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Behavior of total stress by hydraulic infilling soil in rigid drain geocontainer

Hyeong-Joo Kim[1)], *Tae-Woong Park[2)], Sung-Gil Moon[3)],
Hyeong-Soo Kim[4)] and Chung-Yeul Yu[5)]

[1)] *Department of Civil Engineering, Kunsan National University, Gunsan 573-701, Korea*
[2), 3), 4), 5)] *Department of Civil Engineering and Environmental Engineering, Kunsan National University, Gunsan 573-701, Korea*
[1)] *kimhj@kunsan.ac.kr*, [2)] *r2r3r4r5@kunsan.ac.kr*, [3)] *giri@kunsan.ac.kr*,
[4)] *gudtn3004@kunsan.ac.kr*, [5)] *inshakr275@kunsan.ac.kr*

ABSTRACT

The volume of flexible geotextile tube structure decreases due to drainage when infilling soil (silty sand) increases in tube. In addition, the horizontal deflection is increasing with pouring amount and tube effective height also decreases. In this study, the experiment of infilling and draining was practiced by attaching woven geotextile at both ends of rigid container (acrylic tube) as filter to comprehend internal total stress of geotextile tube structure. This experiment was to prepare for maintaining undrain condition while increasing infilling pressure of the soil as maximum as possible in flexible geotextile tube structure. The horizontal stress of geotextile tube structure formed by rapid infilling and delayed drainage decreases drastically due to the transverse direction drainage in isotropic stress condition that effects by infilling pressure in initial infilling time. After the finial infilling, the geotextile tube structure becomes stable due to properties of infilling soil rather than tensile stress of geotextile.

1. INTRODUCTION

Geotextile tubes are made from strong and flexible textile materials that are capable of retaining fine-grained materials though permeable enough to allow the excess water from the hydraulically filled slurry to dissipate. In recent years geotextile tubes were used as groins and breakwaters to protect or mitigate shoreline/coastline erosions as containment dikes for land reclamation, man-made islands, revetments acting as mass-gravity barrier-type structures, and protection dikes to prevent damage to valuable structures caused by natural calamities

Geotextile tubes has been of interest in various studies due to its wide

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[1)] Professor
[2), 3), 4), 5)] Graduate Student

applications in civil engineering. Evaluation results on the permeability and retention characteristics of geotextile tubes can be found in the studies of Moo-Young et al. (2002), Koerner & Koerner (2006). Model tests and large-scale experiments on geotextile tubes can be found in the literature (Kim et al., 2013, 2014). Numerical (Kim et al., 2013, 2014) & analytical methods (Plaut & Klusman, 1999) were also conducted to study the stability of stacked geotextile tubes. This kind of existing research was practiced with numerical analysis and experimental behavior that focuses on the flexible geotextile tube structure. However, to increase the amount of infill for saving construction costs in field, there is using rapid infilling method or high pressure dredge pump ships. Therefore, geotextile tube structure is deposited in undrain conditions, the amount of infilled soil increases more than the amount of geotextile tube's drainage, which occurs because of excessive infilling pressure. This will make hydraulic crater at infill entrance and the excess stress concentrated in tube. Eventually, the non-uniform geotextile tube structure will be formed in longitudinal direction. In order to comprehend the behavior of tube structure during infilling-draining-refilling-draining in the undrain geotextile tube structure, the total stress transducer was attached inside rigid container (acrylic tube) and woven-geotextile at the both ends. The procedures and results are presented in the followling sections.

2. MATERIAL PROPERTIES AND TUBE BEHAVIOR

2.1 Dredged Fill Properties

The fill material was obtained from a local dredging site in the Saemangeum river estuary near Gunsan City. The geotextile tensile strength-strain relationship obtained from a test of the P.P. Initially the polypropylene geotextile is strained up to 15% with minimal force. The physical properties of the dredged fill and the geotextile are shown in Table 1.

Table 1. Dredged Fill Properties and Geotextile Properties

Soil properties		**Geotextile properties**	
Natural water content, ω_n (%)	15.9	Material Type	P.P.***
Specific gravity of soil solids, G_s	2.69	Thickness (mm)	2.0
Plasticity Index, PI (%)	N.P.*	Tensile Strength	
Percent passing #200 sieve	25	Longitudinal (kN/m)	195
Soil classification (USCS)	SM**	Transverse (kN/m)	180

N.P.* = Non-plastic, SM** = Silty sand, P.P.*** = polypropylene

2.2 Behaviour Principal of Rigid Tube and Geotextile Tube

The comparison between rigid and flexible tube with the step by step process of infilling-draining-refilling-draining is represented in Fig.1.

