Performance Evaluation Results Report of Drainbelt and Driantube

Entrusted by: CAPIPHON (DRAIN) CORPORATION

Executed by: Minghsin University of Sciencce and
Technology Disaster Prevention Technology

Planning Period: From May 1, 2021 to September 15, 2021

Reporting Date: September 15, 2021

Performance Evaluation Results Report of Drainbelt and Driantube

Executed by: Minghsin University of Sciencce and
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Minghsin University of Sciencce and Technology Disaster Prevention Technology

Material Test Report

Entrusted by: CAPIPHON (DRAIN) CORPORATION

Deliver Date: April 6, 2021

Test Sample:Drainbelt and Driantube

Test Date: May 21, 2021 to September 8, 2021

Project Name: Performance Evaluation of Drainbelt and Driantube

Reporting Date: September 15, 2021

Notes:

The normative reference for the test is CNS14995 "Permeable Concrete Paving Unit". It is assumed that the overlaying soil of draintube and drainbelt is at a lesser depth, and the average or equivalent (K_{ave}) of lateral and vertical hydraulic conductivity is about the K value (k_r) of axisymmetric one-dimensional radial seepage field. Therefore, kr is used as the K value for estimating relevant infiltration/water permeability behavior in the test report.

1. The hypothetical k value of soilless pure water is analyzed by taking the cross-sectional area of driantube as the infiltration area.
2. The k value of sandy soil (taking coarse sand with a particle size of 1.19mm as an example) is analyzed by taking the outer diameter surface area of the driantube contacted by the soil as the infiltration area.
3.

Test Results			
Test Item	Test Sample	Density(D)	Quantity of flow(q) [cm^3/s]
Pure water	Driantube		489.12
	Drainbelt		673.50
Test Item	Test Sample	Density(D)	Quantity of flow(q) [cm^3/s]
Sandy soil (coarse sand)	Driantube	$1.4t/m^3$	56
	Drainbelt		62

Tester: 防災技術研究中心 工程師 劉美君

Tabulator: 防災技術研究中心 工程師 劉美君

Reviewer: 防災技術研究中心 主任 郭治平

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Chapter 1 Preamble and Purpose of the Test

In recent years, the improper use and over-exploitation of slope land in Taiwan have caused frequent phenomena such as debris flow disasters and slope collapse. Climate change has increased the number and scale of droughts and floods, which is more detrimental to environmental stability. The most harmful factor to slope stability is that the pore water pressure contained in the stratum material can't be vented in time when it exceeds the limit, so that the effective stress of the soil decreases. Therefore, effective, continuous and durable drainage technology is helpful to timely remove the excess water in the stratum. Nowadays, PVC drainage pipe, PE network pipe or infiltration network pipe are buried under the groundwater level for gravity drainage, which is the most commonly used stratum drainage technology. The common problem of all the above methods is that the fine soil around the opening of the outside pipe can easily block the water inlet, leading to the rapid decline or even failure of the drainage function.

This report discusses the design concept of a permeable drainbelt developed by the public. The concept is to design the surface of the draintube with a high opening rate of more than 18% in the form of closely spaced grooves, the use of capillarity phenomenon, Siphon phenomenon, gravity and surface tension at the same time under the role of drainage. The model test is used to compare the drainage effect before and after embedding the drainage system.

Chapter 2 Test Methods

2.1 Test Apparatus

2.1.1 Test sand box

The transparent acrylic box (inner diameter 45×30×40cm) with a thickness of 5mm was used in this test, and the holes at the lower right and upper left were used as the water inlet and the water outlet of the body to be tested.

