Laboratory study on methods to improve dewatering efficiency of geotextile tube filled by clayey silt slurry

Haimin Wu, Zhenyu Tian, Yiming Shu & Guangpin Chang
College of Water Conservancy and Hydropower Engineering, Hohai University, China

ABSTRACT: Geotextile tubes have been widely used to construct dike in the coastal and estuary area of China. However, the dewatering velocity of geotextile tube filled by clayey silt slurry is so slow that can not satisfy the requirement of limit construction period. Several laboratory model tests were conducted to investigate the dewatering efficiency of different filling and discharging methods. The pore water pressure, water content, reserved particle gradation and dry density monitored of the filled soil in different position are tested and analyzed. Through the tested results, the comprehensive dewatering velocities of different construction methods were comparatively evaluated. The model test results showed that the dewatering method which combines actively discharging muddy-water with alternately filling and discharging methods is more effective.

Keywords: geotextile tube, clayey silt, dewatering, model test

1 INTRODUCTION

Geotextile tubes(geotube) can be used to construct dike directly in water or on soft foundation. Relative to traditional dike construction method, geotube has numerous advantages, such as, rapid construction speed, low cost, being less affected by weather and easily adapting foundation deformation. Geotube technology has becoming preferred choice of dike construction in coastal and estuary engineering such as land reclamation, avoid salt reservoir, coastal embankment and cofferdam of harbor (Shu, 2018).

When geotube dike constructed in intertidal zone or on low beach, the dewatering and preliminary consolidation need to be completed in 6~10 hours to ensure enough bearing capacity to support the weight of upper layer of geotubes. So it is critical to investigate a method that can improve dewatering efficiency of geotube filled by clayey silt slurry.

Numerous researches work on dewatering and consolidation mechanism had been made in the last few decades. The computing method of average consolidation degree of slurry filled geotube during dewatering process was defined by Pilarczyk (2000). Soil retention performance and permeability of slurry/geotextile system and the possible controlling factors had been studied using pressure filtration tests (Moo-Young et al., 2002). The effect of water content and AOS of getextile on dewatering velocity was also studied (Muthukumaran and Ilamparuthi, 2006). The dewatering efficiency of different silts and geotextiles was studied using hang bag test by Koerner and Koerner (2006). The choosing criteria of geotextile and silts was established through laboratory and field experimentation by Lin et al. (2005, 2009) and Zhou et al. (2013). The dewatering velocity of geotextile tubes aided by ultrasound was also studied by Zhang et al. (2011). The seepage characteristic of clogged geotextile under pressure was tested by Weggel et al. (2011) and Palmeira and Gardoni (2015).

The above researches on dewatering efficient of geotube did not consider the field complex conditions and ignored the rapid dewatering requirement in intertidal zone or on low beach. In this paper, laboratory model tests were conducted to investigate the dewatering efficiency of several filling and discharging methods. The dewatering velocities under four different filling and dewatering methods were compared and analyzed. The effects of different filled slurry with clay and sand content were also discussed

2 MODEL TEST

2.1 *Set-up*

A unit geotube dewatering model was designed as shown in Figure 1. A big geotube model and a small geotube model were selected to simulated different filling and discharging method. Cross-section views of the two models were shown in Figure 2. Two models were designed 2m and 4m wide, respectively. The height and length of the two models were both designed as 0.6m and 0.2m. The actual widths of the two models were 1m and 2m considering the symmetry of the model. In order to modeling the undrained boundary, the center cross section and two side surfaces of geotube model were covered with impermeable waterproof cloth. A slurry pump was used to model the actual filling construction process. The pumping head was 8 m and pure water transporting velocity was 30 L/min.

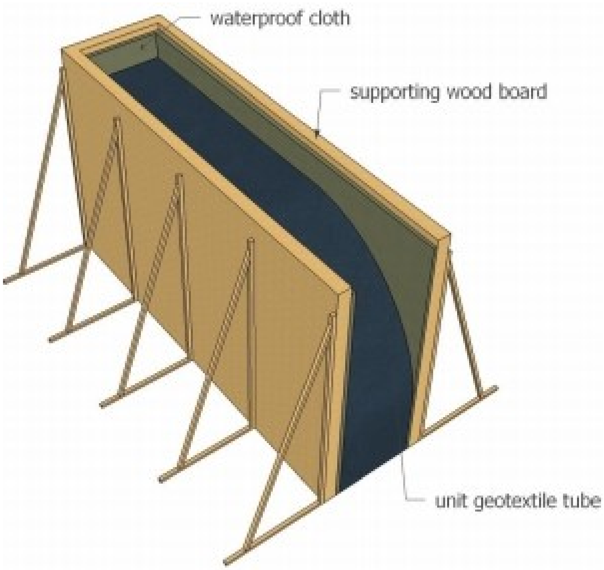
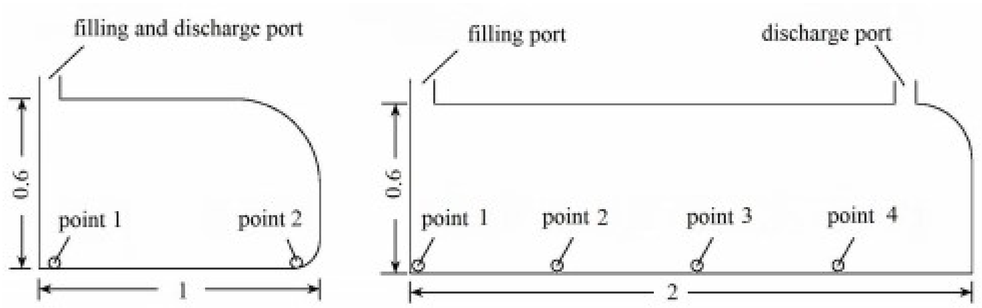


