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The Influence of Filling Port System to the Accretion and Pressure Distribution of Dredged Soil Fill in Acrylic Tubes

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ABSTRACT

A series of slurry filling test were performed to evaluate the dredged soil fill distribution in a cylindrical acrylic tube based on the type of inlet system used. The acrylic tube, referred to as geocell in this paper, is 2.19m long with an inner diameter of 280mm. Both ends of the acrylic tube were covered with permeable geotextile sheets to allow water dissipation. The dredged soil fill material is hydraulically filled into the acrylic tube in the form of soil-water mixture (slurry). Two types of filling ports were used, namely the I-type and T-type inlet systems. The nature of the distribution mechanism of the soil fill inside the geocell with respect to the type of inlet system used is presented in this paper. Load cells oriented in the vertical and horizontal directions were installed inside the geocell to measure the horizontal and vertical pressures inside the cylindrical tube. The pressure readings are collected through a data logger and interpreted by a desktop computer. It was found that the inlet system influence the distribution mechanism of dredged soil fill inside the acrylic tube. Also, the pressure distribution inside the geocell based on the load cell readings are closely related to the theoretical K_0 and K_a conditions.

1. INTRODUCTION

In the past few decades geosynthetics has been in increasingly applied in the field of civil and construction engineering. Presently, geotextile containment system such as geotextile tubes, geotextile bags and geotextile containers are used widely for hydraulic

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and marine applications (Lawson, 2008). Its applications ranges from containment of contaminated materials for manageable disposal to the prevention against collapse of earth structures and mitigation against coastal erosion.

Geotextile tubes are tubular containers that are filled with dredged materials in situ on land on in water (Lawson, 2008). There have been numerous studies regarding geotextile tubes. Koerner and Koerner (2006) performed hanging bag test to evaluate the permeability and retention capabilities of the geotextile as well as study the formation of filter cakes in the bag. Brink et al (2013) performed consolidation modelling for fine-grained material filled geotextile tubes. Kim et al (2013a) presented finite element analysis for the improved stability of geotextile tube reinforced embankments using various ground modification techniques, and so on. Analytical solutions for geotextile tubes were also available as summarized by Chu et al (2011). Most of these are mainly focused on the dewatering, retention and strength performance of the encapsulating geotextile, consolidation modeling, stability and analytical solutions for geotextile tubes.

In this paper, the influence of the type of inlet system used to the deposition behavior of dredged soil fill in a geo-container is studied. Conventionally, the slurry material is filled directly into the geo-container, in this paper, this method is referred as the I-type inlet system. A T-type inlet system is introduced and the soil distribution is presented in the current study. It is difficult to place electronic measuring devices on actual geotextile tubes, hence, an acrylic tube referred to as a geocell was used. The test methods and results are presented in the following sections.

2. MATERIALS, LABORATORY SETUP AND PROCEDURE

2.1 Dredged Soil Properties

The dredged soil used in the present study was obtained from a dredging site at the Saemangeum Development Area located in the eastern coast of the Republic of Korea. The soil properties in its natural soil condition are summarized in Table 1. The average water content of the slurry mixture was 700%.

Table 1. Soil Properties

Properties	**Quantity**
Natural Water Content	15.9%
Specific Gravity	2.687
Plasticity Index, P.I.	Non-Plastic
Percentage Passing #200 Sieve	25.0%
Angle of Internal Friction, ϕ	19°
Soil Classification (USCS)	SM (Silty-Sand)

