Comparison Between Open and Closed System for Dewatering with Geotextile: Field and Comparative Study

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ABSTRACT
The present paper aims to expose two techniques of dewatering for sludge, analyzing its operations and dewatering processes. It describes the field tests performed on two geotextile systems, a closed geotextile tube and an open geotextile drying bed, both of which are submitted to two filling cycles. The sludge used in the filling cycles for the field trials is from a water treatment plant. Data about height abatement and solids content in time due to the dewatering were collected. With the laboratory analysis of the sludge allied to the data collected in the field, it was possible to perform a comparative study between the two systems. The tests were carried out on three fronts: field tests, including the filling cycles of the systems with the sludge, taking measurements of filling time per cycle and maximum filling height per cycle, heights against the abatement by dewatering of the systems over time; laboratorial tests, including the characterization of the sludge and removal of material samples from the systems to ascertain the solids content within per time and; comparing the data obtained in the field and laboratory tests for the two systems. Through the study, it was possible to perceive that the process of densification inside a closed system, such as the geotextile tube, occurs faster than the observed in the drying bed system. This process of accelerated densification can be explained trough the pumping pressure of the sludge in its filling and by the confinement of the residue through the permeable geotextile membrane, accelerating the process of dewatering by its own weight after filling.

1. INTRODUCTION

large amount of wet waste is currently produced in the world, either by the treatment of water and wastewater in water treatment plants (WTP), sewage treatment plants (STP) and industrial wastewater treatment plants (IWTP), or for revitalization and cleaning works, such as river and sea dredging, maintenance of the depth of navigable channels, maintenance of ports, among others.

The transportation and disposal of this type of effluent is impracticable, representing the necessity and the cost of transportation of large volumes, with potential to cause even more environmental problems.

The dewatering technique can be a viable solution for remedying this situation, by increasing the solids content of the sludge/sediment, reducing the moisture content of the final residue and facilitating its handling, such as a solid or semi-solid (GUIMARAES, 2014).

Thus, techniques for dewatering, which collaborate with the decrease of the moisture content of the final residue, are interesting in several situations, allowing the transport of smaller volume and proportionating lower costs of disposal.

The process of increasing the solids content occurs naturally by drainage, relatively fast process, and evaporation, slow and continuous process (Boullosa Allariz et al., 2017; Penman, 1948; Rohwer, 1934). However, natural dewatering is usually time consuming, which is accentuated on fine particulates, therefore an accelerated dewatering process, such as that obtained with geotextile tubes, may represent a better solution.

Among the dewatering techniques, the geotextile tube process is considered a mixed dewatering solution, consisting of a geosynthetic tube hydraulically filled with sludge or similar (Castro, 2005; Koerner, 2005; Pilarczyk, 2000; Tominaga, 2010; Vertematti, 2015; Guanaes, 2009). In the filling stage, corresponding to the mechanical dewatering [3], the hydraulic pressure causes the liquid part to be expelled through the geosynthetic fabric by forced filtration, while the solid part is retained by it. After the filling and with the relief of pressure, the process undergoes to natural dewatering, where the evaporation process becomes increasingly relevant as unsaturated zones begin to form.

In this research, two systems were prepared, one corresponding to a conventional geotextile tube and one to a geotextile drying bed, in order to evaluate the mixed dewatering in comparison to a normal dewatering process.

Through the research, data of admitted volume of sludge, consolidation height and solids content are discussed and compared in order to better understand the differences between the conventional and the mixed dewatering in a geotextile tube.

2. LITERATURE REVIEW

2.1 Geotextile tube

This technique consists of a woven or non-woven geotextile tube, with properties established as a function of the characteristics of the effluent to be dewatered, having a customary length and perimeter and assuming a tubular shape through its hydraulic filling (Castro, 2005; Koerner, 2005; Pilarczyk, 2000; Tominaga, 2010; Vertematti, 2015; Guanaes, 2009).

A geotextile tube can be filled with a large variety of materials, such as sands, mining residues, sludge and others, having a large range of applications, from residues of treatment plants to construction of coastal protection structures, such as dykes and jetties (Pilarczyk, 2000).

The success of this technique has been the ability to retain the solid part while it allows the exit of the liquid part, having good filter function (Moo-Young et al., 2002).