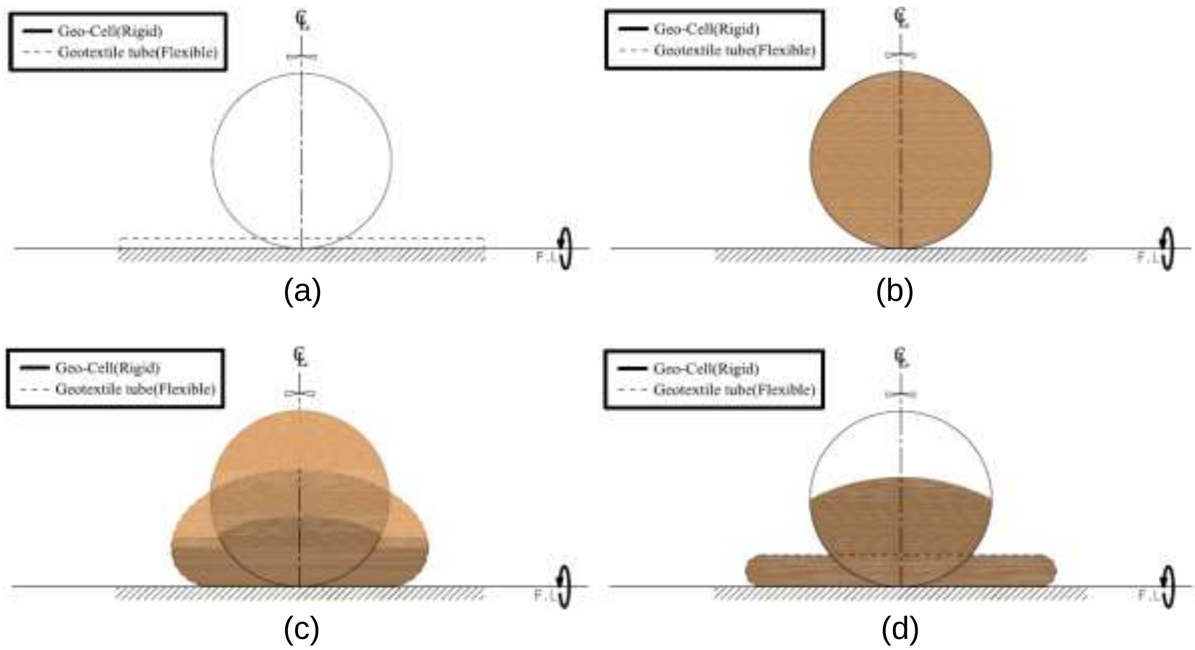


Fig. 1 Behaviour principal of rigid tube and geotextile tube: (a) before filling; (b) fully filled with slurry stage; (c) sedimentation & self-weight; (d) complete drainage & refilling stage