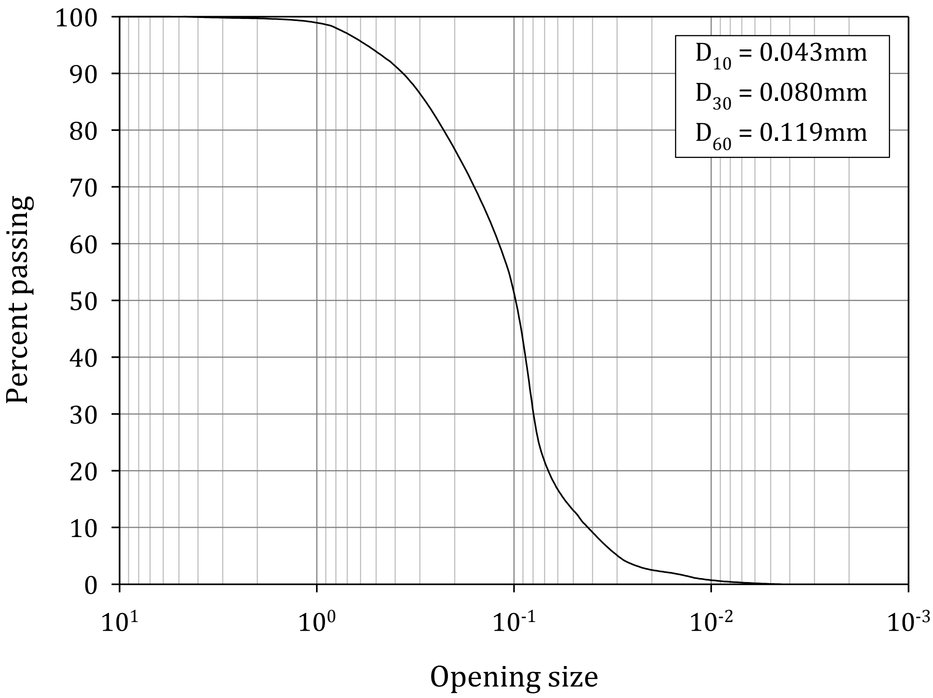


Fig. 1. Grain-size distribution for the dredged fill material

2.1 Laboratory Setup and Procedure

Fig. 2 illustrates the schematic diagram of the apparatus used in the present study. The laboratory setup shown in Fig. 2a comprises of a mixing tank, gravity tank or the elevated tank, and the geocell. The mixing and gravity tanks are equipped with electric driven agitators used for the blending of water-soil mixture. The geo-cylinder detail is shown in Fig. 2b and 2c. Two types of inlet systems or filling ports were used, the I-type and T-type inlet shown in Fig. 2d and 2c, respectively. The filling port for the geo-cylinder is located on the center (Fig. 2b) and another two ports were allocated for the load cell line (sealed after the sensors are installed so that water will not seep out). The height of the soil deposits are gradually measured during the test hence measurement points/sections, shown in Fig. 2c, are provided for this purpose.

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 is 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.

Initially the plan was to fill the geo-cylinder continually until the tube a maximum soil height deposit is achieved (usually at the inlet of the tube, where filling becomes impossible due to the soil deposits blocking the inlet). However, in the case of the present study, the filling process was hindered by the rapid accumulation of filter cake on the permeable geotextiles at the ends of the tube. Hence it was decided to fill the tube more than once.