The process of dewatering with geotextile tube is discontinuous and mixed, occurring mechanically by forced filtration by the filling pressure and, after that, by natural process, by self-weight drainage and evaporation (Müller, 2018).

Generally, a geotextile tube can receive several filling cycles, this occurs because after a fill up to the maximum design height, the system loses water and consequently loses volume. In this way, after sufficient loss of volume, new filling can be accomplished by taking up the available space (Vertematti, 2015; Yee and Lawson, 2012; Guo et al., 2014).

Also, regarding the filling cycles, (Guo et al., 2014) deals with the difficulty in reaching again the maximum height in consecutive cycles due to previous consolidations, showing that the consolidated layers reach width such that, through another filling cycle, the pumping pressure must overcome the layer weight to reach again the maximum design height.

2.2 Drying bed

This technique consists of an area with a certain depth and drainage bed, usually composed of gravel and drain pipe. In this area, the sludge is spread and its dewatering occurs over time (Di Bernardo and Dantas, 2005).

The drying bed solution is classified as a natural dewatering solution, corresponding to the drainage and evaporation of the residue, and this process of dewatering is subject to the local weather, such as rain, snow, sun, among others. Therefore, its process occurs by drainage, rapid process, and evaporation, slow and continuous process (Boullosa Allariz et al., 2017; Penman, 1948; Rohwer, 1934).

Drainage occurs predominantly due to the residue characteristics and by force of gravity, happening rapidly at the beginning of the process of dewatering, representing a great drop in the water content in a short period of time and, after this, stabilizing and ceasing its occurrence. The drainage represents, then, the amount of percolated water of the material (Reali, 1999).

Evaporation occurs more steadily than drainage, governed by the climate, existing from the beginning of the process of drainage, but being more noticeable after the drainage is finished (Boullosa Allariz et al., 2017). It is characterized by the agitation of the molecules of a liquid, in this case, the water. The water of the residue, in the liquid state, has molecules circulating in a disordered and agitated way and at a rate proportional to the temperature that, the greater, the greater the stirring speed, until the energy associated with it is enough to allow some molecules to be released, being lost to the atmosphere, representing a water loss that increases in time.

3. METHODOLOGY

3.1 Field tests

The field trials were conducted in two geotextile systems, a geotextile tube and a geotextile drying bed, both made of the same geotextile fabric. The geotextile having the following characteristics: Filtration aperture (NBR 12.956, 2013) of 0.2 mm, speed of normal flow through the plane of the geotextile (NBR 11.058, 2013) of 20.10-3 m/s and resistance to tensile strength, both (NBR 10.319, 2013) longitudinal and transversal, of 105 kN/m, being usually used for the dewatering function in real cases of application.

Both systems were made with 2.5m long and 2.5m perimeter, the geotextile tube having a filling nozzle of 0.3 m height and 0.3m in diameter centered on the top of the upper face and the drying bed having the entire upper face open.

A draining crib was built to receive the geotextile systems, with bottom coating of geomembrane, leading the percolate to its final destination and, above it, a drainage coating, guaranteeing that the systems were not in direct contact with the geomembrane, which would entail in the blinding of these surfaces, decreasing the dewatering efficiency.

Once the geotextile systems were correctly positioned over the draining crib, the filling cycles started. For this, a submersible pump was used, with maximum working slope of 6.5m, and maximum and minimum flow rates of respectively 1970 l/h and 550 l/h. For the filling cycles in the field tests, the flow rate was 1800 l/h (~ 30 l/min).

The filling cycles pumped wet material from one decanter of the water treatment plant, directly to the systems, without polymerization, until the height of approximately 0.45m, where the pumping was ceased. This process was repeated once more after 5 days from the initial fill-in.

The volume for each fill was measured, considering the pump flow and the filling time in each cycle. Consolidation height data for the systems were collected shortly after completion and, periodically during the draining process.

3.2 Laboratory tests

The laboratory tests included the characterization of the sludge as to the solids content of the sludge from the water treatment plant, determination of the specific gravity of solids for the sludge and the determination of solids content by time for the systems during the dewatering process.

For determining the solids content in time of dewatering, in each system 5 samples were collected equidistant for each measurement moment. The collections following the scheme presented in the Fig. 1. This procedure was performed in five opportunities in time, in different positions in the systems.

