Development of a water-leading hose for enhancing drainage of groundwater and dewatering effect of cohesive soil

Kiyoshi Omine[1] and S. Sugimoto[1]

[1] Graduate School of Engineering, Nagasaki University, 1-14 Bunkyo-machi, Nagasaki 852-8521, Japan.

ABSTRACT

A water-leading hose using siphon with capillary phenomenon was developed for enhancing drainage of groundwater and dewatering of cohesive soil. Amount of drainage was measured at a lower point of drainage hose using water container attached soil moisture meter. The water-leading hose was applied to a slope of embankment made of cohesive soil. It was confirmed that amount of drainage is increased after using the water-leading hose. Field test was also conducted on slope of highway with existing drainage pipe and spring water from the surface. It was indicated that water-leading hose works effectively at heavy rain.

Keywords: siphon; drainage; dewatering; groundwater

1 INTRODUCTION

In recent years, many sediment disasters have occurred by increasing in torrential rain. A technique to reduce ground water using drainage pipes has been used so far. However, it is not always to function the installed drainage pipes effectively by damage or clogging. Drainage from ground is important for various types of soils.

Drainage device with water-leading hose can be easily manufactured for dewatering of cohesive soil (Omine and Sugimoto, 2017). The purpose of this paper is to develop a water-leading hose for enhancing drainage of ground water and dewatering of cohesive soil by negative pressure with capillary and siphon phenomena. The effects are verified by laboratory and field tests. Drainage device attached water-leading hose can be easily manufactured. In addition, dewatering effect of cohesive soils is clarified by laboratory and field tests.

2 OUTLINE OF THE WATER-LEADING DEVICE

2.1 Principle and fabrication of water conduction device

Schematic diagram of drainage device with water-leading hose is shown in Fig.1. The drainage device consists of water-leading hose, drainage hose, water tank and perforated pile. The perforated pipe is inserted into soil surface. Cross section of the water-leading hose is shown in Fig.2. The water-leading hose is manufactured by using a hose inside diameter of 18 mm and inserting another hose inside diameter of 9 mm together with 10 pieces of acrylic string in diameter of 3 mm.

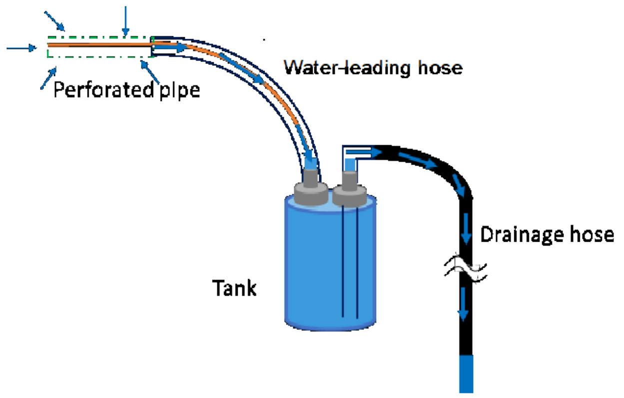
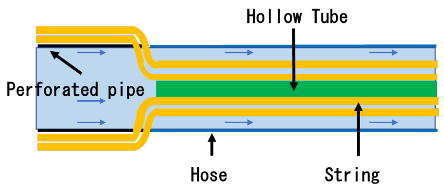
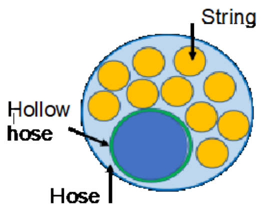


Fig. 1. Schematic diagram of drainage device with water-leading hose.

The water-leading hose is connected to the perforated pipe. Non-woven cloth is wrapped a surface of the perforated pipe for preventing soil particles from breaking into the pipe. Edge of the acrylic strings is attached on the surface of perforated pile. After inserted this perforated pile, the acrylic strings adsorb a small volume of water in a soil at first due to capillary phenomenon of the string and lead it to the water-leading hose gradually. Water moves to the water tank through the water-leading hose. After the tank is filled up, the water flows out from the drainage hose equipped at the top of the tank and siphon phenomenon occurs. Then, negative pressure will be applied and it is expected that dewatering from a soil starts. If a soil contains enough volume of water, the water will go through the inside hollow hose in the water-leading hose smoothly



(a) Direction of length



(b) Direction of perpendicular

Fig. 2. Cross section of water-leading hose.

2.2 Measurement of water volume

Measurement of drainage amount was used the soil moisture meter (EC-5) and the measurement container. Figure 3 shows schematic diagram of device for measurement of drainage volume. The measurement container was opened the hole and measured the water level in container. The drainage amount can be measured by adjusting the hole size and position.