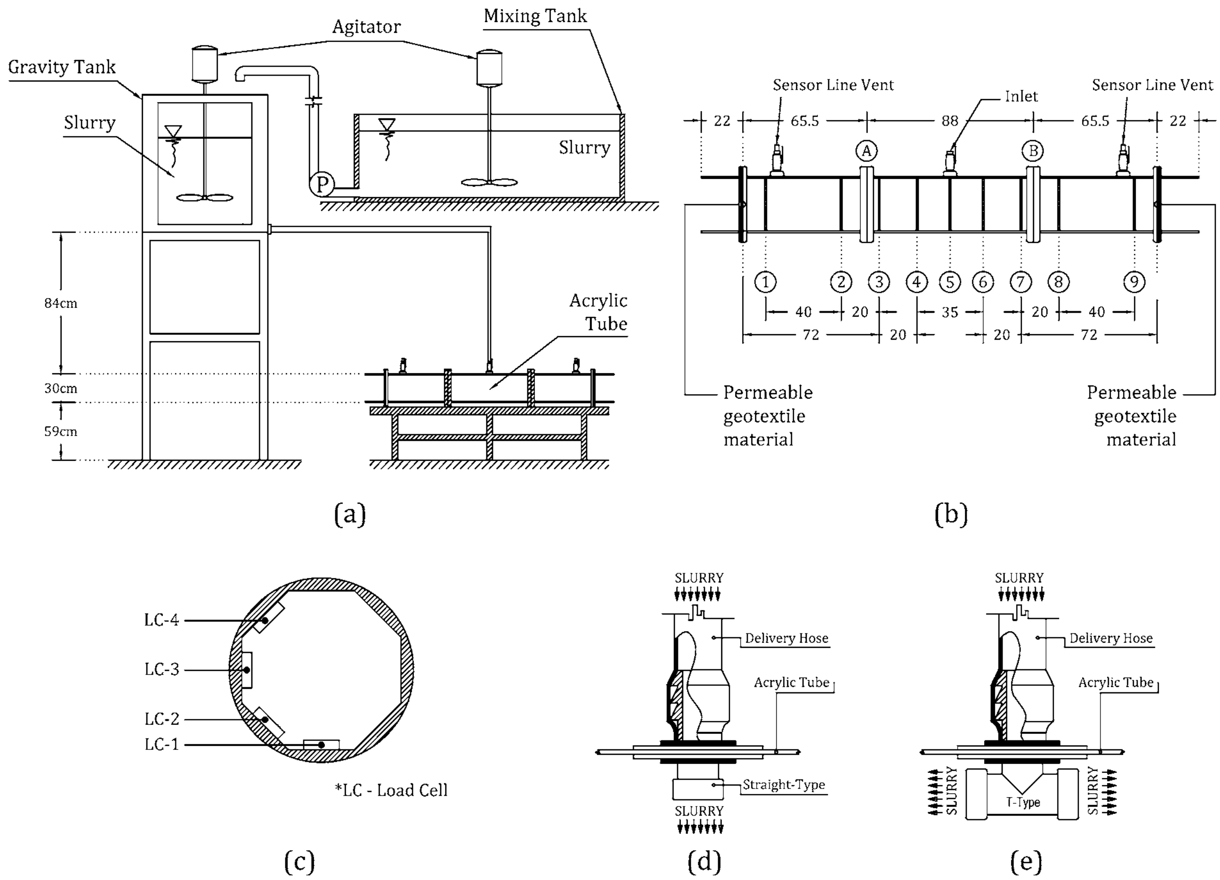


Fig. 2. Schematic diagram for apparatus used in the present study

3. THEORETICAL BACKGROUND

The soil parameters of the fill material deposited in the geo-cylinder were determined based on the laboratory results from the soil samples taken after the test. The soil parameters of the filled soil is shown on Table 2. To calculate for the saturated unit weight of the soil deposit, the average water content (w_{ave}) of the soil fill inside the geo-cylinder was determined. With this data, the void ratio and the saturated unit weight (γ_{sat}) of the soil fill can be determined using the following classical equations:

$$e = \frac{w_{ave} G_s}{S} \tag{1}$$

$$\gamma_{sat} = \frac{(G_s + e)\gamma_w}{1+e} \tag{2}$$

Load cells were placed in sections A and B shown in Fig 2b. The load cell orientation is illustrated in Fig. 2c. The data obtained from these sensors can be compared with the computed values based on the soil data gathered. Using Rankine's theory on earth pressures (Craig, 2004) the total vertical and horizontal soil pressures can be approximated using the recorded height data and the laboratory test results for the dredged soil fill. For the determination of the total vertical pressure (σ_v), the following equation was used:

$$\sigma_v = \gamma_{sat} h_{soil} \tag{3}$$

where γ_{sat} = saturated unit weight of the soil fill obtain from eq. (2) and h_{soil} = soil height at the section where the load cells were installed. For the determination of the horizontal pressures the following equations for the lateral active and passive pressure coefficient were used:

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} \text{ , } K_p = \frac{1+\sin\phi}{1-\sin\phi} \tag{4}$$

For the coefficient of lateral pressure at rest, Jaky's formula (Craig, 2004) was used:

$$K_0 = 1-\sin\phi' \tag{5}$$

The internal angle of friction (ϕ) value shown in Table 1 is obtained from direct shear test. Finally, the three lateral earth pressure conditions can be computed using the following equation:

$$\sigma_h = K_{[a/p/0]}\sigma_v' h_{soil} + u \tag{6}$$

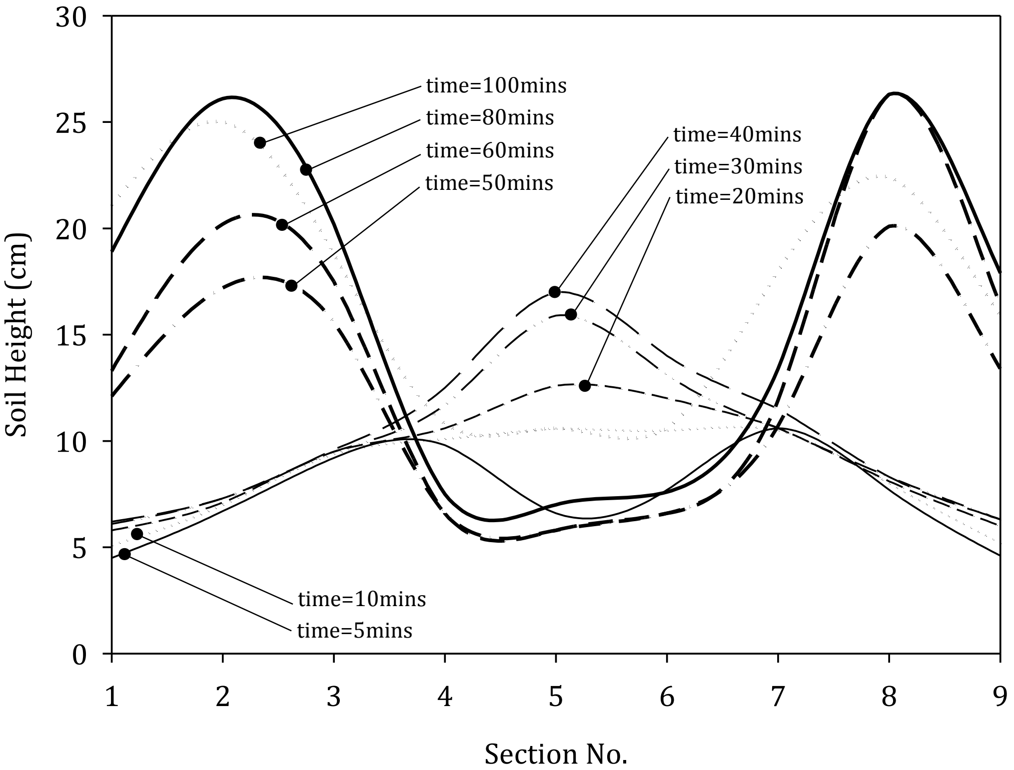
where σ_h = the total horizontal pressure exerted on the wall of the geo-cylinder, $K_{[a/p/0]}$ = the pressure coefficients with respect to either active, passive, and at rest conditions, h_{soil} = the height of soil at the section where the load cells were installed, and u = pore water pressure inside the cylinder, in this case the product between the unit weight of water (γ_w) and height of water (h_w)above the sensor to the top of the tube.

4. RESULTS AND DISCUSSIONS

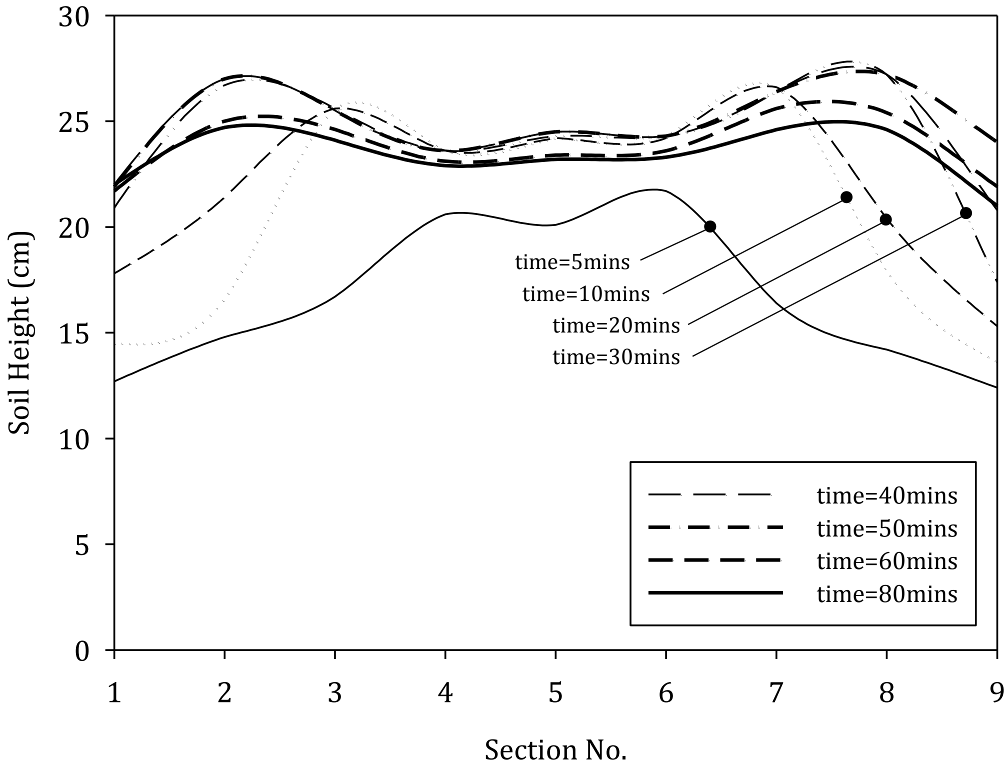
4.1 Comparison of the Soil Height Distribution using I-Type and T-Type inlet systems.