Figure 1. Schematic diagram of unit geotube dewatering model.



(a) Small model with width of 1 m. (b) Big model with width of 2 m.

Figure 2. Cross-section views of the two models. (m).

Tests were conducted in model boxes showed in Figure 3. Figure 4 presents the actual photo of unit model geotube fully filled by slurry.

Figure 3. Profile photo of model test

Figure 4. Geotube model filled by slurry

2.2 *Materials*

The geotube models in the tests were made of 200 g/m^2 polypropylene woven geotextile. The filling soil was taken from field site of Tiaozini project in Jiangsu, China. The solid content of the slurry was 25% mixed and blended with soil and water.

2.3 *Procedure*

A series of dewatering model tests were performed using the above model test set-up and materials. The different groups of tests considering the combination of different clay content, sand content and filling-dewatering methods were shown in Table 1 and Table 2.

Table 1. Test scheme for small mode.

No.	clay content/%	sand content/%	geotube width/m	filling and dewatering method
1	10	50	1	spontaneous dewatering
2	10	50	1	dewatering with beat disturbance
3	10	50	1	alternately filling and discharging
4	10	40	1	alternately filling and discharging
5	10	30	1	alternately filling and discharging
6	15	40	1	alternately filling and discharging
7	20	30	1	alternately filling and discharging

Table 2. Test scheme for big model.

No.	clay content/%	sand content/%	geotube width/m	filling and dewatering method
8	10	40	2	simultaneously filling and discharging
9	20	40	2	simultaneously filling and discharging

Four filling and dewatering methods were simulated: spontaneous dewatering after filling repeatedly (for small mode); dewatering with beat disturbance (for small mode); alternately filling and discharging (for small mode); simultaneously filling and discharging (for big mode). The alternately filling and discharging method means performing a dewatering process spontaneously after a single filling until it clogs, then the filling port is opened to discharge the surface muddy-water that mainly contain fine grain. The simultaneously filling and discharging method means that the filling was conducted; meanwhile the surface muddy-water was discharged using a drainage port settled at the side of geotube.

Osmometers were installed in the bottom of the model to monitor pore water pressure of the slurry in geotubes. The installation locations were point 1 to point 4 in models with different widths as shown in Figure 2. The particle gradation, water content and dry density of the reserved soil in the geotube were tested when the slurry had completely deposited and dewatered. The test results were compared to estimate actual dewatering efficiency of the geotube model.

3 TEST RESULTS OF SMALL MODEL

3.1 *Effects of different filling methods*

In test 1, test2 and test 3, the initial filling height slurry was 60 cm. Test 1 and test 2 had one filling period while test 3 had four. Figure 5 show the change process of pore water pressure at measure point 1 in test 1~ test 3. It can be seen that the alternately filling and discharging method had the most positive effect on pore pressure dissipation, while test 1 using spontaneous dewatering method had the least dewatering velocity.

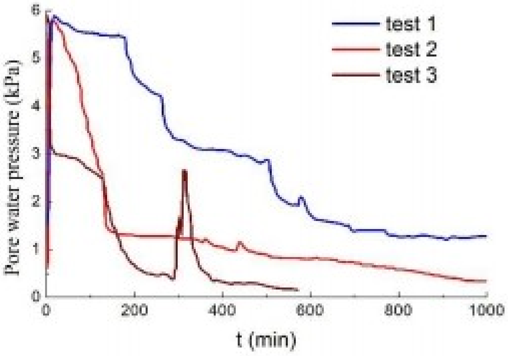


Figure 5. Pore water pressure change process at measure point 1 in test 1 ~ test 3.

