Laboratory tests of soft ground improvement with drained-timber pile:A new timber pile technique

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Abstract. In modern times, with the rise of high buildings, the timber piles were replaced by steel piles, precast concrete piles and various composition foundation, the main reason is that the soft ground improved with timber piles has the weakness of low bearing capacity and large post construction settlement. To overcome the weakness of the traditional pine-pile technology and expand its application in engineering practice, the drained-timber pile: A new timber pile technology was developed. To verify the feasiblity and evaluated the effectiveness of the drained-timber pile technology, four types of laboratory soil-column consolidation tests were performed. The test results revealed that under the same loading and consolidation time, the radial consolidation of the drained-timber rod has a domiant contribution to the total degree of consolidation, the drained geotextle layer of drained-timber rod can obviously increase the degree of consolidation comparing with traditional timber rod. It can be expected that the new timber pile technique has a good application prospect in soft ground improvement for medium-small size hydraulic structures.

Research background

Pine pile is an ancient technology applied in soft ground improvement for more than 1000 years. For example, Hayashi reported that even after more than one thousand years, wood reinforcement under the Mizuki embankment in North Kyushu, Japan still has high durability in an under water-table condition [1]; It was reported that the soft clay foundation of the ancient Water-Gate site of the Southern Taizhou (Jiangsu province, China) was reinforced with timber piles, which still remains a relatively complete state more than one thousand years at underground water condition [2]. Many ancient ruins were excavated and it was found that the pine piles were still remained in good status, which verified that the pine piles have good durability and strong corrosion resistance under water condition.

Yet, it can not be concluded that timber pile technique has disappeared in soft ground improvement. On the contrary, in some special conditions, timber piles have a certain advantages comparing with concrete piles, steel piles et al. For example, timber-piles are widely employed in small-medium size hydraulic structure engineerings in the regions with rich pine resources [3-5]. Especially, in recent years, with the enhancement of environmental protection and resource protection consciousness, the timber pile has been attracting the attention of the engineers and researchers due to its environment-friendly characteristics, obvious economic benefits and suitability[6,7].

However, the traditional timber pile technique has the following two disadvertages while applied to improve soft ground, one is that: 1) the low bearing capacity of timber pile due to the low shear strength of the soft clay restrict the height of the superstructures; another is that 2) the large post-construction settlement due to the low permeability of the soft clay frequently lead to cracking of superstructures. The above two problems restrict the extensive application of timber-pile composite foundation for buildings in soft soil area.

To overcome the weakness of the traditional timber pile technology, the drained-timber pile technique was developed by the research group [8,9]. In the study, a special laboratory soil-column apparatus was designed to perform consolidation tests for drained-timber rods. Totally, four types of soil-column consolidation tests were carried out to investigate the feasibility and efficiency of the drained-timber pile technique. The test results revealed that the drained-timber rod can obviously

Table 1 Physical properties of the mucky clay used in the test

Term	Natural density ρ (g/cm^3)	Water content ω (%)	Specific gravity G_s	Plastic limit PL	Liquid limit LL	Plasticity Index PI	Liquidity Index LI
Quatity	1.74	90.26	2.67	26.0	52.2	26	2.47

Table 2 Set up of soil-column consolidation tests with (drained)-timber rods

Type of Tests	Diameter of rod (mm)	Drained geotextile	Length of embedded rod (mm)	Drained geotextile	Height of soil column (mm)	Vertical drain	Radial drain
L1	No	No	No	No	100	√	---
L2	10	No	100	No	100	√	---
L3	10	2 layers	100	2 layers	100	---	√
S0	10	2 layers	100	2 layers	100	√	√

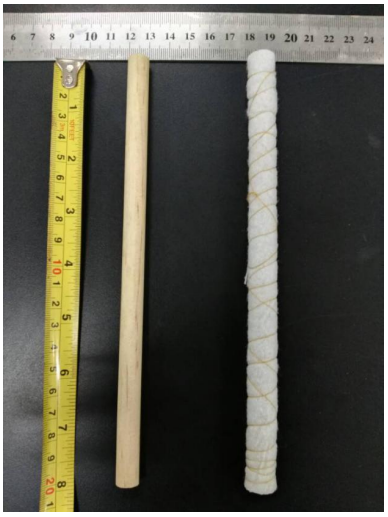

Fig.1 Photos of timber rod and drained-timber rod for wooden rod with diameter of 10 mm

Fig.2 Set up of soil-column with (drained)-timber bolt before loading

increase the degree of consolidation comparing with traditional timber rod. It can be expected that the drained-timber pile technique has a good application prospect for the medium-small hydraulic engineering structures and pretreatment of super soft foundation in the pine rich area.

Test Schematic Design

Soil Preparation. The soil tested was collected from Diezi Lake of Nanchang city, Jiangxi Province. The main physical and mechanical properties of the soil were listed in Table 1, the soil is a typical soft clay in the Poyang Lake region.