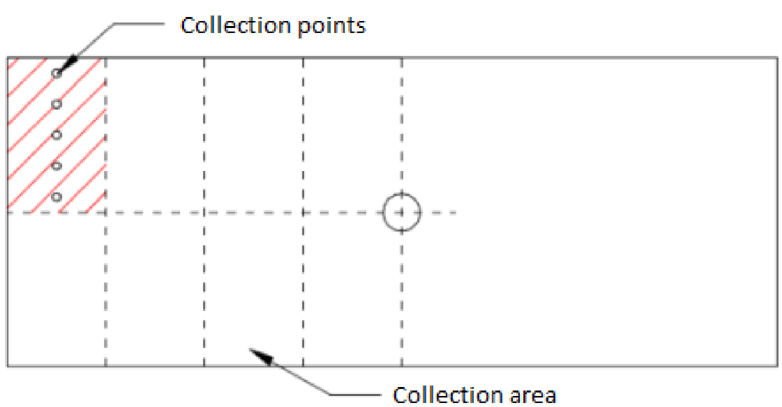


Figure 1. Collection points and areas at each moment in time (Authors, 2020).

Finally, the samples collected from the systems were analyzed and their solids content determined for each collection moment. It should be noted that the systems were kept in open outdoor space, subject to the weather and changes in the clime.

4. RESULTS

4.1 Field tests

The field tests were conducted in two geotextile systems, an open and a closed system, filled with sludge from the CTA's (Campus Tecnológico de Aeronáutica) water treatment plant. At Fig. 2 and 3, the systems can be seen at the end of each filling cycle.

Figure 2. Open geotextile system, drying bed (Authors, 2017).

Figure 3. Close geotextile system, geotextile tube (Authors, 2017).

The systems were filled in such a way that each received two filling cycles. As the open geotextile system received a total of 1.83m³ and the closed geotextile system received a total of 2.31m³.

In view of the filling cycles and dewatering, the maximum heights and consolidation heights by time were collected. These data for the open geotextile system can be found in Table 1.

Table 1. Heights per time for the open system.

Time (days)	Height (m)
0	0,00
0,0215	0,43
1	0,35
3	0,23
5	0,19
5,0208	0,45
6	0,29
8	0,23
13	0,19
15	0,18
22	0,17

These data for the close geotextile system can be found in Table 2.

Table 2. Heights per time for the closed system.

Time (days)	Height (m)
0	0,00
0,0326	0,47
1	0,15
5	0,10
5,0208	0,40
6	0,18
7	0,14
8	0,12
11	0,11
12	0,11
21	0,09

With these time-related data, it is possible to draw a chart expressing the filling cycles and the process of dewatering by the decrease of height. Fig. 4 shows the curves obtained.