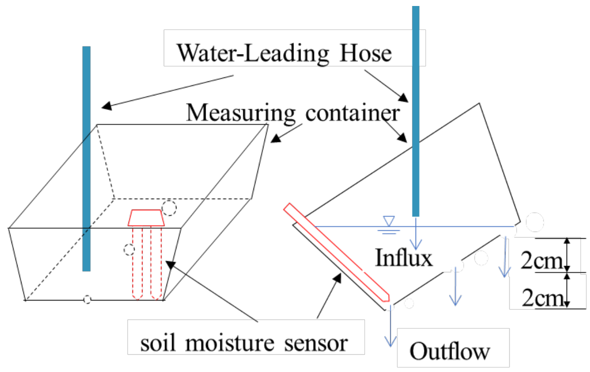


Fig. 3. Schematic diagram of device for measurement of drainage volume.

3 LABOLATORY TEST

Laboratory test using the water-leading hose was performed in different high of drainage hose with 2 or 8 m. The perforated pipe in length of 75cm was inserted into water or soil (Masado; granite decomposed soil). Figure 4 shows schematic diagram of laboratory experiment.

The test result is shown in Fig.5. The drainage amount of the soil was decreased comparing with only water. The drainage amount in both of water and the soil was increased as the water head is increased.

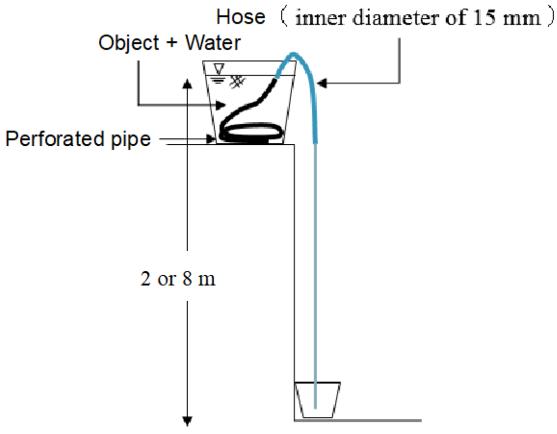


Fig. 4 Schematic diagram of laboratory experiment.

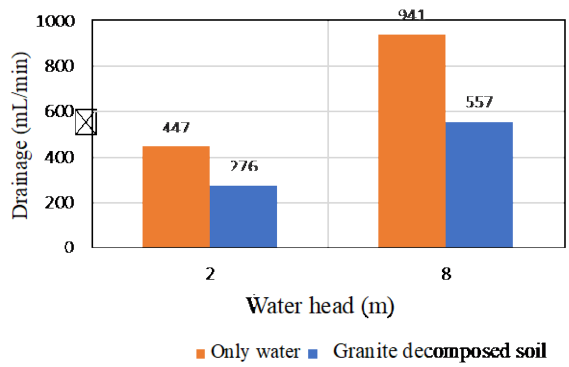


Fig. 5. Test result of drainage using water-leading hose in difference water head.

4 FIELD TEST

4.1 Embankment of cohesive soil

Field test was conducted on slope of embankment in Kin-cho, Okinawa, Japan. The embankment was built with cohesive soil (red soil). This area is in a high level of underground water, so that spring water has been seeped from the embankment slope. The perforated pipe with the water-leading hose was installed at two points on the slope of embankment.

Cross sections of the test fields are shown in Figs. 6 and 7. Test method of each site is as follows:

(Site A) A hole of 30 mm in diameter and 0.8 m in length was drilled almost horizontally at the spot where the spring water was found at the site (Fig.6). The perforated pipe in length of 0.8 m connected to the water-leading hose with was inserted into the hole. The drainage hose in length of 20 m and inside diameter of 9 mm was hung down on the slope. A difference of water head from the water tank was approximately 5 m. A volume of drainage was measure at a lower point of drainage hose.

(Site B) A hole of 30 mm in diameter and 0.8 m in length was drilled vertically at the spot where the spring water was found at the site (Fig.7). The water-leading hose was set in the similar way to the site A.

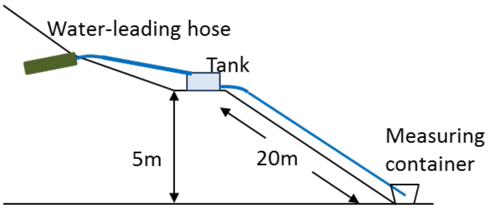


Fig. 6. Cross section of test field at Okinawa (Site A).