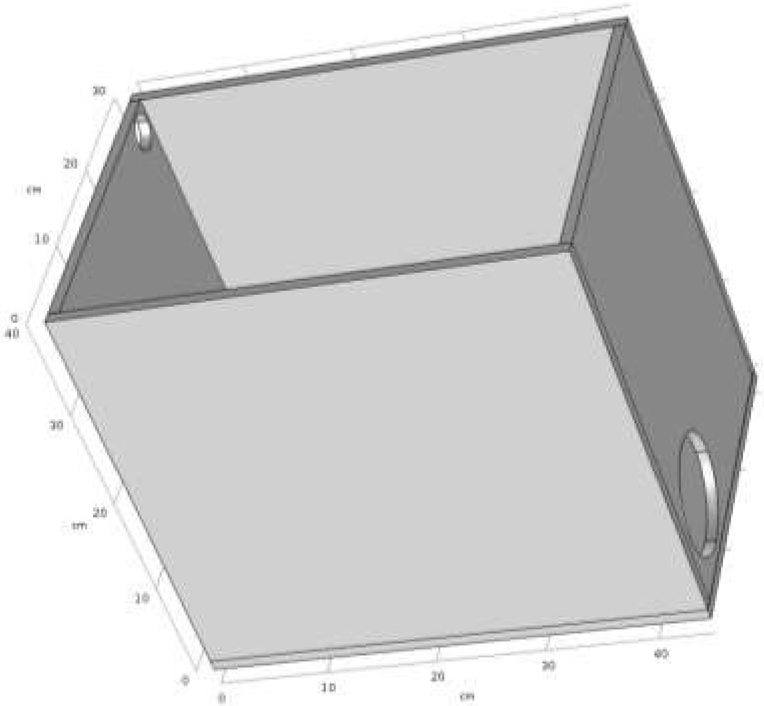


Fig. 2-1 Schematic diagram of test box

2.1.2 Flowmeter

Its specification is flow range: 10~100L/min, accuracy: 1.0%, repeatability: 0.3%.

Fig. 2-2 Electronic flowmeter

2.2 Normative reference

The normative reference for the test is CNS14995 "Permeable Concrete Paving Unit". It is assumed that the overlaying soil of driantube belt is at a lesser depth, and the average or equivalent (K_{ave}) of lateral and vertical hydraulic conductivity is about the K value (k_r) of axisymmetric one-dimensional radial seepage field.Therefore, kr is used as the K value for estimating relevant infiltration/water permeability behavior in the test report.

The formula used in the test is Darcy's Law, which refers to the flow rate of the specimen per unit time, as shown in Eq.(1) and Eq.(2).

$$q=\frac{Q}{t}=k\times i\times A \qquad \text{Eq.(1)}$$

$$i=\frac{\Delta h}{L} \qquad \text{Eq.(2)}$$

Q	=Total seepage quantity	cm^3
i	=Hydraulic gradient (total head difference/streamline length)	
q	=quantity of flow in unit time	cm^3/s
L	= Length of specimen	cm
Δh	=Height of water head difference	cm
A	=The area through which the specimen passes	cm^2
k	=Permeability coefficient	cm/s

Eq.(3) and Eq.(4) can be obtained by combining the above Eq.(1) and (2)：

$$q=k\times\frac{\Delta h}{L}\times A \qquad \text{Eq.(3)}$$

$$k=\frac{qL}{\Delta hA} \qquad \text{Eq.(4)}$$

2.3 Test Programme and Procedures

2.3.1 Test Programme

The objects to be tested in this test are driantube and drainbelt, and the testing context is pure water and sandy soil, respectively. The testing flow is shown in Fig. 2-3. The detailed dimensions of the sand box in this test are shown in Tab. 2-1, and Fig. 2-4 and Fig. 2-5 are schematic diagrams of the sand box.