In test 1, pore pressure dissipated only 0.5 kPa after 3-hours dewatering. The muddy-water at the top of the geotube model need another 27 hours to discharge out. About 5~6 more filling periods was needed to reach the expected height of 60 cm, which is the design height of geotube after dewatering process.

In test 2, the pore pressure dissipation was faster compared to test 1, but muddy-water also need 3 hours to discharge out. After a 10 hours dewatering process, the consolidation degree just reached 30%, which means that it will take about 3 days to finish whole filling and dewatering periods.

In test 3, alternately filling and discharging method was used with 4 filling periods. After 10 minutes-filling of each period, the coarse particle of the slurry approximately settled and then muddy-water on the surface was discharged out. A 30 cm high geotube formed after 1 h. Sand content at the bottom and the top of geotube was more than 79%, and clay content was less than 1.5%. After a 6 hour-dewatering process, the surface water content in the geotube decreased to 22.3% and bottom water content decreased to 27.8%. Dry density of surface soil was 1.54 g/cm^3, which was the required minimum value of specification JYJ239 (China, 2005). It is showed that the geotube had enough bearing strength to support upper geotubes.

3.2 *Effects of different filling slurry*

The change process of pore water pressure at measure point 1 in test 4 ~ test 7 were shown in Figure 6. In test 4 and test 5, the spacing between filling and discharging was 10 minutes. After 4 filling and dewatering periods, the soil height in the geotube reached 47 cm and 35 cm, respectively. Based on the pore pressure dissipation rate, 140 min and 185 min would be needed to ensure the bottom consolidation degree of 75% in test 4 and test 5, respectively.

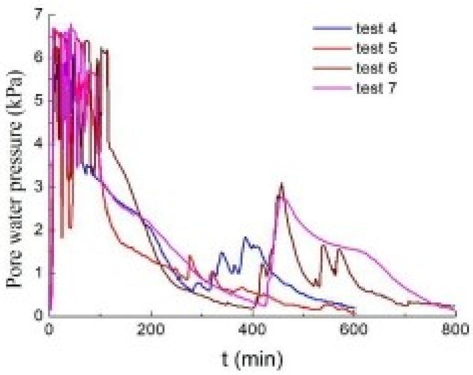


Figure 6. Pore water pressure change process at measure point 1 in test 4 ~ test 7.

In test 4, after dewatering, the surface soil in the geotube had a sand content of 72% and a clay content of 1.1%. Six hours later, water content near measure point 1 and 2 are 15% and 35.7%, while dry density was 1.68 g/cm^3 and 1.26 g/cm^3, respectively. The former met the requirement of specification JYJ239 (China, 2005), but the latter did not. In test 5, the sand content of surface soil in the geotube reached 87%. After 6 hours' dewatering, water content of soil at measure point 1 and 2 were 26.6% and 36.8%, meanwhile their dry densities were both greater than 14.5 g/cm^3, meeting the specification.

In test 6 and test 7, the spacing between filling and discharging was 10 minutes. After 5 and 6 filling and dewatering periods, the soil height reached 38 cm and 33 cm, respectively. It took 120 min and 100 min to finish dewatering progress in test 4 and 5, respectively. Based on pore pressure dissipation rate, it could form a 50~60 cm high geotube within 6 hours.

In test 6, after dewatering, the surface soil in the geotube had a sand content of 58% and a clay content of 1.7%. Six hours later, water content near measure point 1 and 2 are 23.2% and 31.7%, respectively, while dry densities were both greater than 14.5 g/cm^3. In test 7, the sand content of soil at bottom of geotube reached 45%, failed to meet the sandy soil requirement. After 6 hours-dewatering, dry density of soil at 15 cm beneath the surface was only 1.19 g/cm^3.

4 TEST RESULTS OF BIG MODEL

The above model test results shown that all geotube models that using simultaneously filling and discharging method could finish dewatering progress in 6 hours except test 7. However, considering the prototype was only 2 m wide and using the same cuff as filling and drainage port, the actual effect may be restricted when this method is applied on wide geotube. So, two more big model tests were carried out to simulate large geotube with an independent filling port set in the middle and a drainage port set on the edge as shown in Figure 2 (b). The width of unit prototype geotube was designed as 4 m. Filling and discharging were conducted simultaneously to get a faster dewatering velocity.

In test 8 and test 9, the change processes of pore water pressure at measure point 1 were showed in Figure 7. Initial sand contents of the slurry were both 40%. Initial clay contents were 10% and 20%, respectively. During test process, the initial 100 min was simultaneously filling and discharging phase and the next 100 min was dewatering phase. In test 8, the soil reserved in the geotube reached 41 cm high after dewatering. 160 minutes were needed to reach 75 percent consolidation degree. In test 9, the soil reserved in the geotube reached 42 cm high after dewatering. 6 hours later, the pore pressure reduced to 1.3 kPa. About one more hour was needed to reach 75 percent consolidation degree.