The distributed height of the soil deposited inside the geocell at each specific section is shown in Fig. 3. The soil distribution inside the geocell using the I-type inlet is shown in Fig. 3a. Here it can be seen that initially during the 1st 40mins of the filling and dewatering processes most of the soil deposits accumulates at the inlet section (middle) of the geocell. However, as the height of the soil deposit in the inlet section exceeds 50% of the geocell height, a change in the soil distribution emerges. This time, the concentration of the accumulation of soil sediments are shifted to the ends of the geocell. This is due to the phenomenon known as hydraulic jump. The slurry is filled into the geocell at high velocity due to the pumping pressure. Consequently, upon entering the tube, the slurry at high velocity (supercritical flow) discharges into a zone with lower velocity (subcritical flow). As the stream of slurry at high velocity impinges on the surface of the soil deposits in the geocell, the result is an abrupt rise in the surface in the region of impact (Akan, 2006; Gupta, 2001). Similar trend was observed in the experimental studies conducted by Kim et al (2013) on impermeable geo-containers, where a crater exists at the inlet portion of the geo-container after the filling and dewatering stages.

Results for the soil distribution in the geocell using the T-type inlet system is shown graphically in Fig. 3b. Here a different distribution mechanism of the soil sediments can be observed. Initially during the early filling stages the same sedimentation mechanism can be seen and compared to the I-type inlet system where most of the soil accumulates around the geocell inlet area. However, as the filling process progresses, the sediment height at the ends of the geocell gradually increases without the occurrence of the crater at the inlet section. Hence, it would be safe to conclude that the soil distribution can be improved by modifying the inlet system of geo-containers.



(a)



(b)

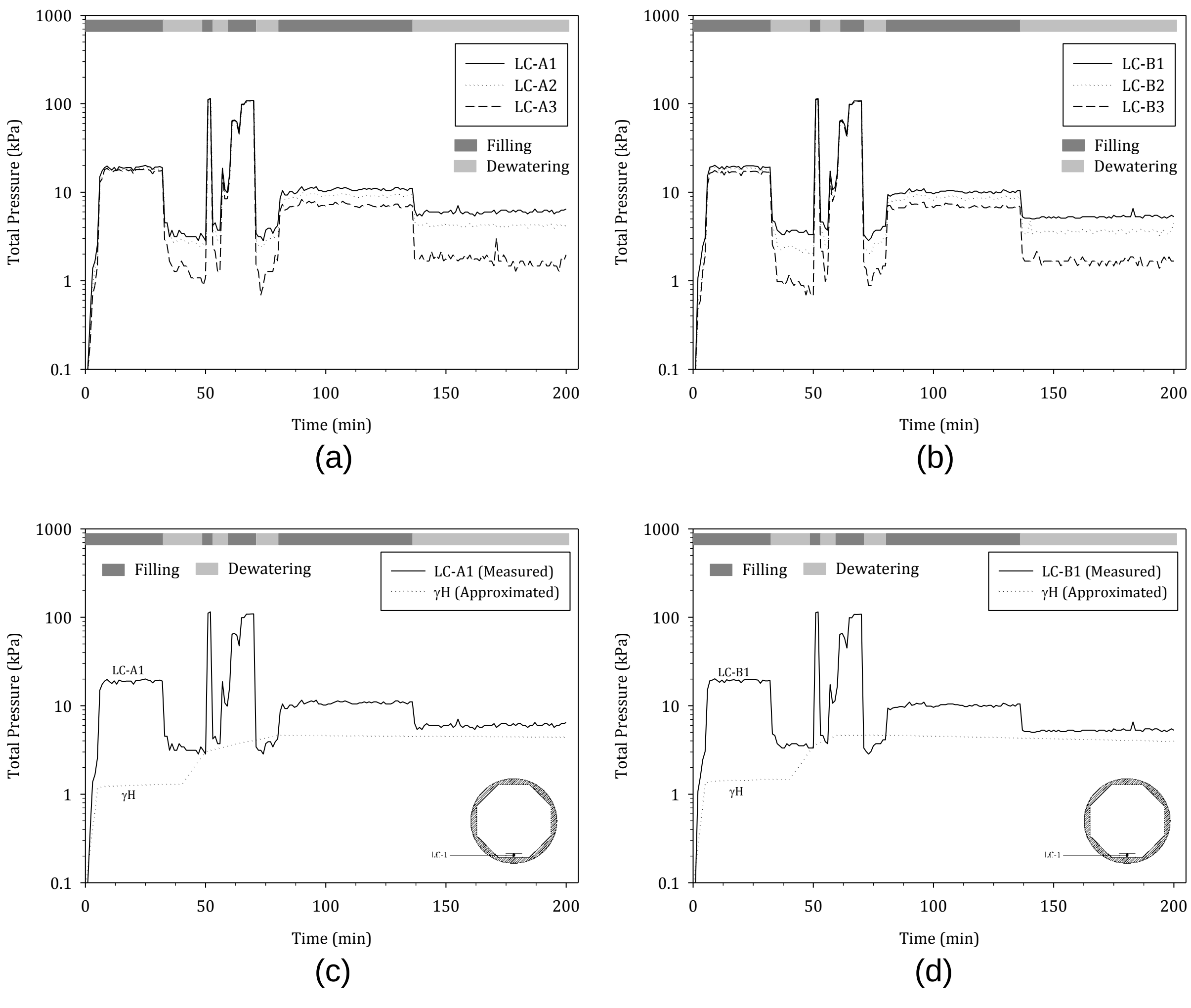
Fig. 3. Soil height distribution, (a) I-Type inlet, (b) T-type inlet

