evaluation of drainage ability of SDM column

Dissipation of excess pore pressure and drainage effect of column: Fig.3 gives the measured and predicted degree of consolidation of the induced excess pore pressure. As seen in this figure, the measured dissipation rates of excess pore pressure was much faster than the predicted values by FEM in which the radial dissipation via column was not taken into consideration. The predicted values by Barron's consolidation equation agreed well with the measured. The radial drainage factor can be evaluated from the measured values as followings.

The measured time-dependent degree of consolidation in expression of excess pore pressure can be fitted by following equation:

$$U(t) = 1 - \frac{\Delta u_t}{\Delta u_0} = 1 - \exp(-Kt) \qquad (1)$$

Where Δu_t-excess pore pressure at t time; Δu_0-initial excess pore pressure after column installation; K—drainage factor (fitted, Broms, 1977).

The Barron's (1948) consolidation equation in the case of symmetrical

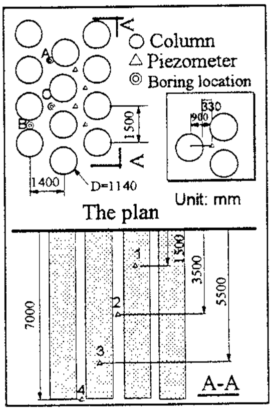

Fig.2 Layout of columns and test instrumentation

Keywords: Improvement column, Drainage ability, FEM analysis, Improvement to surrounding clay
1 Honjo-machi, Saga 840, Tel: 0952-28-8576 Fax: 0952-28-8190

radial flow with no smear and isotropic conditions can be written as:

$$U(t) = 1 - \exp\left(-\frac{8C_v t}{D^2 \cdot f(n)}\right) \qquad (2)$$

Where $f(n) = \frac{n^2}{n^2-1}\cdot\ln(n) - \frac{3}{4} + \frac{1}{4n^2}$ (3)

Comparing the Eq(1) and (2), the drainage factor (K) become: $K = \frac{8C_v}{D^2 f(n)}$ (4)

Table 2 tabulates the estimated value of K by Eq.(4) and fitted value from Eq.(1). As seen in the table, The drainage ability of a ϕ1140mm SDM column is equivalent to a ϕ900mm or 6~9 ϕ150mm sand drain.

Physical and mechanical properties: Fig.4 shows the variation of water content, liquid limit, plastic index and specific gravity of soil grains. One month after construction, water content decreased 5~10%; specific gravity in-creased. The liquid limit and plastic index only slightly decreased. Fig. 5 plots the strength variation of surrounding clay after column construction. One month later the strength had not only recovered but also increased about 20~30%.

4.Conclusions 1)SDM column can be used as vertical drain. The drainage ability of a ϕ1140mm SDM column is equivalent to a ϕ900mm or 6~9 ϕ150mm sand drain. 2)Test results show that one of the reasons of the strength increase of the surrounding clay after one month is due to this drainage effect.

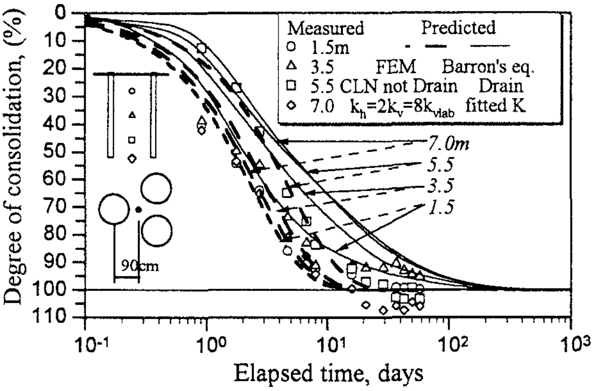

Fig.3. Measured and predicted degree of consolidation at the measured points after SDM column installation

Table 1 Comparison between calculated and measured drainage rates

Test depth (m)	Calculated values as equivalent sand drain (from laboratory results)				Test fitted values (field test results)
	C_v, (cm²/d)	Drainage factor, K (1/day)			Drainage factor, K (1/day)
		ϕ1140	ϕ900	ϕ150	
1.5	312.3	0.683	0.33	0.04	0.388
3.5	367.8	0.797	0.38	0.05	0.334
5.5	327.6	0.707	0.34	0.05	0.256
7.0	387.9	0.848	0.40	0.05	0.543

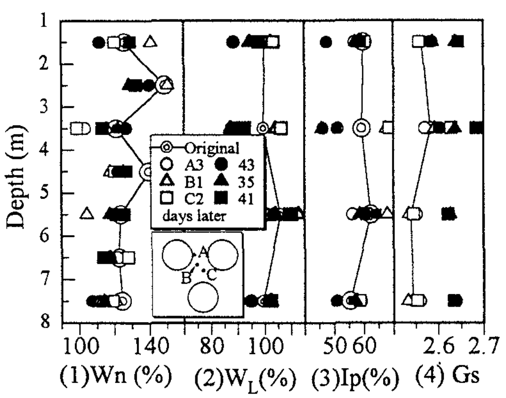

Fig.4 Variation of physical properties with depth

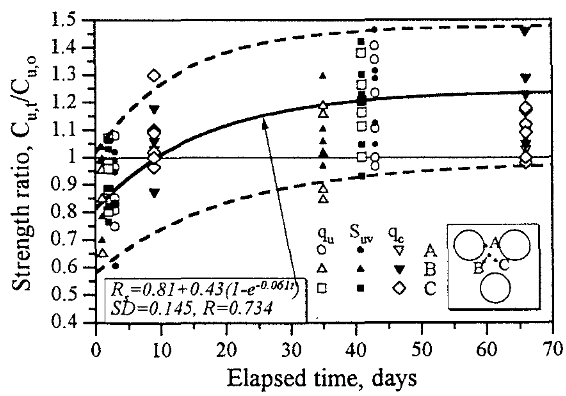

Fig.5. Variation of strength ratio after construction

Acknowledgements We would like to thank Takeo office, Ministry of Construction, and Matsuo Construction Co. Ldt., for their support in carrying out this study.

References 1) Broms, B.B., Boman, P.O.(1977): "Lime columns-a new type of vertical drains," Proc. of 9th *ICSMFE*, Tokyo, pp.427~432. 2)Takeo Office, Ministry of Construction, (1996), "Report of the embankment protection project on the bank of Rokkaku river", March, 1996, Saga.