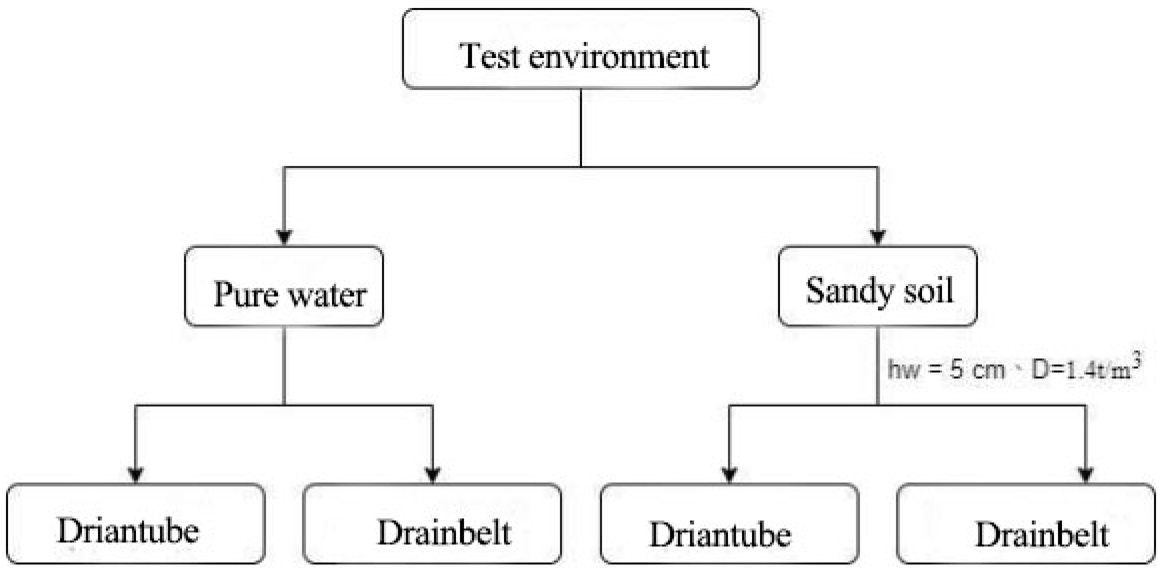


Fig.2-3 Test Flow Chart

Tab. 2-1 Detailed Dimensions of Test Sand Box

L = 45 cm	Sand box length
W = 30 cm	Sand box width
H = 40 cm	Sand box height
h_m = 26 cm	Height of made ground
h_s = 17 cm	The height of covering soil on driantube
h_w = 5 cm	Height of covering soil to water level
Δh = 22 cm	Head difference

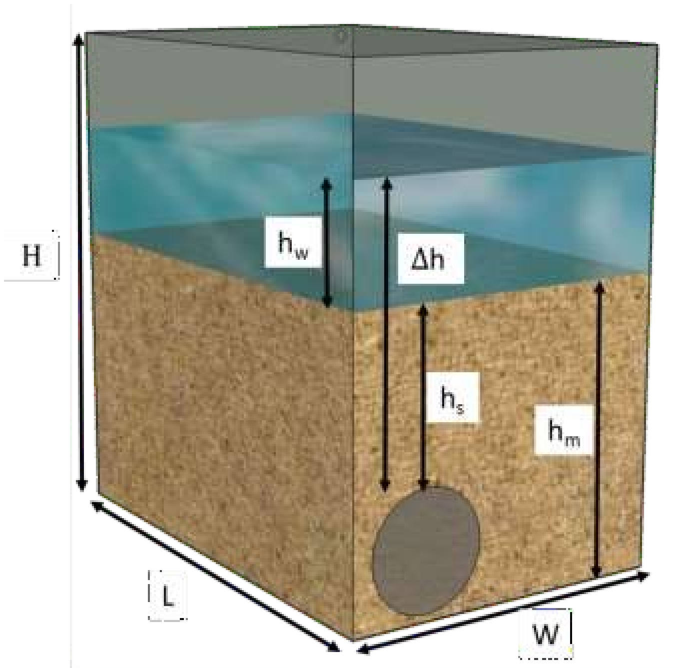


Fig. 2-4 Schematic diagram of sand box


Fig. 2-5 Schematic diagram of sandbox experiment

2.3.2 Test procedure

The testing steps of water penetration for draintubes are as follows:

1. Put the sand in a 105°C oven for 24 hours.
2. Rubber rings are respectively inserted into the water inlet and water outlet of the acrylic box to waterproof and fix the water tube.
3. Put the draintube to be tested into the acrylic box, and use the seal tape where the draintube contacts the rubber ring.
4. Weigh the sand and fill it in the acrylic box until the Height of made ground is 26cm.
5. Open the water inlet valve and adjust it to a constant head (h_w= 5 cm) to make it stable and maintain for more than 30 minutes.
6. Take the graduated cylinder to measure the total seepage quantity (*Q*) in time (t).
7. According to the table shown in Tab.2-2, the total seepage quantity (*Q*) obtained by the experiment is converted into the quantity of flow(q) in unit time by Darcy's Law.

