UP-LIFT RESISTANCE OF SCREW ANCHOR IN SOFT ARIAKE CLAY

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1.INTRODUCTION Anchors are extensively used in a number of instances to strengthen the foundations subjected to uplifting forces and/or overturning moments of the natural and/or artificial slope. They are also used in the berthing structures or the retaining walls of vertical and/or inclined face of embankment with panel and in excavation, etc. to provide stability against horizontal pulls. The common types of anchors in use are pile anchors, grouted anchors, plate anchors, and screw anchors etc. The aim of this study is to investigate the behavior of vertical screw anchors in remoulded soft clay.

2.EXPERIMENTAL WORK

[Test device] Figure 1 shows the experimental set-up for carrying out uplift test, it composed of soil mould, screw anchor, uplift loading frame, weight hanger and dial gauges. The moulds used in the tests are of inner dimensions, ϕ194mm×200mm and were made of 10mm thick polyvinyl-chloride cylinder. The uplift load was exerted with the help of wire rope passing over two pulleys and the wire rope had been subjected to tension with the help of cast iron weights. The upward displacement of the anchor was measured with the help of dial gauge of at least count 0.01mm.

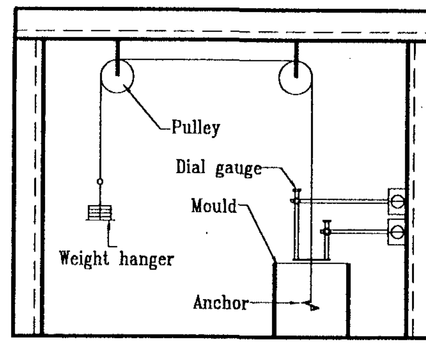

Fig.1 Frame of uplift test apparatus

[Screw anchor] The anchors used in the test were made out of helical shaped circular stainless steel plates welded to a steel shaft with a given spacing of h=10mm. **Fig.2** shows the design dimensions of the anchor.

[Soil samples] A completely remoulded Ariake clay was used in this test. The initial properties of the sample are density of soil grains: ρ_s =2.63g/cm^3, natural water content: w_n=148%, liquid limit: w_L=98.1%, plastic limit: w_p=41.6%, and plastic index: I_p=56.5, grain size distribution: clay 70%, silt 26.5%, sand 3.5%. This remoulded soil samples were extracted from a depth of 2 to 3m at the site near Saga Airport.

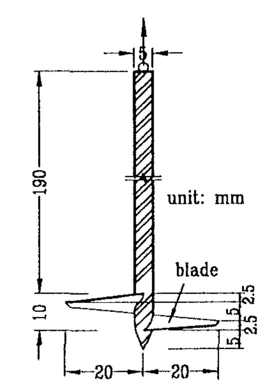

Fig.2 Structure of anchor

[Testing Procedures] Two sets of uplift tests had been conducted for investigate the uplift behaviour of the anchor in soft Ariake clay. The first one was performed in order to investigate the effect of thixotropy on the uplift resistance, that is, anchor was set in the soil mould in the middle of remoulded clay and was rested for 0, 3.5, 7, 14, and 28days under unconsolidation undrained condition and the mould was sealed in a vinyl bag. Then, uplift tests were conducted.

The second type of uplift test was made to investigate the effect of consolidation on uplift resistance, that is, anchor was set in the middle of mould filled with remoulded Ariake clay. Then, a consolidation pressure of 5kPa was put on the clay and let it consolidated for 3, 7, 14, and 28 days, thereafter, the uplift behaviour of the screw anchor was observed. For reduction the friction of the mould wall, grease was plastered on the inner wall of mould. Geotextiles were put on the top and bottom of the soil to let the drainage of water from two directions.

Pullout load of each step in the first uplift test was 0.5N and in the second uplift test was from 1 to 2.5N. For each loading step, it had been maintained for 30 minutes. The undrained shear strength (c_u) was measured using a laboratory vane shear apparatus.

3.TEST RESULTS AND ANALYSIS Typical uplift load versus upward displacement curves for the anchor are shown in **Fig.3.** Under consolidation condition, the soil become stronger and stiffer. The displacement of yield point under consolidation is about 1/2 of those under rest condition. The uplift yield load (P_y) and failure load (P_u)of the anchor are derived from the method of *logP-logS* curves and P-S curves. The determination procedures are followed the suggestions by JSF 1811. The yield loads and failure loads

Table 1 Measured and calculated uplift resistance

Elapsed days	c_u(kPa)		P_y(N)		P_u(N)		Q_u(N)	
	rest	cons.	rest	cons.	rest	cons.	rest	cons.
0	0.27	0.27	2.13	2.13	5.13	5.13	3.04	3.04
3	0.51	2.22	3.25	12.3	6.75	15.7	5.27	16.7
7	0.74	3.67	6.43	15.71	9.72	20.9	7.02	27.2
14	0.94	5.04	9.61	21.1	12.5	28.3	8.94	37.1
28	1.32	7.39	15.4	25.9	15.99	39.8	11.9	54.2