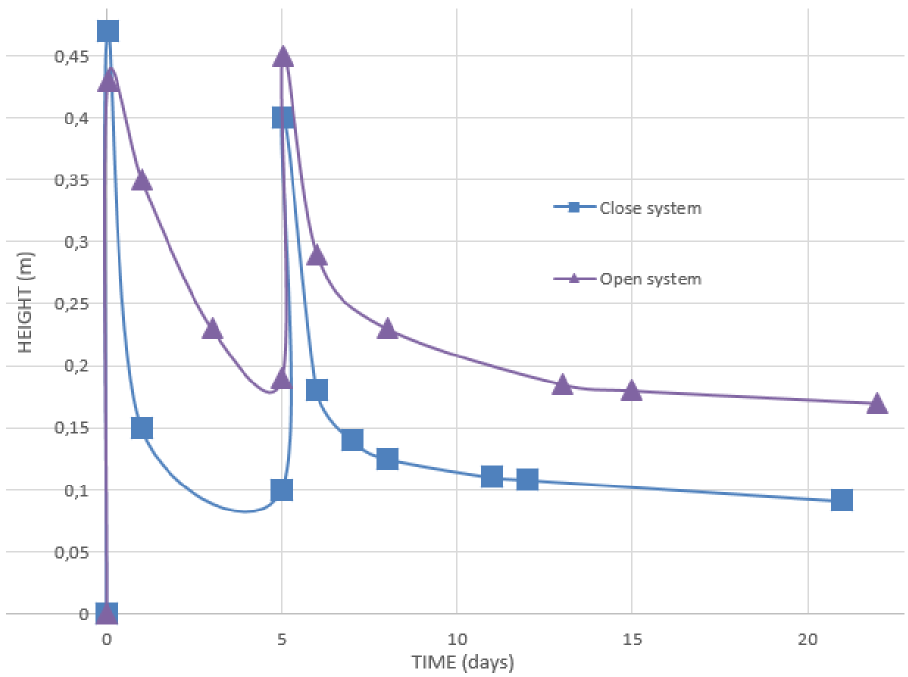


Figure 4. Decrease of height through dewatering for the systems (Authors, 2019).

4.2 Laboratory tests

First, the sludge was characterized as to the solids content by weight (in pumping) and dry grain density. For the solids by weight (tsp), the value of 1.74% was found, and for the dry density of the grains (Gs), the value of 2.58 g/cm³.

Material samples were collected from both geotextile systems through time, these samples were taken to the laboratory and their solids contents were evaluated. Tables 3 and 4 were prepared, expressing the data found.

Table 3. Solid content per time for the open system.

Time (days)	Solid content (%)
0	1,74 ±0,15

12	9,38±0,90
21	18,80±3,50
28	24,97±1,51
92	85,19±1,89

Table 4. Solid content per time for the closed system.

Time (days)	Solid content (%)
0	1,74 ±0,15
12	16,34±0,45
21	23,73±3,35
28	26,45±0,77
92	78,66±1,95

Graph illustrating the increase in solids content by weight in time for both geotextile systems can be found in Fig. 5.

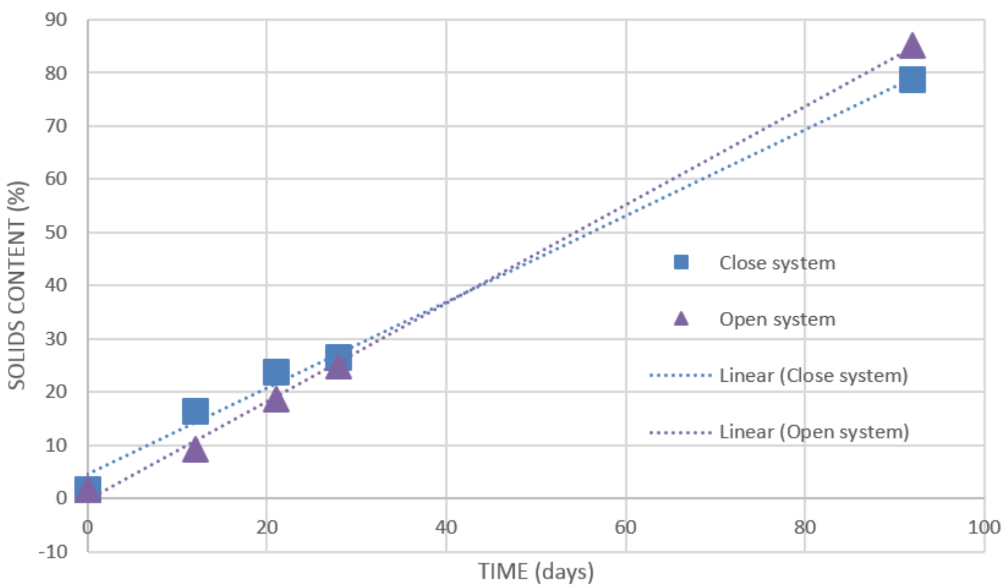
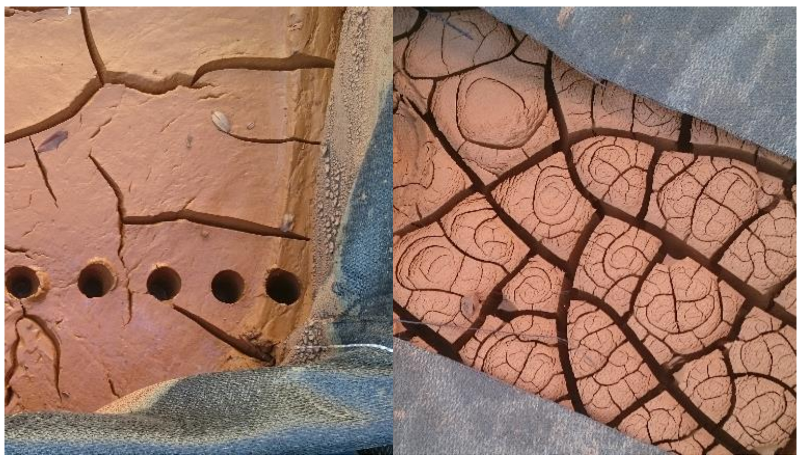


Figure 5. Increase in solids content by weight in time (Authors, 2019).