Tab.2-2 Testing data

Testing data	Value	Unit
Measurement time(t)	t	sec
Graduated cylinder reading(Q_1)	X_1	cm^3
Graduated cylinder reading(Q_2)	X_2	cm^3
Graduated cylinder reading(Q_3)	X_3	cm^3
Quantity of flow(q) in unit time	$(X_1+ X_2+ X_3)/t\times3$	cm^3/s

Chapter 3 Testing data

3.1 Pure water environment

The K value of pure water without covering soil (the outer diameter surface area of the draintube is the minimum, and the sectional area (Arc) is taken as the seepage area for analysis), and the experimental data are shown in Tab.3-1 and Tab.3-2.

3.1.1 Driantube

Given the total seepage quantity (Q), measurement time(T), head difference Δh, overlapping length (L_c) and cross-sectional area (Arc) of connecting casing and driantube, find the quantity of flow(q) in unit time as shown in Tab. 3-1.

Tab.3-1 Testing Data of Driantube

Testing factor	Value	Unit
Head difference Δh	20	cm
Overlapping length of connecting casing and driantube(L_c)	1.5	cm
Outside diameter of permeable tube(D_p)	6.8	cm
Inner diameter of permeable tube(D)	6.4	cm
Inner diameter of connecting casing(D_c)	6.9	cm
measurement time(t)	60	sec
Tubular section circumference(C)	66.9	cm
The contact length between made ground and tube(L_r)	32.5	cm
Flowmeter reading(Q)	29.347	l/min
Sectional area(A_{rc})	125.193	mm^2

3.1.2 Drainbelt

Given the total seepage quantity (Q), the measurement time (T), the fixed head difference (Δh) of 20cm, the overlapping length (L_c) and surface area (A_r) of the connecting casing and the draintube, as shown in Tab.3-2, find the quantity of flow(q) in unit time.

Tab.3-2 Testing Data of Driantube and Drainbelt

Testing factor	Value	Unit
Head difference Δh	20	cm
Overlapping length of connecting casing and driantube(L_c)	1.5	cm
Outside diameter of permeable tube(D_p)	6.8	cm
Inner diameter of permeable tube(D)	6.4	cm
Inner diameter of connecting casing(D_c)	6.9	cm
Measurement time(t)	60	sec
Tubular section circumference(C)	66.9	cm
The contact length between made ground and tube(L_r)	32.5	cm
Flowmeter reading(Q)	40.41	l/min
Sectional area(A_{rc})	125.193	mm^2

3.2 Sandy soil environment (coarse sand)

Measure the water discharge for 10s under the condition that the soil density is 1.4t/m^3, and the measured data are shown in Table 3-8. Given the total seepage quantity (Q), the measurement time (T), the head difference (Δh=5cm) , the overlapping length (L_c) and surface area (A_r) of the connecting casing and the draintube, as shown in Tab.3-4, find the quantity of flow(q) in unit time of driantube and drainbelt.

Tab.3-3 Testing Data of Driantube

Driantube		
Testing factor	Value	Unit
Seepage quantity(Q_1)	56	cm^3
Seepage quantity(Q_2)	55	cm^3
Seepage quantity(Q_3)	56	cm^3
Seepage quantity(Q_4)	56	cm^3
Seepage quantity(Q_5)	57	cm^3
Average(q)	56	cm^3/s
Drainbelt		
Seepage quantity(Q_1)	62	cm^3
Seepage quantity(Q_2)	62	cm^3
Seepage quantity(Q_3)	62	cm^3
Seepage quantity(Q_4)	63	cm^3
Seepage quantity(Q_5)	63	cm^3
Average(q)	62	cm^3/s

Chapter 4 Case of durability

Name of project: Renovation Project of Collapse Slope in the Second Section of Jiuzhuang Street, Nangang District in 2001.