3. LABORATORY SETUP AND PROCEDURE

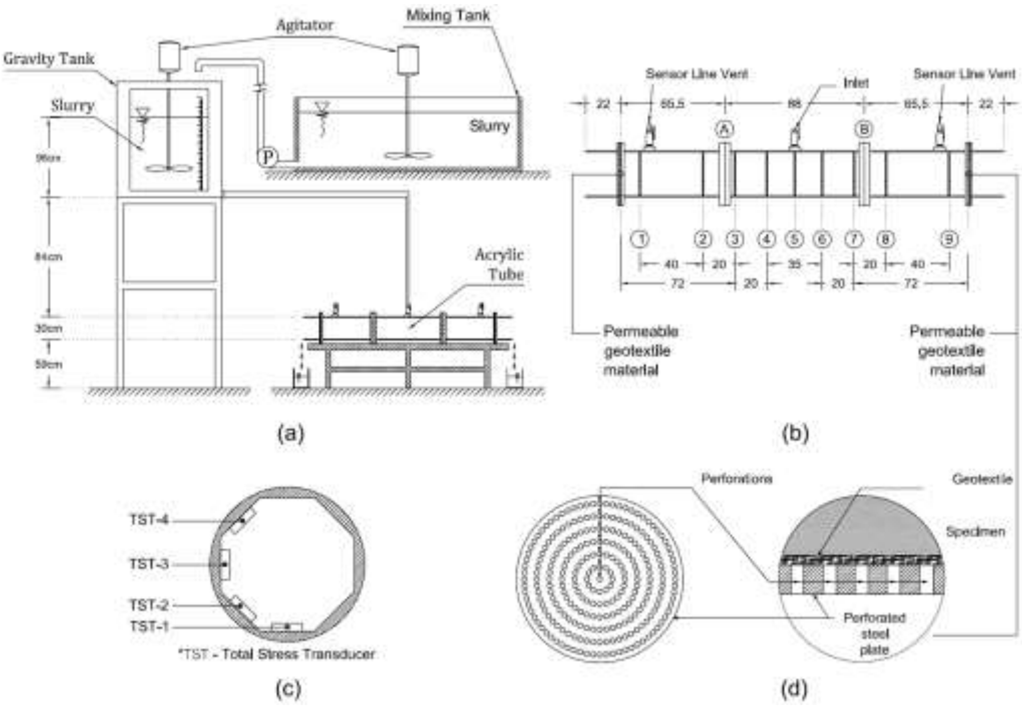


Fig. 2 (a) Laboratory setup; (b) acrylic tube detail, and; (c) total stress transducer (TST) placement; (d) perforated steel plate

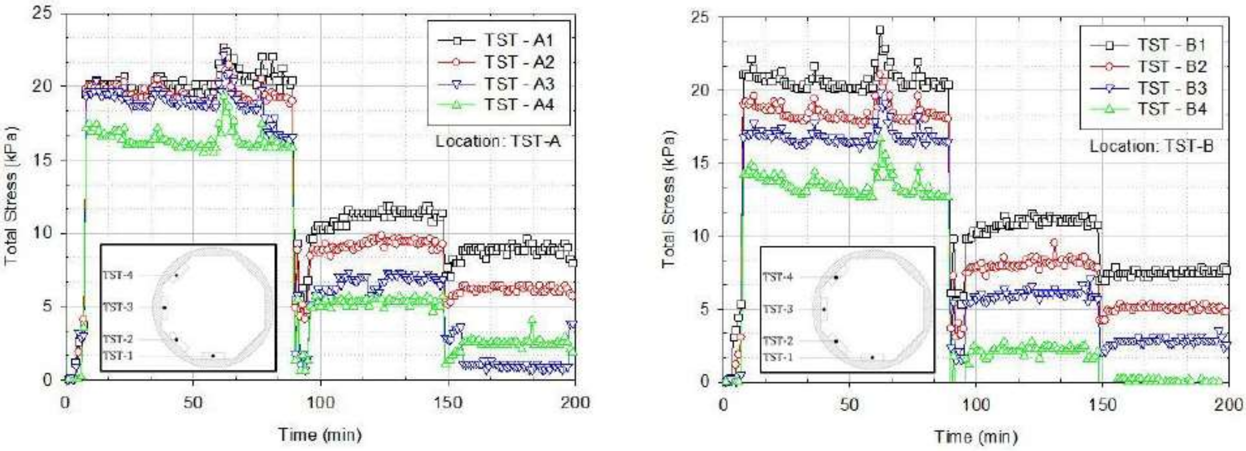
Fig. 2 illustrates the schematic diagram of the apparatus used for test. The laboratory setup shown in Fig. 2(a) comprises of a mixing tank, gravity tank or the elevated tank, and the acrylic tube. The mixing and gravity tanks are equipped with electric driven agitators used for the mixing of the water-soil mixture. The detail for the acrylic tube is shown in Fig. 2(b). The acrylic tube's filling port is located on the center. Measurement points/sections for the height of accumulated soils are located at ①, ②, ③, ④, ⑤, ⑥, ⑦, ⑧, and ⑨, as shown in Fig. 2(b). The TST contraption shown in Fig. 2(c) are located at Ⓐ and Ⓑ.

The slurry is prepared in the mixing tank where water and dredged soil are combined and is constantly agitated with an electric agitator. After the desired slurry consistency reached the soil-water mixture is hydraulically pump to the gravity tank. An electric agitator are also provided in the gravity tank to maintain the slurry consistency.

