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EVALUATION OF LABORATORY TESTS FOR DISCHARGE CAPACITY OF DRAINS

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ABSTRACT : Prefabricated Vertical Drain with surcharge is a widely used method of soil improvement to accelerate the consolidation of soft soils. In such applications, discharge capacity is an important parameter to determine the effectiveness of the prefabricated vertical drains. Hence many manufacturers of prefabricated vertical drains and researchers developed their own drain tester to determine discharge capacity. Hansbo (1983) described what an "ideal test" should be for a standard drain tester. This paper consists of a brief review of six drain testing device, including the ASTM recommended prefabricated vertical drain test device. The features of each test device is compared to the "ideal test" defined by Hansbo. The sixth drain tester is a new device developed at National University of Singapore (NUS), and this will be discussed in detail in the paper.

INTRODUCTION

Ground improvement schemes are needed to accelerate consolidation for cohesive soil. One of the most common method is the use of prefabricated vertical drains. Various types of prefabricated vertical drains are marketed hence we need to have some measure of drain discharge capacity for comparative purposes. For selection of suitable drains on ground improvement works, drain discharge capacity is one of the important factor to consider. Many drain testers have been developed to determine the discharge capacity of prefabricated drains. However, most drain testers are meant to study the performance of the specimen of fixed length at constant confinement pressure and hydraulic gradient. In this paper, six drain testers, including the ASTM recommended test device and the drain tester developed by NUS will be discussed.

"IDEAL TEST" FOR DRAIN TEST DEVICE

Hansbo (1983) has discussed the definition of discharge capacity and conditions for an "ideal test" to determine the discharge capacity of a prefabricated vertical drains. The "ideal test" condition is to place a drain specimen in impervious soil with its ends connected to drainage layers at the top and bottom of the specimen. The soil specimen, with the drain should be consolidated, preferably under K_o conditions and at vertical pressures corresponding to the applied loading in the field.

Hansbo reported that the Ontario Research Foundation (ORF) test is inaccurate compared to the ideal test. The ORF test used a drain strip of 500mm length and is one example of how manufacturers of drains determine the discharge efficiency of their drains. The drain was enclosed by a film of polythylene sleeve and placed between two steel plates. An external pressure against the platės of 300kPa was applied and the volume of water discharged axially through the drain was measured. No figure for the ORF test device was available in Hansbo report.

ASTM RECOMMENDED DRAIN TESTER

The ASTM drain tester is specified in the ASTM D4716-87 : "***Standard Test Method for Constant Head Hydraulic Transmissivity (In-plane flow) of Geotextiles and Geotextile Related Products***", as shown in Figure 1.

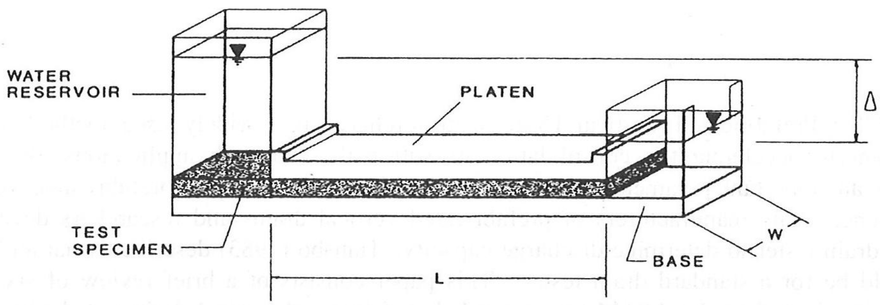


Figure 1 : A constant head hydraulic transmissivity testing device

This is a standard drain tester to determine the discharge capacity and transmissivity of prefabricated vertical drains. It consist of a flat base, inlet and an outlet collection and a loading mechanism to exert pressure for the simulation of lateral pressure. The drain tester uses the constant head method with inlet and outlet reservoir to maintain a constant head for measuring drain discharge capacity.

However due to the existence of the rigid base plate, there is little space to allow the drains to form natural kinks from soil settlement, or to place a kinking mechanism in the drain tester. Hence it is unable to determine the reduction of discharge capacity of a kinked drain compared to straight drains. Based on Hansbo's (1983) paper, in order to have an accurate measurement, clay must be packed around the drains. For the ASTM standard test, there is no requirement for clay to be packed around the drain. The length effect of the drain is not considered to be an important factor in the test. The ASTM recommendation is that specimen length is at least twice of specimen width up to a width of 300mm.

DRAIN TESTER IN NTU (BROMS ET AL, 1994)

This drain tester was developed in Nanyang Technological University, Singapore. It is a relatively small apparatus for the measurement of discharge capacity of prefabricated drain when embedded in soil. Figure 2 shows a diagram of the drain tester. The tester consists of rectangular loading plate with a base container. The container is packed with two layers of clay and the drain sample sandwiched between the clay for discharge testing. The loading mechanism is a lever type loader as in an oedometer test, and is placed at the top of the soil in the base container.