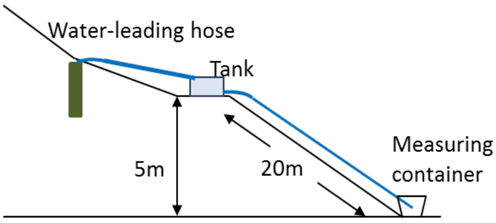


Fig.7. Cross section of test field at Okinawa (Site B).

(Site A) The drainage flow rate was measured at first before connecting the water tank and drainage hose and it was 1810 ml/min. Although a siphon pressure is not applied, a large amount of water is drained from this spring water point. After that, the water tank and drainage hose were connected to the water-leading hose and siphon pressure was applied. Drainage flow rate was measured from 11th November 2017 continuously by using data logger. Relationship between drainage volume and rainfall at Site A during 12 - 19 Nov. 2017 is shown in Fig. 8. The drainage flow rate more than 4 L/min was found and it continued almost constantly independent of rainfall. The drainage volume was increased more than twice after siphon occurred. It is considered that a large amount of water was stored in this area.

Relationship of drainage volume and rainfall at Site A during 18 - 25 January 2018 is shown in Fig. 9. The drainage volume was decreased in this period and after rainfall it was increased up to 2 L/min of drainage flow rate. As shown in this figure, it seems that siphon pressure was applied repeatedly.

(Site B) The drainage flow rate was measured at first before connecting the water tank and drainage hose and it was 1190 ml/min. After that, the water tank and drainage hose were connected to the water-leading hose and siphon pressure was applied. Then the drainage flow rate was 2020 ml/min and the value increased twice. Relationship between drainage volume and rainfall at Site B during 12 - 31 January 2018 is shown in Fig. 9. The drainage volume was increased and decreased repeatedly. It is found that maximum drainage flow rate was 3.5 L/min.

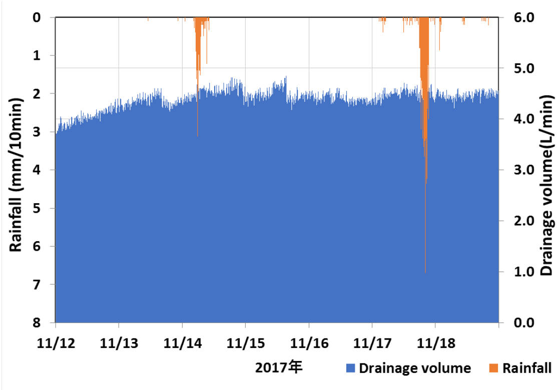


Fig. 8. Relationship between drainage volume and rainfall at Site A (12 - 19 Nov. 2017).

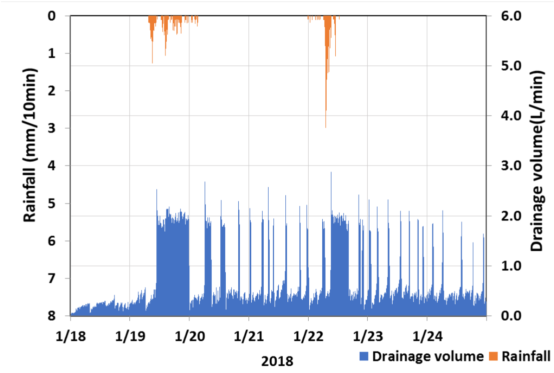


Fig. 9. Relationship between drainage volume and rainfall at Site A (18 - 25 Jan. 2018).

4.2 Natural slope with drainage pipe

Field test was conducted on slope of highway with existing drainage pipe in Nagasaki, Japan. Geology of the site is andesite tuff breaccia and spring water is found from the surface. Several drainage piles have been installed on the surface for countermeasure of slope. However, some drainage pipes are not working adequately. A drainage pipe of less than 1 L/min of drainage at rainy season was selected for application of water reading hose. Maximum drainage volume of selected drainage pipe was 0.9 L/min on June 2016.

Cross section of the test field is shown in Fig.10. The water-leading hose was attached at the end of drainage pipe and sealed up the gap. The drainage hose in length of 10 m and inside diameter of 9 mm was hung down on the slope. A difference of water head from the water tank was approximately 8 m. A volume of drainage was measured at a lower point of drainage hose by date logger.

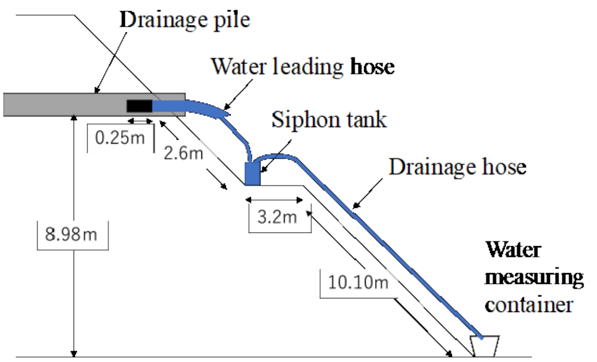


Fig. 10. Cross section of test field at Nagasaki.