Note: cons.- consolidation conditions; P_y-measured yield load; P_u-measured failure load; Q_u-calculated failure load;

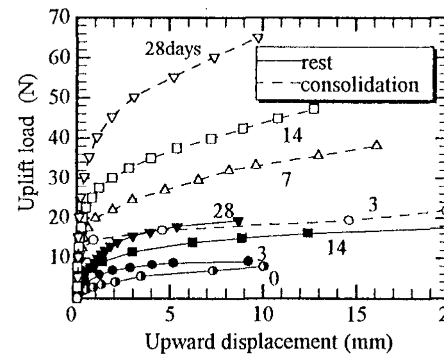

Fig.3 Typical uplift load-upward displacement curves

under these two test sets are given in **Table 1**. **Figure 4** plots the uplift capacity with elapsed rest and consolidation time. The increase of shear strength with elapsed time is also plotted in this figure. The capacity and strength increase rapidly with elapsed time. **Figure 5** depicts the increment uplift capacity - shear strength ratio, which is defined as followings:

$$R_{qc}(t) = \frac{q(t) - q_0}{c_u(t) - c_{u,o}} \qquad (1)$$

in which: $R_{qc}(t)$ =ratio of uplift capacity increment to strength increment after t days of rest or consolidation; $q\ (t)$ = uplift capacity after t days; q_o = uplift capacity immediately after remoulding; $c_{u,}(t)$ = shear strength after t days; $c_{u,o}$ = remoulded shear strength. As shown in **Fig.5**, at the beginning stage, the ratio of $R_{qc}(t)$ is almost same under rest and consolidation conditions. Then, $R_{qc}(t)$ under rest condition increases with elapsed time and that under consolidation condition decreases with the consolidation time. After 14 days, $R_{qc}(t)$ becomes a constant under any conditions and after 28 days, $R_{qc}(t)$ at rest condition is about twice of that under consolidation condition. Meanwhile, from **Fig.6**, the calculated bearing capacity under these two conditions is different. The calculation for the uplift capacity of an anchor in a cohesion soil is expressed as following equation (Vesic; 1971):

$$q = Q_u / A = \gamma H + cF_c \qquad (2)$$

in which; Q_u= failure load by theoretical calculation; A =area of anchor; H= embedment depth of anchor; c= cohesion of soil; F_c =breakout factor with respect to the soil cohesion (Vesic,1971).

This indicates that the uplift behavior of screw anchor is different from the soil condition.

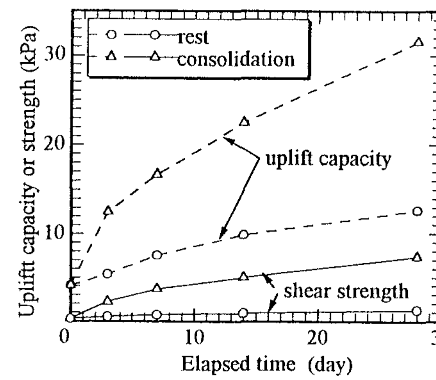

Fig4 Variation of uplift capacity and shear strength with the elapsed time

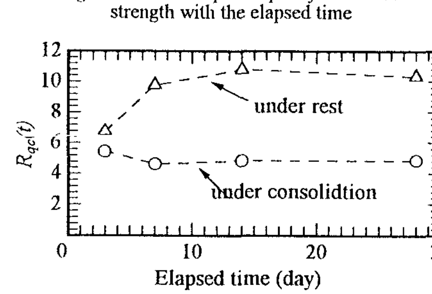

Fig.5 Variation of increment capacity-strength ratio with elapsed time

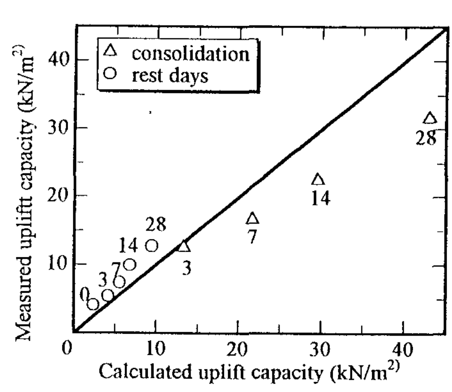

Fig.6 Comparison between measured and calculated upliflt capacity

4.CONCLUSIONS Based on the experimental results the following conclusions can be drawn: The uplift capacity of screw anchor buried in soft Ariake clay depend upon the undrained shear strength and stress history. The increase rate of uplift capacity due to increase of shear strength from thixotropic hardening is greater than that from consolidation effect.

REFERENCE Vesic, A.S. (1971), "Breakout resistance of objects embedded in ocean bottom," J. of SMFE, ASCE, Vol.97, No.SM9, pp.1183-1205.