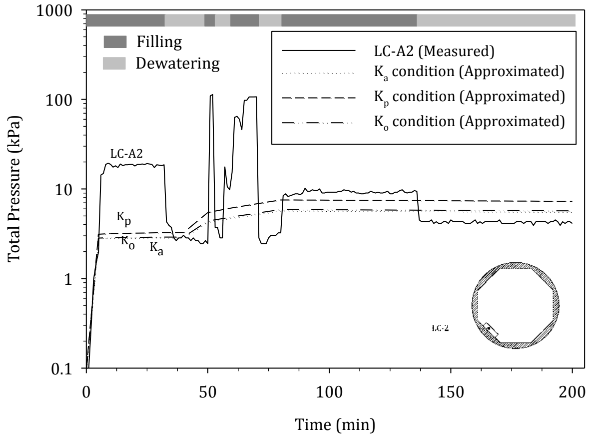
4.2 Comparison between the measured and approximated total soil pressures.

Comparison between the measured and computed total pressure values for the geo-cylinder using the I-Type inlet is shown in Fig. 4. The load cell (LC) readings for sensors at A and B is shown in Figs. 4a and 4b. Here we can see good load cell readings wherein the bottom of the tube carries the maximum total pressure followed by the diagonal sensor reading and then the vertical sensor readings. The pressure spikes in the graph, however, can be attributed to the intense pumping pressure during the filling of slurry in the cylinder (direct pumping using hydraulic pumps). For the total vertical pressure at the bottom of the cylinder (1st layer, e.g. A1, B1), a comparison between the results at A and B is presented in Figs. 4c and 4d. Due to the fluctuations of the curve affected by the pumping pressure during the 1st 150 minutes or so during the test, there is no clear connection between the measured and computed total pressure values. However it can be seen that after each slurry pumping the measured data drops closest to the proximity of the approximation curve. After the filling process of the cylinder, the measured and computed pressure values became closely related. For the load cells at the 2nd layer oriented diagonally (e.g. A2, B2), the computed results are slightly higher than the measured values, with the results on K_o and K_a

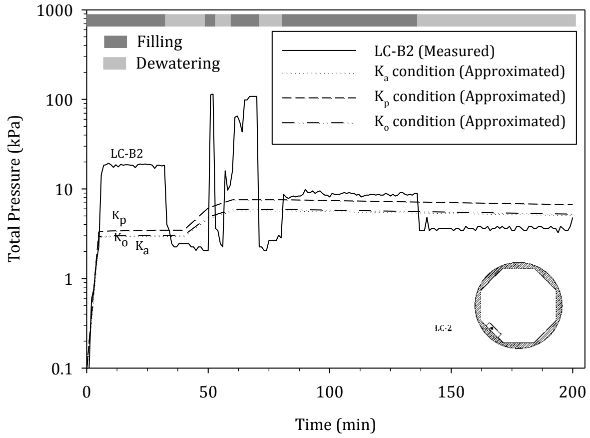
conditions closest to the measured value (Fig. 4e and 4f). The same can be observed on the data for the 3rd layer, however the computed values are much closer to the measured values. Hence, it is safe to say that the results for both measured and computed values for the geo-cylinder using I-type inlet are in good agreement with each other.