Project location: Section 2, Jiuzhuang Street, Nangang District, Taipei

Completion date: 2002

Field survey date: 4:15pm, March 24, 2021

Surveyor: CAPIPHON (DRAIN) CORPORATION General Manager Du Yongan

Director of Disaster Prevention Center of Minghsin University of Science and Technology Associate Professor Chihping Kuo

Survey process:

The field survey of a project case was carried out to verify the durability of the driantube in this test report. There was no rain on the day of the survey. This is a case study of a landslide slope renovation project conducted by the Taibei government after Typhoon ’Xiangshen’. The driantube studied in this report is used as a horizontal driantube for the new retaining wall. The soil behind the retaining wall is mostly silty clay. The retaining wall has been built for nearly 20 years. The continuous drainage of driantube can be looked specifically.

Conclusion:

1. There was no rain on the day of the survey, and the project case was about 20 years, and there was no obvious crack and slop on the wall surface. Therefore, it was judged that the driantube still effectively and continuously discharged the groundwater behind the wall, reducing the water pressure behind the wall.

2. From the visual bending in the driantube on site, it is judged that the soil and filter layer behind the retaining wall may have been hollowed out, but the driantube is not affected by the blockage after bending, and its efficiency is better than that of the traditional PVC tube.

3.The water discharged from the field is visually clear and not turbid. After standing for 5 months after taking water on the same day, there is still no large-scale particle precipitation. It was concluded that the current driantube system was collected and discharged through capillary grooves in the driantube, the driantube function is normal.

Documentary film of survey:
https://youtu.be/3OQb1-qIr-A
(Scan QR code to get the video)

Fig. 4-1 Survey Shooting

Fig. 4-2 Site Soil

Fig. 4-3 On-site water intake

Fig. 4-4 Water after standing for 5 months

Chapter 5 Conclusion

1. The results of test data are shown in Tab.5-1, which shows that in this model, when the k of in-situ soil layer material is about 10-3cm/s, the discharge of a single group of driantube system can reach 55± 5cm^3/s, equivalent to about 5t/day of water.
2. There was no rain on the day of the survey, and the project case was about 20 years, and there was no obvious crack and slope on the wall surface. Therefore, it was judged that the capillary permeable drain pipe still effectively and continuously discharged the groundwater behind the wall, reducing the water pressure behind the wall.
3. From the visual bending in the driantube on site, it is judged that the soil and filter layer behind the retaining wall may have been hollowed out, but the driantube is not affected by the blockage after bending, and its efficiency is better than that of the traditional PVC tube.
4. The water discharged from the field is visually clear and not turbid. After standing for 5 months after taking water on the same day, there is still no large-scale particle precipitation. It was concluded that the current driantube system was collected and discharged through capillary grooves in the driantube, the driantube function is normal.

Tab. 5-1 Testing Data of Flow

Test Item	Test Sample	Density(D)	Quantity of flow (q) cm^3/s
Pure water	Driantube		489.12
	Drainbelt		673.50
Test Item	Test Sample	Density(D)	Quantity of flow (q) cm^3/s
Sandy soil	Driantube	1.4t/m^3	56
	Drainbelt		62

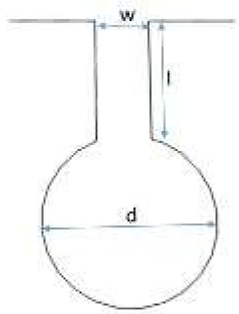
Appendix

Appendix 1. Specification of driantube

Given the basic specifications of driantube (as shown in Appendix Tab.1-1 and Appendix Fig.1-1), find the sectional circumference (C), surface area (A_r) and Sectional Area(A_{rc}) of the driantube.

Appendix Tab.1-1 Specification of driantube

Specification		Unit
Capiphon hole width(w)	0.3	mm
Capiphon downward grooving(L)	0.5	mm
Capiphon slit diameter(d)	1	mm
Holes	133	
Outside diameter of permeable tube(D_p)	68	mm
Length of contact between made ground and tube(L_r)	325	mm
Inner diameter of casing(D_c)	69	mm