Drainage Geotextile. The drained geotextile is the main composition of the drained-timber pile, a non-woven geotextile, which is made of 150A by the factory with the quality of 150 g/cm^3 and thickness of 1.0 mm, was employed as the drained layer of the drained-timber rod. The permeability coefficient of the geotexitle is about 1 x 10^{-1}cm/s.

Preparation of timber rod and drained-timber rod. In the experiment, the timber rod is made from the pine rod with a diameter of 10 mm. The drained-timber rod is made up of a timber bolt (diameter

10 mm) with 2 layers of drainage geotextile wrapped around the timber bolt. The timber rod and the drained-timber rod are shown in Fig.1

Model Design of Laboratory Soil-Column Consolidation Test. The laboratory soil-column model was composed of plexiglass cylinder, pressure plate, plexiglass hollow transfer column, loading and data monitoring recording system, the details of the soil-column apparatus can be referred in the reference [8,9].

Design of Four Types of Laboratory Column Consolidation Tests. In order to verify the drainage consolidation performance of the drained-timber rod, a total of four types of soil-column consolidation tests were designed, as listed in Table 2. In all the tests, the initial height of the soil column was set as 100 mm, and the total length of the (drained) timber rod was 150 mm, and the embedded length in soil of the rod was 100 mm.

Test L1 is just soil column without (drained) timber rod at vertical upward drainage condition; test L2 is soil column with just timber rod at vertical upward drainage condition; test L3 is soil column with drained-timber rod at radial drainage condition, the top boundary of the soil column was sealed with a thin geomembrane; test S0 is soil column with drained-timber rod at both vertical upward drainage and radial drainage condition, test S0 is designed as the basic standard tests for drained-timber rod.

Test Procedures

Sample Preparation.The test samples were prepared with initial moisture content of 90% and 100 mm in height, the photo of the soil-column consolidation sample before loading is shown in Fig. 2. (Note:for test L3, a piece of impermeable geomembrane pad is used to take the place of the permeable geotextile to achieve the only radial drainage condition).

Loading Scheme. The loading scheme is designed as 6 steps, which are 6.25 kPa, 12.50 kPa, 25 kPa, 50 kPa, 100 kPa, 200 kPa, respectively; each loading step is maintained for 24 hours.

Analysis and Discussion of the Test Results

Relationship Between the Consolidation Settlement and Time. The relationships of the consolidation settlement with time of the four types of tests are plotted in Fig.3 to Fig.6.

Compring Fig.3 and Fig.4, it indicates that the final settlements are 32.60 mm and 32.70 mm for the test L1 and test L2, respectively, the curves of settlement with time under each step loading are almost close to agreement. It means that the traditional timber-rod is impermeable and has little contribution to increasing the consolidation degree of soft clay, this is a reasonable results and agree with theoretical speculation.

Comparing Fig.4 and Fig.6, it indicates that the final settlements are 32.70 mm and 36.85 mm for test L2 and test S0, respectively. For test L2 and S0, the only difference is that test S0 use drained-timber rod and L2 use timber rod, it reveals that under the same loading and drained condition, the two geotextile layer of the drained-timber rod can well play the role of radial drainage and contribute a lot to the total consolidation degree.

Comparing Fig.5 and Fig.6, it indicates that the final settlements are 36.50 mm and 26.85 mm fore test L3 and test S0, respectively, the curves of settlement with time for tests L3 and S0 under each step loading are almost close to agreement. It means that for the drained-timber rods, with two drained layers of geotextile, the radial drainage has a dominant contribution to the total consolidation degree, and the vertical drainage has little contribution to the total consolidation degree, the phenomenon reveals that the two thin layers of geotextile is quite effective for increasing the radial consolidation;

Relationship of Void Ratio to Consolidation Pressure. The relations of the void ratio vs. consolidation pressure of four types of tests are plotted in Fig.7. Figure 7 indicates that, under the same load increment and the same consolidation time (24 hours), the increments of consolidation settlement of tests L3 and S0 are always greater than that of the Tests L1 and L2 , which reveals that the drainage layer structure of the drained-timber rods can effectively improve the consolidation degree of soft clay.