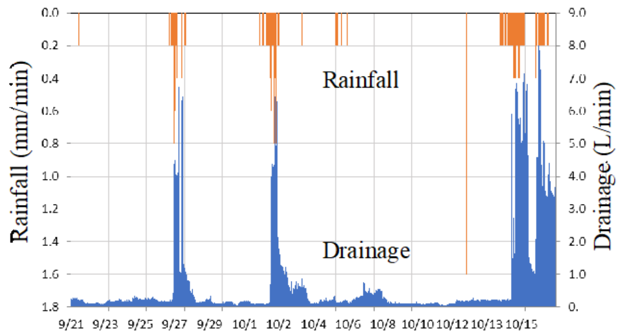


Fig. 11. Relationship between drainage volume and rainfall at Nagasaki (21 Sep. ~ 17 Oct. 2017).

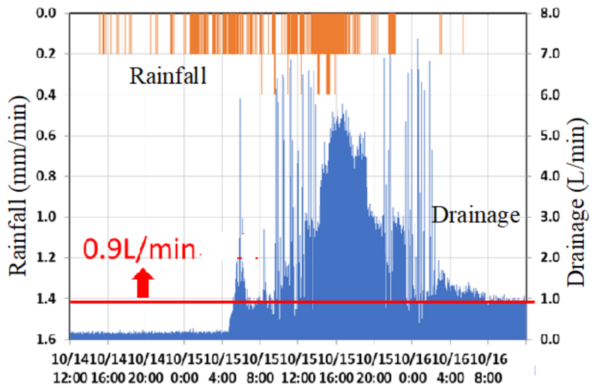


Fig. 12. Relationship between drainage volume and rainfall at Nagasaki (14 ~ 16 Oct. 2017).

Relationship between drainage volume and rainfall during 21 Sep. ~ 17 Oct. 2017 is shown in Fig. 11. A large amount of drainage is found at fairly large rainfall. It is indicated that water-leading hose has worked effectively at heavy rain. Maximum drainage of 9.07 L/min was obtained at 16 Oct. 2017.

Figure 12 shows relationship between drainage volume and rainfall during 14 ~ 16 Oct. 2017. Rainfall of 0.2 mm/min (=12 mm/h) continued more than 24 hours. After 12 hours from start of the rain, the volume of drainage increased gradually and drainage of more than 6 L/min was found repeatedly. The value exceeds 0.9 L/min before installed water-leading hose.

Figure 13 shows relationship between drainage for 24 hours and rainfall for 24 hours during two years. Drainage for 24 hours increases as rainfall for 24 hours increases and it increases sharply at rainfall for 24 hours of more than 50 mm/24h.

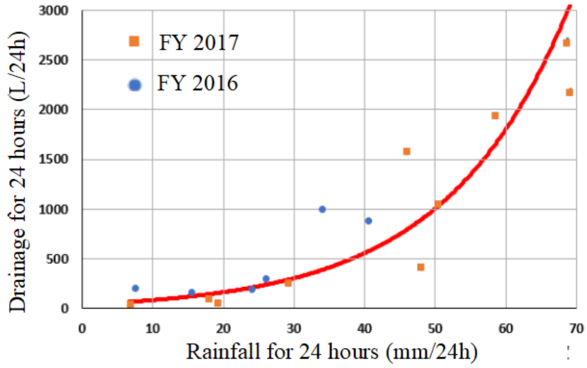


Fig. 13. Relationship between drainage for 24 hours and rainfall for 24 hours.

3 CONCLUSION

In this study, a water-leading hose with perforated pipe, water tank and drainage hose was developed for enhancing drainage of groundwater and dewatering of cohesive soil based on capillary and siphon phenomena. Laboratory and field experiments were performed by using the water-leading hose.

In the field experiment, the water-leading hose was applied to a slope of embankment made of cohesive soil where spring water was found. It was confirmed that amount of drainage is increased after using the water-leading hose. Maximum drainage flow rate exceeded 4 L/min. It was also found that the drainage volume increased more than twice after siphon occurred.

Field test was also conducted on slope of highway with existing drainage pipe and spring water from the surface. A large amount of drainage was found at fairly large rainfall. It was indicated that water-leading hose works effectively at heavy rain. Maximum drainage of 9 L/min was obtained at this field test.

This dewatering method is simple and cheap. In the future, it is expected to apply this method to various fields for improving stability of slope.

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