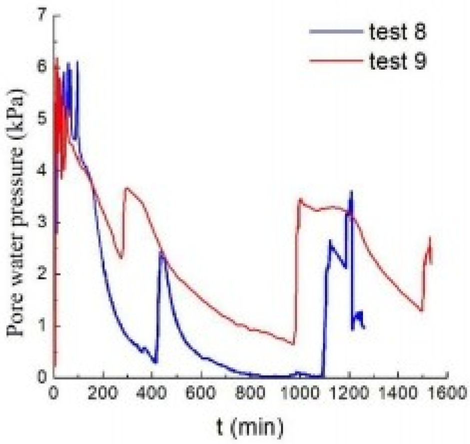


Figure 7. Pore water pressure change process at measure point 1 in test 8 ~ test 9.

In test 8, the sand content of soil layer near measure point 1 and 3 were 48% and 48.5%, respectively, but this layer was thinner than 2 cm. Soil located at 15 cm beneath the two measure points had sand content of 71.5% and 75.5%, which both reached 50% as the specification required. After 6 hours-dewatering, water content of these deep-seated soil reduced to 28% and 29.9%, respectively. Their dry densities were also greater than 14.5 g/cm^3.

In test 9, the sand content of soil layer near measure point 1 and 3 were 49% and 65%, respectively, which basically reached 50% that the specification required. Soil located at 15 cm beneath the two measure points had sand content of 85% and 65%, respectively. After 6 hours-dewatering, water content of these deep-seated soil reduced to 25.2% and 25.5%. Their dry densities were 15.9 g/cm^3 and 14.53 g/cm^3, respectively. The consolidation degree met requirement of specification.

The two further large model geotube tests shown that simultaneously filling and discharging method was an effective construction method for wide geotubes filled with high clay content slurry.

5 CONCLUSION

The following conclusions can be summarized from dewatering model tests results of geotubes.

(1) Neither spontaneous dewatering method nor dewatering with beat disturbance method can finish dewatering processes within 6 hours.
(2) Alternately filling and discharging method could improve dewatering efficiency of geotube filled by clayey silt slurry.
(3) While clay content is greater than 20% or sand content is less than 30%, alternately filling and discharging method failed to complete dewatering process within 6 hours.
(4) Simultaneously filling and discharging method could be used on large geotubes to get a better dewatering efficiency.

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REFERENCE

China, M.o.T.o.t.P.s.R.o., 2005. Technical Code for Application of Geosynthenics for Port and Waterway Engineering. China Communications Press, Beijing, p. 63. (in chinese)

Koerner, G.R., Koerner, R.M., 2006. Geotextile tube assessment using a hanging bag test. Geotextiles & Geomembranes, 24, 129-137.

Lin Gang, Shu Yiming, Lin Yong, 2005. Principal of mud- filled bag embankment and practice. Yangtze River, 36, 25-27. (in chinese)

Lin Gang, Shu Yiming, Wu Haimin, 2009. Primary Study on Dewatering Test Method of Geotextile Tubes with Small Section. Water Resources and Power, 27, 156-158. (in chinese)

Moo-Young, H.K., Gaffney, D.A., Mo, X., 2002. Testing procedures to assess the viability of dewatering with geotextile tubes. Geotextiles & Geomembranes, 20, 289-303.

Muthukumaran, A.E., Ilamparuthi, K., 2006. Laboratory studies on geotextile filters as used in geotextile tube dewatering. Geotextiles & Geomembranes, 24, 210-219.

Palmeira, E.M., Gardoni, M.G., 2015. The influence of partial clogging and pressure on the behaviour of geotextiles in drainage systems. Geosynthetics International, 7, 403-431.

Pilarczyk, K.W., 2000. Geosynthetics and geosystems in hydraulic and coastal engineering. A. A. Balkema, Rotterdam,Netherlands.

Shu Yiming, 2018. Advances in technology of geotube dam engineering in China. Advances in Science and Technology of Water Resources, 1-11+18. (in chinese)

Weggel, J.R., Dortch, J., Gaffney, D., 2011. Analysis of fluid discharge from a hanging geotextile bag. Geotextiles & Geomembranes, 29, 65-73.

Zhang Jinghui, Liu Zhaohui, Lu Dan, Wang Wenqian, 2011. Dewatering of contaminated reservoir /lake sediment by using geotextile tubes aided by ultrasound. CHEMICAL ENGINEERING, 39, 16-18. (in chinese)

Zhou Baohua, Li Zhichao, Liu Qing, Wang Hongjie, 2013. Laboratory study on the dewatering and consolidation settlement of the arsenic sludge using geotextile. Hebei Journal of Industrial Science and Technology, 30, 87-91. (in chinese)