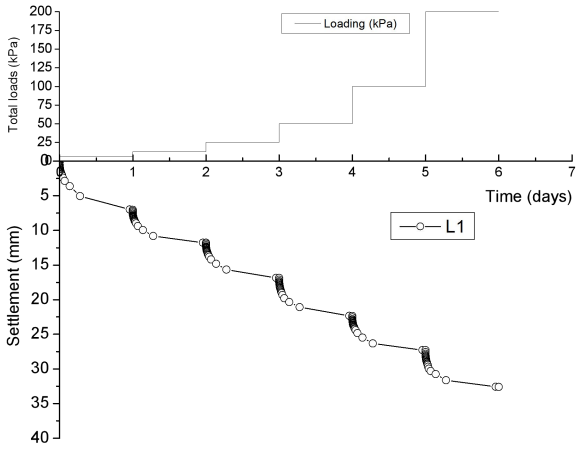

Fig.3 Loading and consolidation settlement vs. time for test L1

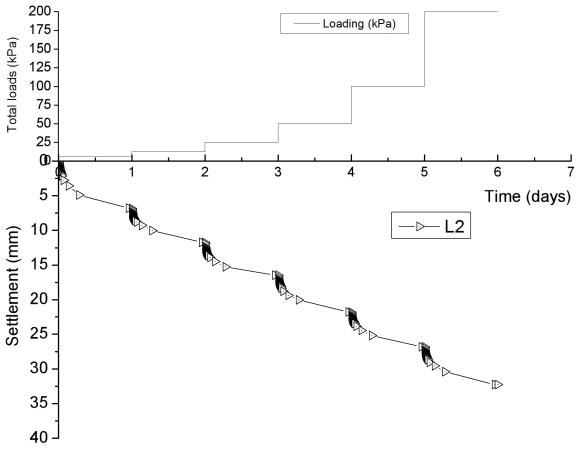

Fig.4 Loading and consolidation settlement vs. time for test L2

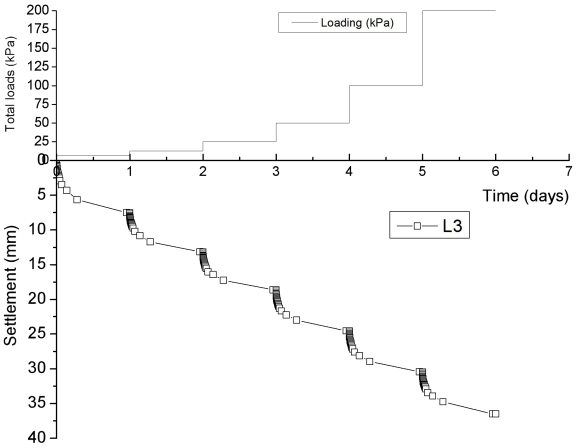

Fig.5 Loading and consolidation settlement vs. time for test L3

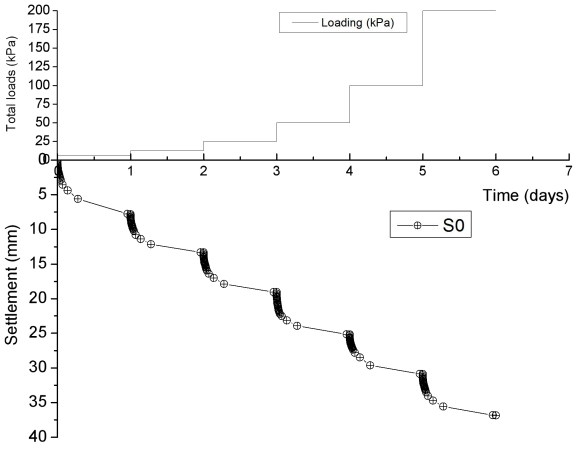

Fig.6 Loading and consolidation settlement vs. time for test S0

Conclusions

Aiming to improve the weakness of the traditional pine pile in reinforcing soft clay foundation, the drained-timber pile was developed. Four types of laboratory model tests were carried out to evaluate the effectiveness of the drained-timber pile, the conclusions are made as follows: 1) the traditional timber-rod is impermeable and has little contribution to increasing the consolidation degree of soft clay, this is a reasonable results and agree with theoretical speculation; 2) for the drained-timber rods, with two drained layers of geotextile, the radial drainage has a dominant contribution to the total consolidation degree, and the vertical drainage has little contribution

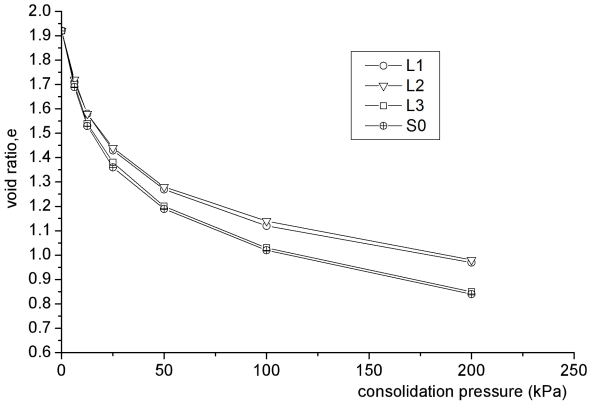

Fig. 7 Curves of void ratio vs. consolidation pressure for the four types of tests

to the total consolidation degree, the phenomenon reveals that the two thin layers of geotextile is quite effective for increasing the radial consolidation; 3) it is recommended that the effectiveness and contribution of the drained-timber pile should be evaluated further in a more longer soil column model test; 4) it can be expected that the drained-timber pile will have a prosperous application in small-medium size.

Acknowledgements

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