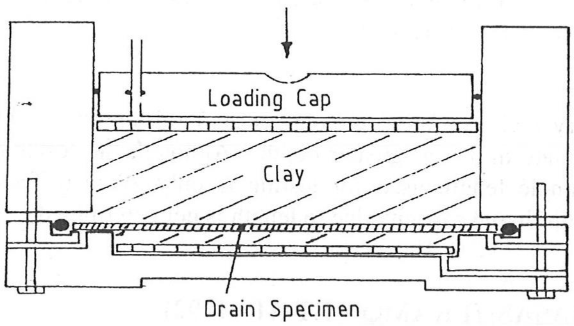


Figure 2 : NTU drain tester (Broms et al, 1994)

Due to the size of the apparatus, it can only accommodate 100mm (or 300mm) long and a 100mm wide drain. The tester is designed to fit into a standard oedometer loader. This made the tester very portable and routine laboratory consolidation cum discharge capacity test can be done easily. However because of the setup, kinked drains cannot be tested.

DRAIN TESTER IN CHUNG-YUAN UNIVERSITY, CHUNG-LI, TAIWAN (CHANG ET AL, 1994)

This drain tester is for the determination of the performance of vertical drains for the ground improvement project in Taipei. It is developed in order to understand how lateral earth pressure may influence the performance of drains in insitu condition. The drain tester is quite similar to the triaxial cell, as shown in Figure 3.

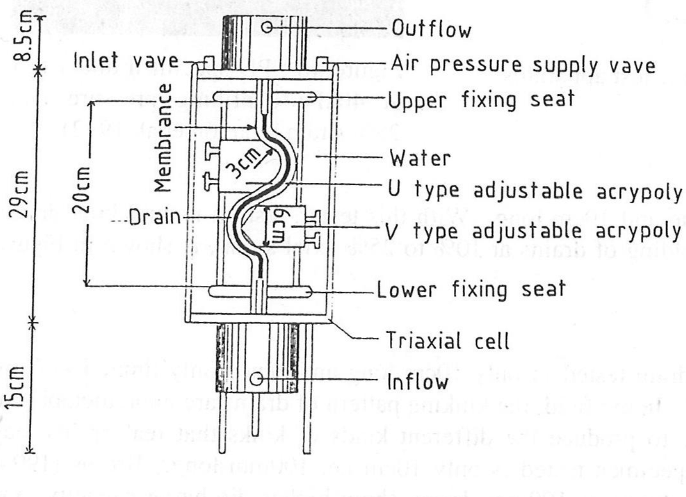


Figure 3 : Drain tester for Chung Yuan University
(Chung et al, 1994)

A kinking tool is designed to simulate 10% settlement of soil layer, and this is applied to the test drain specimen. Hence the variation of discharge capacity due to kinking can be studied. But the kink produced is artificial hence it might not give an accurate estimation of the discharge capacity of kinked drains. Furthermore, drains will not have similar kinking patterns in the field. So it is not accurate to place an artificial kink in the drain during testing.

The testing chamber is designed for very high confining pressure, test for drains under high lateral pressure can be done, i.e. to simulate drains at greater depth. Although the tester can simulate drains at greater depth, the sample length used for testing is only 20cm (effective length). That means that the variation of discharge capacity due to length is not determined.

DRAIN TESTER DEVELOP BY MASASHI KAMON ET AL (1992)

The drain tester developed is a modification of a triaxial cell. Figure 4a shows the schematic diagram of the drain tester.

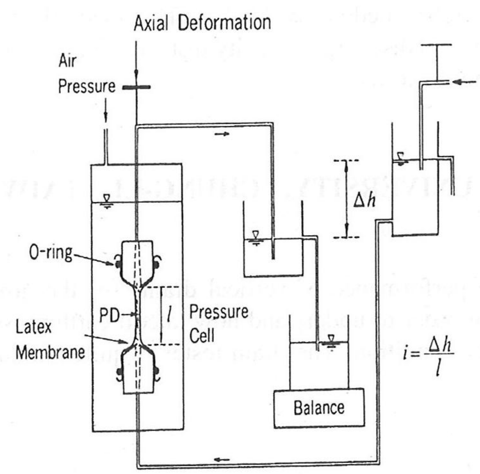


Figure 4a : Schematic diagram of the test apparatus (M.Kamon et al, 1992)