Images of the moments of sample collection for the two geotextile systems are presented in Fig. 6 to 10.

Figure 6. Collection at day 0 (Authors, 2017).

(a) (b)
Figure 7. Collection at day 12, a) Open system, b) Close system (Authors, 2017).



(a) (b)
Figure 8. Collection at day 21, a) Open system, b) Close system (Authors, 2017).

(a) (b)
Figure 9. Collection at day 28, a) Open system, b) Close system (Authors, 2017).

(a) (b)
Figure 9. Collection at day 92, a) Open system, b) Close system (Authors, 2017).

5. DISCUSSION

It is possible to notice that the inclination of the curves in Fig. 4 for the close and open systems are different, presenting an accelerated fall of height by the close system, representing that the exit of water by forced filtration and drainage in these systems occurs in a more accentuated way than in the open system.

From Fig. 5 it can be seen that the solids contents by weight in the close system are initially higher than the solids content of the open system. This observation reinforces that the initial water loss occurs in an accelerated manner in a close geotextile system, due to the increase of pressure inside de tube, promoting a forced process during the filling cycles.

However, it is possible to notice that the open system surpasses the closed system at a certain moment, as observed through the solids content at day 92 in Fig. 5. This probably occurs due to the evaporation, which occurs more effectively in this open system, due to its direct insolation, good bottom drainage and no obstacles to the steam outlet.

It is observed that the closed system was able to admit a larger volume due to its internal pressures, which accelerated the water outflow. However, according to (Müller, 2018; Yee and Lawson, 2012; Guo et al., 2014), due to the consolidation of material inside the geotextile tube, to reach a maximum filling height again, higher pressures must be reached, so that in the second cycle the maximum height reached in the first fill couldn´t be reached again.

From the images from Fig. 6 to 10 it is possible to notice a great difference in the initial and final moisture between the studied systems, where visually the system with the highest solids content by weight until the day 28 is the close system, passing to the open system on the day 92.

It can be seen from Tables I, II, III and IV that water loss occurs most significantly at the beginning of the dewatering process, through drainage, representing a large initial volume reduction. On the other hand, since the volume of material inside the system reduces and contract, increasing its surface area, the evaporation becomes more significant, representing the main water exit path of the systems.

It should be noted that the loss of water by evaporation in the close system occurs in a different way from the open system, and no studies have been found to evaluate this evaporation. However, the slope of the curves presented in Fig. 5 point to a greater water loss through evaporation for the open system.

6. CONCLUSION

The large volumes of sludge generated and the impacts of its direct release into the environment make it possible to realize that the techniques of dewatering are very useful and are being increasingly demanded, as they provide a reduction in the volume of wet material, allowing it to be more easily transported, handled and correctly disposed of.

The results of the research show that the dewatering process in close and open geotextile systems occur in a different way. Where in a closed system, the internal pressures increase during filling, expelling the water from the system with greater speed, thus achieving higher levels of solid content than an open system in a shorter period. However, if the weather conditions are favorable, the open system can reach solids contents similar or even higher than a close system in the long run, because the water loss through evaporation.

It was observed through the tests that at first the forced filtration is very significant, providing high solids contents to the close system. On the other hand, for a longer rest period, the evaporation becomes more significant and, thus, the open system obtained at the end of one month results similar to the close system in terms of solids content, after three months, obtained even better results than the other system.

However, it must be noted that the open system received less amount of sludge in its fills, about 26% less sludge than the close system, contributing to the increase of solids content.

It should be also noted that the tests comprise small modules/systems and that larger scale tests must be performed to confirm these results.

For future research, it is suggested the study of the differences of dewatering between geotextile tubes and drying beds, focusing on the loss of water through evaporation.

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