The results for the T-type inlet test are shown in Fig. 5. Hydraulic filling was not conducted during this test due to the adverse effect of directly pumping the slurry to the geo-cylinder. Instead, the method mentioned in section 2.1 in this paper was used. That is why pumping pressure fluctuations are smaller compared to the previous I-type test results. Almost the same observations can be made to the T-type test from the I-type test. The computed total vertical pressure at the bottom of the cylinder (1st layer) is lesser yet closer to the measured value. Computed values under K_o and K_a conditions also meets a good agreement with the measured values.

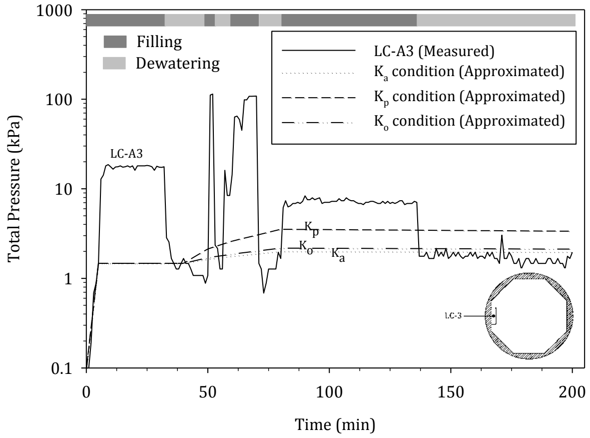




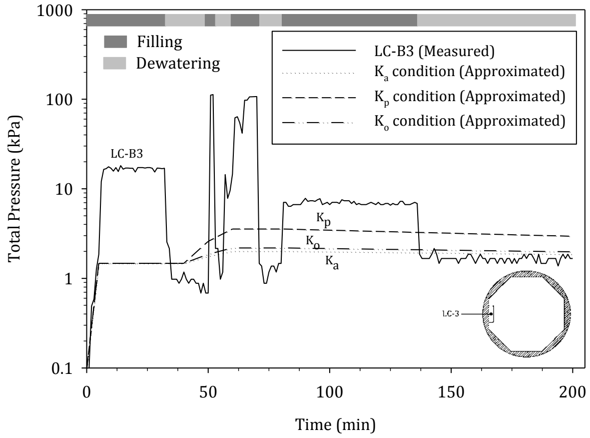
(e)



(f)

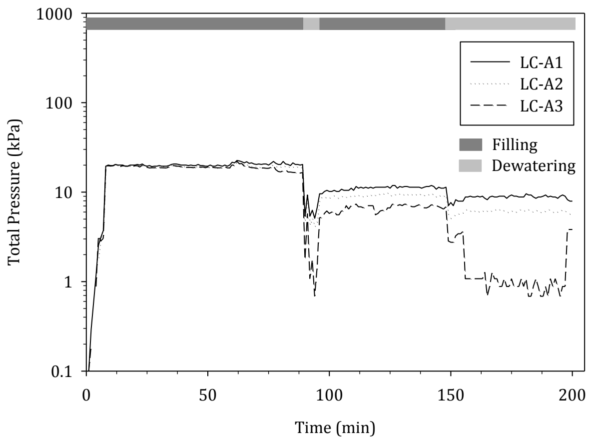


(g)

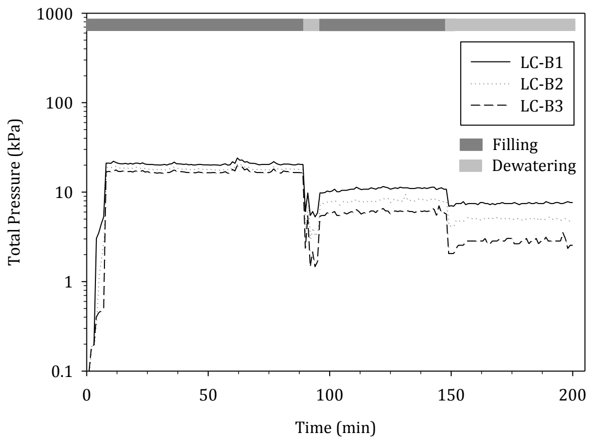


(h)

Fig. 4. Measured and calculated total pressure distribution in the geo-cylinder using the I-type inlet system.