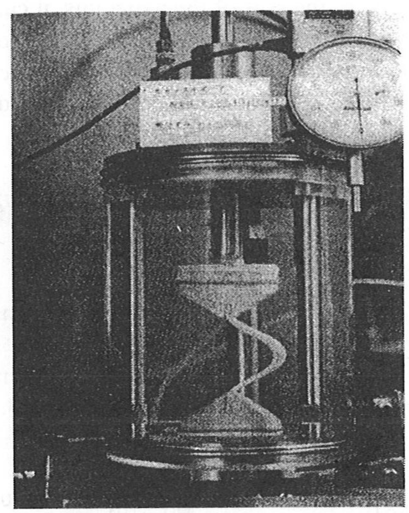


Figure 4b : PD specimen under test at 40kPa confining pressure and 25% strain (Kamon et al, 1992)

The sample used is only 5cm wide and 10cm long. With this tester, test on natural kink drains can be performed. The natural folding of drains at 10% to 25% axial strain, is shown in Figure 4b.

Unfortunately, the length of the drain tested in only 10cm long and hence only limited kinking pattern of the drain can be studied. In the field, the kinking pattern of drains are unpredictable, so this drain tester may not be able to produce the different kinds of kinks that real drains may experience. For this tester the specimen tested is only 10cm i.e. 100mm long. Broms (1994) have stated that the discharge capacity of 100mm drains show higher discharge capacity than 300mm drains. That is due to the error involved in the hydraulic gradient measurement which is larger for shorter drains. Hence this drain tester will tend to give a higher discharge capacity than other drain tester.

DRAIN TESTER BY LAWRENCE AND KOERNER (1988)

Lawrence and Koerner developed a drain tester to determine the discharge capacity of kinked drains. The device, as shown in Figure 5, consist of water supply reservoir, the stand and the kinking mechanism.

The kinking mechanism consist of mated kinking platens through which the drain passes during testing, a reaction frame and a driving screw. There are two configuration of kinks platens: 90° wedge and a 13mm cylinder.

Although this tester is able to test kinked drains, the setup is not in an enclosed chamber. That means the drains were tested without confinement of lateral pressure. In this case, the effect of lateral pressure on kinked drains were not studied. And because of the space constraint, the testing of drains with the placement of clay around it (as specified in "ideal test") is not possible.

Presently there are few drain testers that meet the "ideal test" that Hansbo (1983) defined. Recently, NUS had developed a drain tester that comply with ASTM specification, and can also meet all the conditions of an "ideal test".

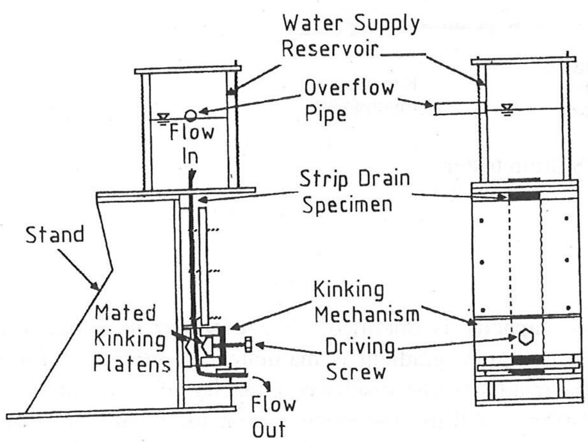


Figure 5 : Diagram of kinking device (Lawrence et al, 1988)

NUS DRAIN TESTER

NUS has developed a drain tester to determine the discharge capacity and the transmissivity of the prefabricated drains. The design of the apparatus follows closely the ASTM D4716-87 specifications and the conditions stated in the Hansbo "ideal test".

This apparatus consist of 3 main detachable component: a constant head inlet reservoir, an outlet reservoir and a transparent cylindrical compressed air chamber, as shown in Figure 6. The compressed air chamber have enough free space for the placement of kinking mechanism to allow the drains to kink freely. Clay at a constant water content (w = 67%) are packed around the drains so that the testing conditions can be quite similar to the "ideal test". Compressed air is applied and hence the effect of lateral pressure to the discharge capacity of the drain can be studied.

As the components of the drains are detachable. The discharge due to the effect of specimen length can be determined. The compressed air chamber is a reinforced perspex cylinder of diameter 200mm. Hence by changing the length of the cylinder, different specimen length can be tested.