4. TEST RESULTS

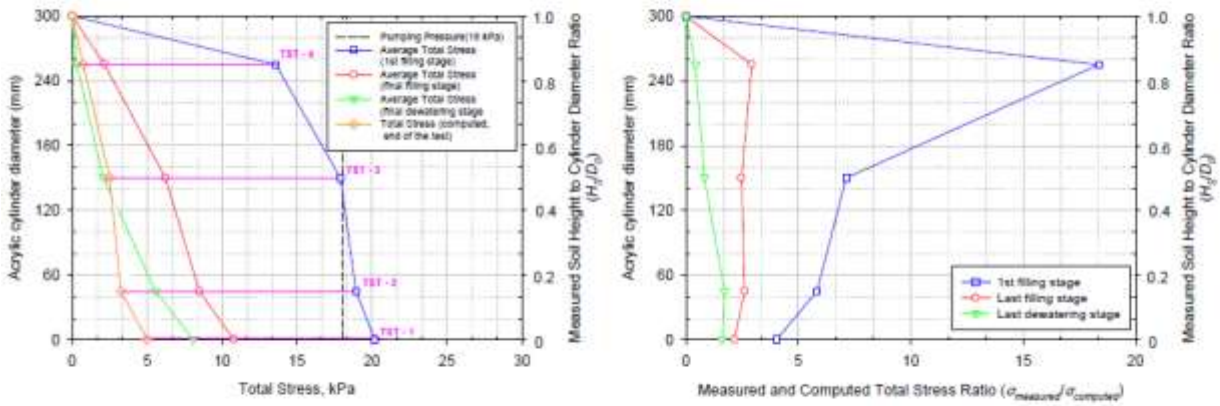
The filling rates for the test were methodically constant. The test was initially planned to hydraulically filled (though gravity force) with slurry at Q_1 = 0.0106 m^3/min. The measured pumping pressure was approximately 18 kPa during the entire experiment. The slurry material was injected into the tube at water content ω = 300%. The first filling stage lasted for approximately 80 min. Ten minutes after the first filling, clogging due to the accumulation of filter cakes on both the geotextile sheet covers at the ends of the acrylic tube occurred.

The total stress readings for the test are shown in Fig. 3 (for the placement and orientation of these devices in the acrylic tube, please refer to Fig. 2). The readings for the stress transducers at Locations Ⓐ and Ⓑ are exhibited at Figs. 2(b) and 2(c), respectively. The recorded pressures for test clearly reflects the hydrostatic pressure from the gravity tank. The measured pumping pressure was 18 kPa. The average total stresses during the 1^{st} & 2^{nd} filling, and during the final dewatering stages acting on the acrylic tube wall were plotted and shown in Fig, 3. It can be seen that the hydrostatic pressure from the gravity tank has a significant effect on the total stresses acting on the acrylic tube walls, especially on the 1^{st} filling stage. At the last stage where the pumping pressure was removed, it can be observed that the total stresses acting on the acrylic tube walls were decreased eventually. After the experiment, laboratory tests were conducted on soils samples from the acrylic tube. The average bulk unit weight γ_{bulk} of the fill material after the test is 17.9 kPa. With this value, the total stresses acting at TST1, TST2, TST3 and TST4 can be approximated. The calculated total stress based on γ_{bulk} is also plotted in Fig. 4(a) and the ratio between the calculated (reference value) and measured values are plotted in Fig. 4(b). The calculated values for TST3 and TST4 correspond closely the measured values during the final dewatering stage. There is a substantial difference between the measured and calculated values for TST1 and TST2. The idealized average total stress distribution around the acrylic tube's wall is shown in Fig. 5.



(a) (b)