(a)



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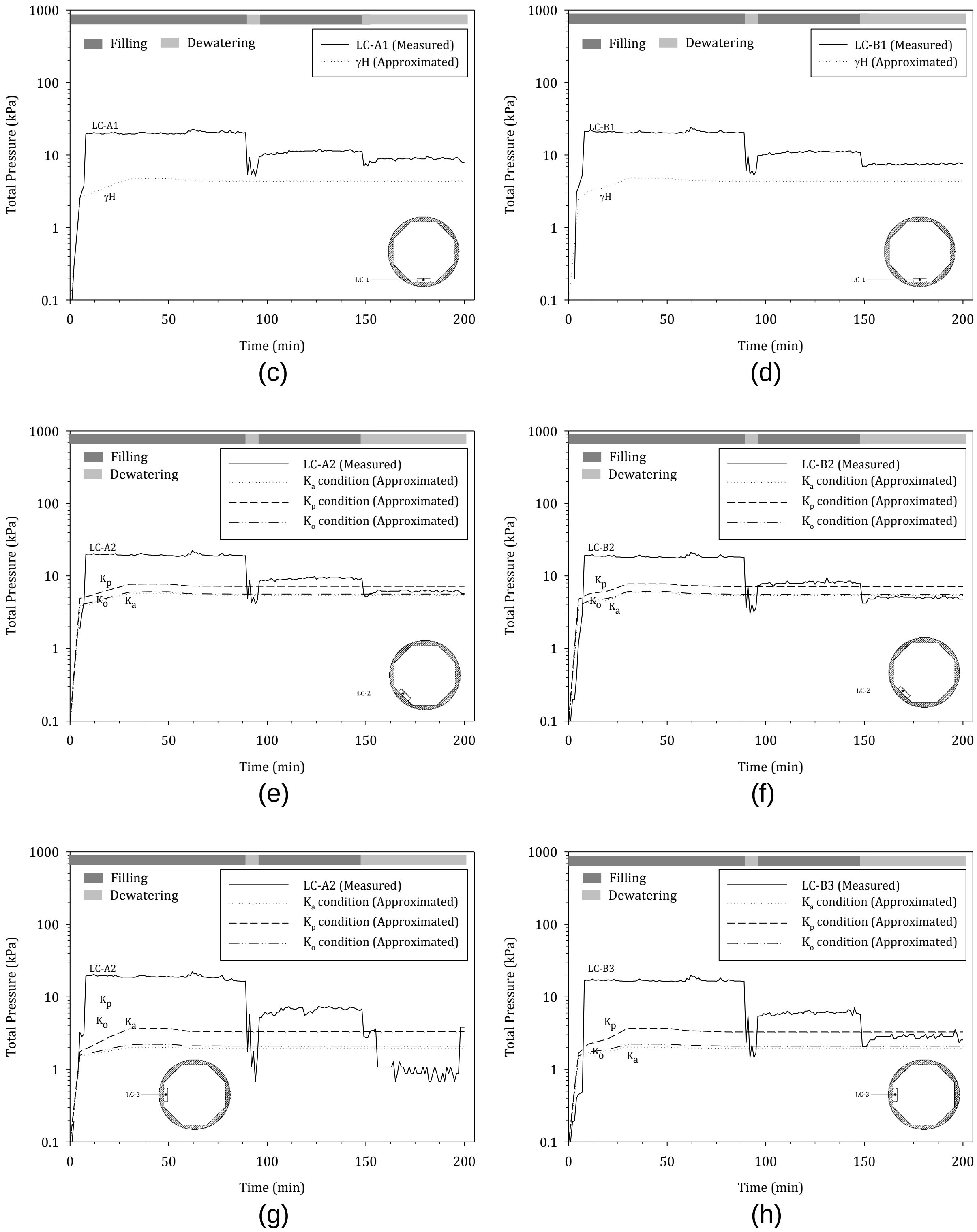

Fig. 5. Measured and calculated total pressure distribution in the geo-cylinder using the T-type inlet system.

5. CONCLUSIONS

The type of inlet system used influences the soil distribution inside geo-containment systems. In the study results presented, the use of T-type inlet system is more advantageous than the conventional I-type system. The utilization of a T-shaped inlet system improves the soil distribution in the geocell, alleviating crater formation usually observed in the geo-containment using conventional I-type inlet systems. Based on the pressure readings, the pressure distribution inside the geocell is closely related to the theoretical K_0 and K_a conditions.

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