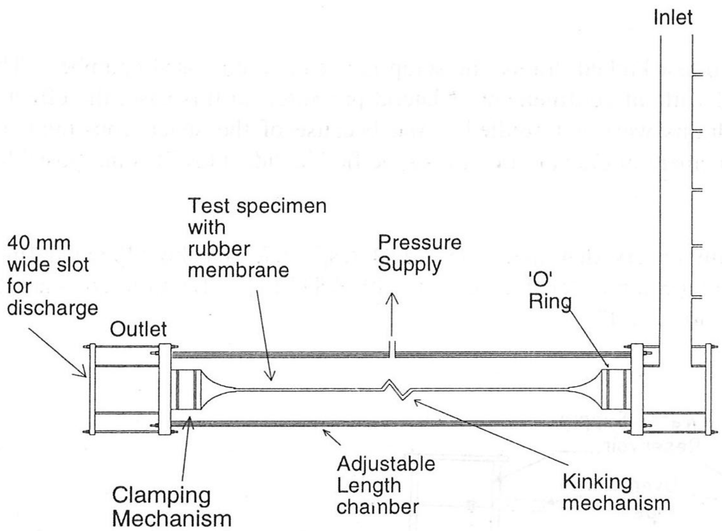
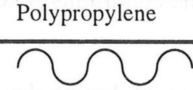


Figure 6 : schematic diagram of NUS drain tester

TEST RESULTS

For the NUS drain tester, discharge capacity is obtained using constant head test method to maintain the hydraulic gradient. The hydraulic gradient is maintained from 0 to 1 for 1m long drain specimen. Figure 7 shows the results of the discharge capacity of the 4 drains. VD1 is Fibredrain which is made of natural fibres. All its components are made of jute and coir. VD2, VD 3 and VD 4 are geosynthetic drains. VD 2 and VD 3 are drains that are still under evaluation and not sold in the market, whereas VD 4 is a colbond drain. Table 1 shows some physical charactertics of the drains.

Table 1 : Physical Properties of the Prefabricated Vertical Drains

	VD 1	VD 2	VD 3	VD 4
Mass/Unit area (g/mm^2) x10^{-4}	11.81	2.92	4.06	3.4
Core type	Coir	Polypropylene	Polypropylene	Polyester
Core structure		 continuous channel	 button extrusion	XXXXXXX nylon web
Filter type	Jute	Fabric	Fabric	Polyester
Dimension (W x t)	100mm x 8mm	100mm x 6mm	100mm x 6mm	100mm x 6mm

From figure 7 it is observed that VD 1 has the lowest discharge capacity compared to the remaining 3 drains. As for VD 2 the discharge capacity obtained is the highest among all the drains in the lower pressure range. However at a pressure of 300kPa, VD 4 gave the highest discharge capacity.

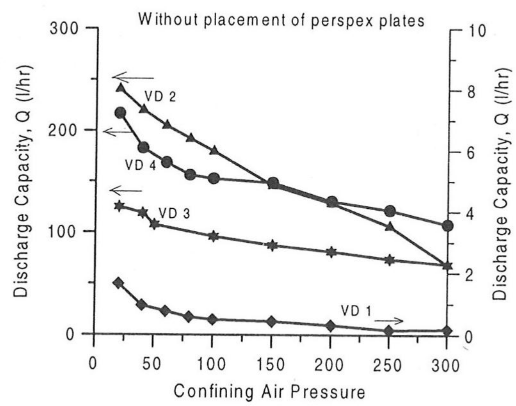


Figure 7 : Discharge capacity vs. confining pressure f or different types of drains

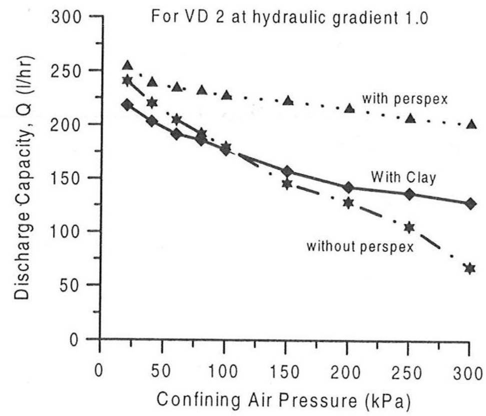


Figure 8 : Discharge capacity vs. confining pressure for different confinement

Figure 8 shows the discharge capacity of vertical drains under different confinement. Confining pressure and clay will cause the filter to be squeezed into the channels of the cores and this will lead a to reduction in discharge capacity. The case of clay packed around the drain is similar to the condition in the "ideal test", whereas the test with perspex plates sandwiching the drain is similar to the ASTM standard test. From the figure, it is observed that the discharge capacity of the drain with the placement of clay around the drain, result in the discharge capacity somewhat between the case of drains with and without perspex plate. This would represent the situation under field condition.

CONCLUSIONS

There are many drain testers developed to determine the discharge capacity of prefabricated vertical drains. However, most drain testers are unable to perform tests that are close to the field conditions. As for the NUS drain tester, many different conditions can be applied to simulate field behaviour. Preliminary results are shown, and it is noted that the discharge capacity is dependent on drain types and the confinement applied.

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