Appendix Fig.1-1 Schematic diagram of capiphon hole

Step1：

$$\text{Capiphon circumference } c=\pi d - w+2\times L$$

$$c=\pi\times 1-0.3+2\times 0.5=3.842\text{mm}$$

Step2：

$$C=\pi D-(w\times 133)+(\pi d-w+2\times L)\times 133$$

$$C=63\pi-(0.3\times 133)+c\times 133$$

$$C=64\pi-(0.3\times 133)+3.842\times 133=669.006\text{mm}$$

Step3：

$$Ar=(C\times Lr)$$

$$Ar=(669.006\times 325)=217426.95mm^2$$

Step4：

$$Arc=\left[\left(\frac{\pi d^2}{4}\right)+(w\times l)\right]\times 133+\left(\frac{\pi (dc\text{-}dp)^2}{4}\right)$$

$$Arc=\left[\left(\frac{\pi 1^2}{4}\right)+(0.3\times 0.5)\right]\times 133+\left(\frac{\pi (69\text{-}68)^2}{4}\right)=125.193mm^2$$

Appendix 2. Constant head permeability test

Size of permeable mould:

Diameter: 10.14 cm; Height: 11.77 cm; Area: 80.754 cm^{2};

Weight(permeable mould+bottom plate): 12000 g

Weight(Permeable mould+bottom plate+soil) : 14200 g

Soil weight：2200 g

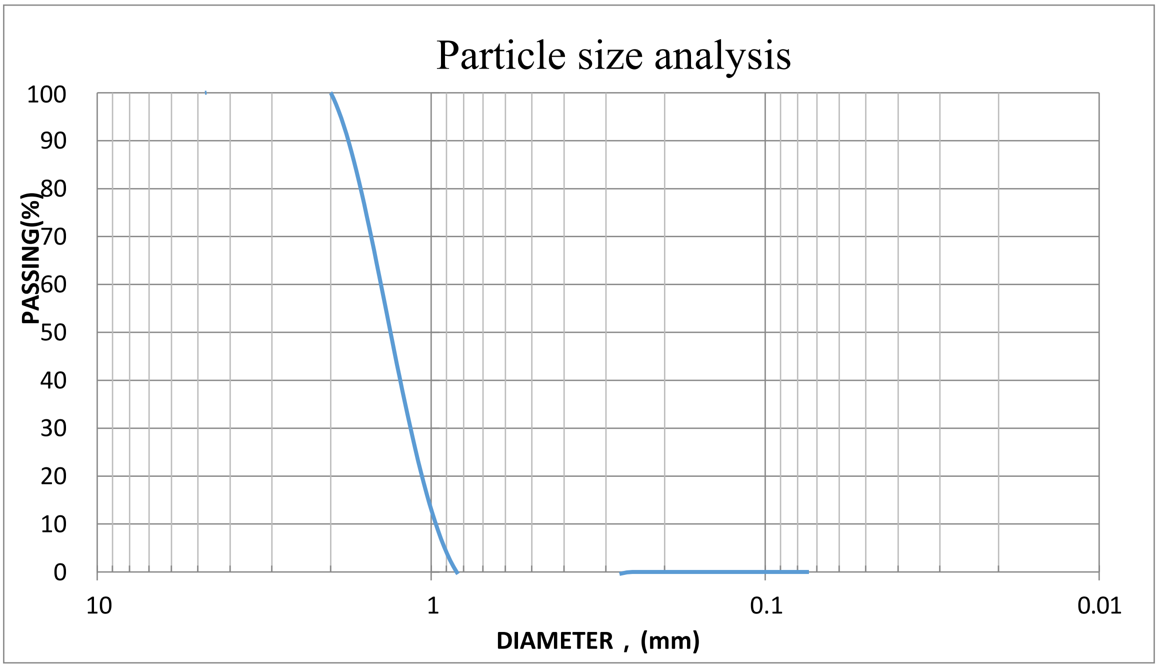
Constant head height： 189 cm

Test No.	t(s)	Q(cm^3)
1	300	700
2	300	700
3	300	690
Average	300	696.67

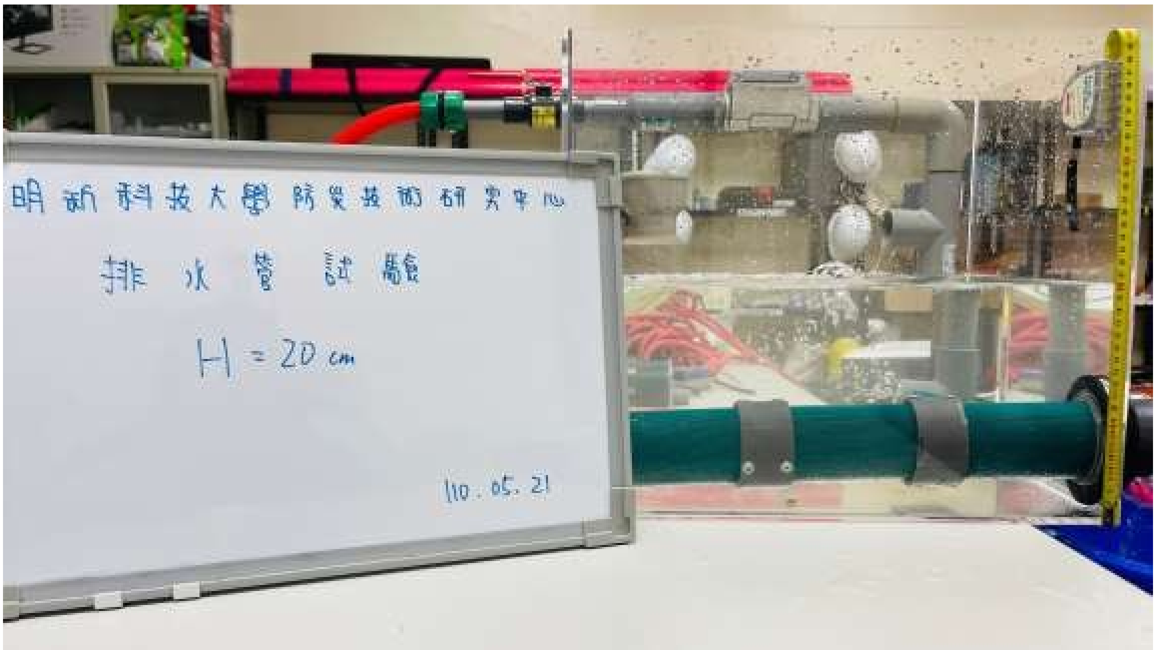
$$k=\frac{QL}{\Delta hAt}=\frac{696.67\times 11.77}{189\times 80.754\times 300}=1.79\times 10^{-3}$$