Fig. 3 Total stress readings for: (a) TST-A; and (b) TST-B

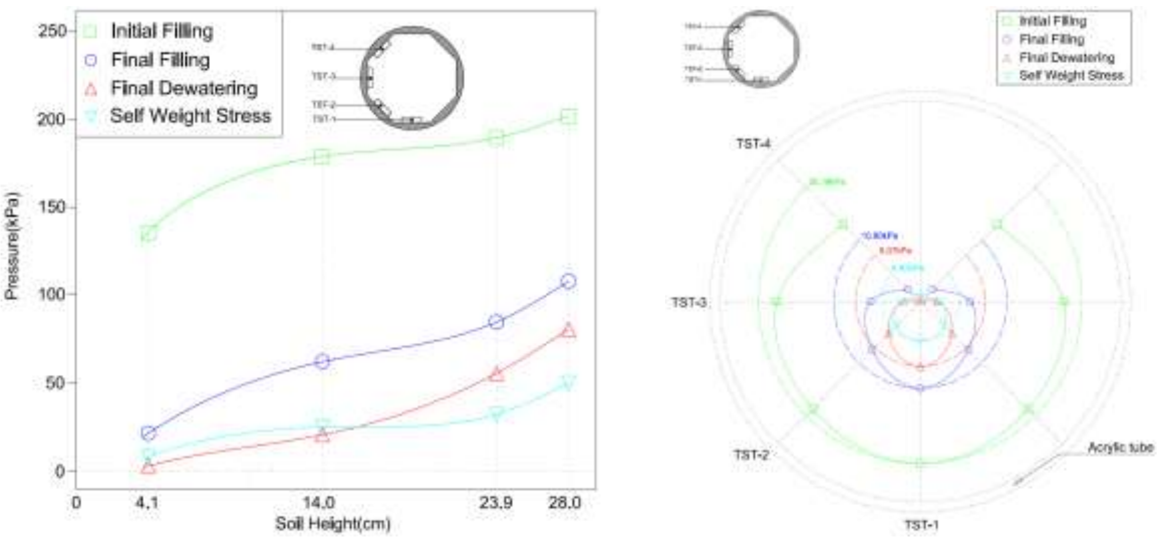


(a) (b)

Fig. 4 (a) Total stress distribution; and (b) total stress ratio distribution

Fig. 5(a) shows measured average stress in each step inside arcylic tube, which expresses vertical depth with pressure during infilling-draining-reinfilling-draining stage. Total stress measured inside the arcylic tube structure showed maximum 20.18 kPa at bottom, 18.94 kPa on lower section, 13.58 kPa on upper section section for initial ① infilling case. The arcylic tube is affected by the infilling pressure, but as overall deposited soil increases inside arcylic tube makes stress decrease in upper section. Closing ② inlet valve and infilling sandy soil will make water go through the drainer. After the natural drainage step, in the case of the final infilling, the sediments will increase and influence of infilling pressure will decrease. During the final infilling, the total stress at bottom section of arcylic tube was reduced to 10.80 kPa. The total stress of arcylic tube decreases excessively over the horizontal surface, because infilling pressure decreases due to effects of drainage, which is attached to the side end. ③ is for final drain condition, influenced by the residual pore pressure. Therefore due to the average water content of 42% of the soil deposits, it shows that the total stress during final dewatering stage is bigger than geostatic stress.

Fig. 5(b) shows the curve connection of total stress measured from the bottom of arcylic tube (TST-1) with total stress measured from each section (TST-2, 3, 4). In the Fig. 5(b), dotted line express the infilling and draining process with showing measured maximum value at bottom section TST-1 as dotted circular arc line. As for the upper part, the measured value of the total stress decreases gradually and approaches to the isotropic state. However for the upper part, a total stress decreases excessively, which approaches to anisotropic state. With increasing deposited soil inside arcylic tube, the liquid state deposited soil rises. The arcylic tube, which restricts transverse deformation, will become plastic soils that affectes the drain speed and drainage rate (diameter, D/horizontal distance, L) by decreasing the initial pressure. In addition, with decreasing residual pore pressure, total stress approaches to geostatic stress, which is K_0.



(a) (b)

Fig. 5 (a) Pressure distribution by filling and dewatering; (b) circular pressure distribution

6. CONCLUSIONS

Based on the tests conducted, the following conclusions are drawn:

- Rigid container (arcylic tube) during initial filling, draining, refilling, and again draining process, the total stress increases at the bottom section of acrylic tube by injection pressure and increment of deposited soil inside acrylic tube. However, in the upper section it decreases due to drainage.
- With increasing of deposited soil inside acrylic tube, it shows the deposited layer is at plastic condition, which has decreasing water content of deposited layer due to permeability at the drains.
- As the part of rigid container that restricts the transverse direction drainage and displacement, the total stress of acrylic tube decreases severely due to injection and drainage.

- In addition, the circle stress that occur inside acrylic tube showed anisotropic behavior at the upper surface section and show isotropic behavior at the lower surface section.
- Therefore, the center of gravity that occurs in rigid tube moves to the bottom section. Lastly, the drainage of pore water pressure approaches to the geo-static earth pressure K_o.

ACKNOWLEDGEMENTS

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