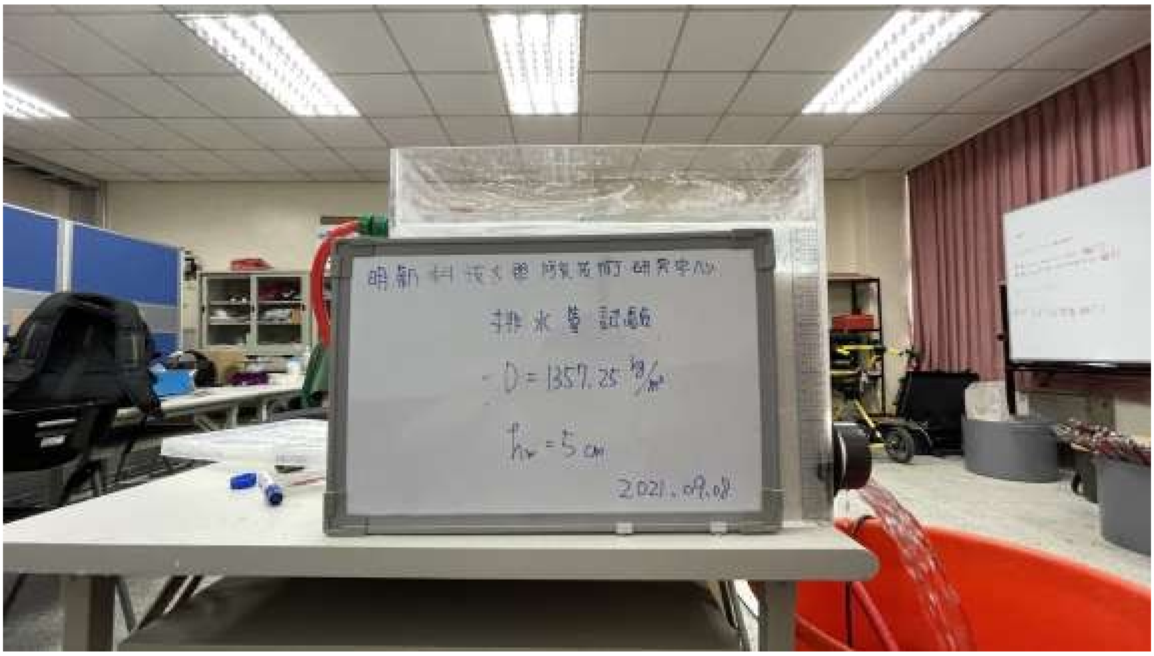
Appendix 3. Particle size analysis test

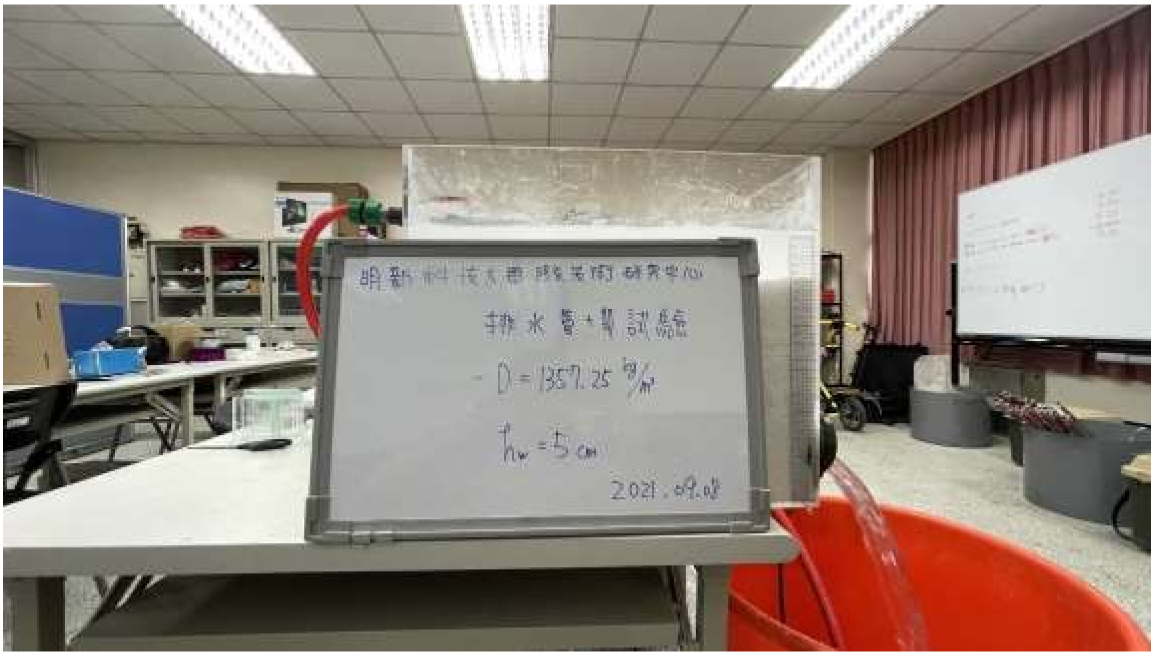
Mesh No.	Diameter of hole (mm)	Empty (g)	Plug+soil (g)	Soil(g)	Retention percentage (%)	Cumulative retention percentage (%)
4	4.75	472.5	472.5	0	0.0	0.0
8	2.38	323.5	323.5	0	0.0	0.0
16	1.19	312	512	200	100.0	100.0
40	0.42	293	293	0	0.0	100.0
100	0.149	275	275	0	0.0	100.0
200	0.074	284	284	0	0.0	100.0
Base		416	416	0	0.0	100.0



Appendix 4. Test photos




排水量試驗
D = 1357.25
hw = 5 cm
2021.09.08


D = 1357.25
hw = 5 cm
2021.09.08