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Hydraulic performance and degradation of geotextile tube in sediment dewatering: A remediation study

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ABSTRACT: Geotextile tubes are a technology used in different sectors, such as water supply and sanitation, mainly in the final stage, to dewater the sludge generated in wastewater and water treatment plants. This paper presents geotextile tubes at the beginning of the water supply system (i.e. catchment). This paper shows a large-scale remediation project that used geotextile tube dewatering technology to desand the stream where part of the water catchment of São Carlos city – (São Paulo, Brazil) is carried out. This paper aims to present the system's hydraulic performance and the geotextile degradation. The effluent quality throughout the operation was monitored. Granulometric distribution at different heights of the filter cake is presented to better understand the deposition of particles inside the geotextile tube during the dewatering process. Decreases were observed in the geotextile's tensile strength and permittivity properties after application.

1 INTRODUCTION

The process of inadequately occupying urban watersheds can cause surface erosion and siltation in water bodies due to the accumulation of sediments. Among the consequences of silting up water bodies is a reduction in the volume of water, shortages in the water supply and intensification of floods. Dredging is the most common form of environmental remediation for sediment accumulation (Lawson 2008). Geotextile tubes filled with dredged material provide an innovative and cost-effective alternative to traditional techniques due to their simplicity and flexibility. These structures can even be used for erosion prevention due to their stability against erosive forces (Fowler *et al*. 1994).

Geotextile tubes are manufactured from geotextiles with high tenacity, durability and small pore openings. Geotextile tubes are made with reinforced seams, forming permeable structures with the property of draining the material with which it is filled. Sludge dewatering application using geotextile tubes were first used in the 1990s. The general dewatering process using geotextile tubes comprises three steps: containment, dewatering and consolidation (Lawson 2008). The containment step involves pumping the waste into the geotextile tube. In the dewatering stage, a geotextile tube can receive several filling cycles. After the system reaches the maximum height stipulated in the design (first filling), the system loses water through forced filtration, drainage and evaporation (Müller 2018). It should be noted that after the first filling cycle, the maximum height of the system is no longer reached.

The performance of geotextile tubes depends on an extensive source of variables that can be classified a priori as hydraulic, mechanical and durability. Heilman *et al*. (2003) state that

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trial and error is a common design method in projects with geotextile tubes, as the known design methods do not fully represent the complexity of the systems.

For geotextile tubes, Leshchinsky *et al.* (1996) highlight the use of four safety factors: factors related to creep over time; seam resistance; installation damage; and durability. Validating the sizing methods found in the literature for geotextile tubes, and determining appropriate safety factors, requires carrying out full-scale tests. This is due to the fact that in these tests, significant differences are observed regarding the requests imposed on the geotextile (Silva *et al.* 2021).

The present study presents the hydraulic performance of a geotextile tube installed to desand the Monjolinho stream, part of the water catchment of São Carlos city – (São Paulo, Brazil). Geotextile samples were collected at the end of the service life to assess its degradation. Sediment samples were also collected at the consolidation phase for geotechnical analysis. The main aim of this study is to provide information that contributes to understanding the geotextile tube's behavior in sediments dewatering applications. Moreover, this study investigates the deposition of sediment particles inside the geotextile tube during the dewatering and consolidation process.

2 METHODOLOGY

2.1 *Study area*

The city of São Carlos, in the state of São Paulo – Brazil, is supplied by surface sources (Monjolinho and Ribeirão do Feijão stream) and ground sources from 28 deep wells that draw water from the Guarani aquifer. At the water treatment plant, 35.3 million m^3 of water is produced, where 16% of the water comes from surface catchment from the Monjolinho stream. Problems in the drinking water supply operation resulting from the sediment transport of the Monjolinho stream forced the rapid execution of a remediation project. A geotextile tube was used for desanding the stream. Geotextile tubes are a technology widely used in the sanitation sector, known for their ease of installation and efficiency in dewatering. Figure 1 shows the location where the geotextile tube was installed.

Figure 1. Geotextile tube location (21°59’11.85”S; 47°52’32.14”W).

2.2 *Materials*

The geotextile tube was manufactured from woven polypropylene geotextile, with the following characteristics: apparent opening of 0.343 mm, tensile resistance in the machine direction (MD) of 78.2 kN/m, and 106.5 kN/m in the cross direction (CD). The geotextile tube meets Sabesp's technical specification (NTS 301 2015), which establishes reference values for the dewatering application. The geotextile tube (Figure 2) was 10 m wide and 15 m long with a maximum height of 2.3 m (indicated by the manufacturer). The tube was installed on a dewatering platform, consisting of a High-Density Polyethylene geomembrane (1.00mm), and a draining geocomposite with a double layer of 200 g/m^2 nonwoven geotextile. The draining geocomposite was used to replace the layer of gravel and the layer of nonwoven geotextile of 300 g/m^2 suggested in the NTS 301 (2015). The stream sediments were pumped into the tube with a pump of 100 m^3/h. The percolate from the tube was returned to the stream through a channel. A Parshall gutter was installed in the channel to measure the outflow (Figure 2). The sediments had a specific gravity of 2.74 g/cm^3 and a grain size distribution of 88.8% sand, 4.9% silt, and 6.3% clay.

Figure 2. Geotextile tube.

2.3 *Monitoring*

The percolate quality was monitored over the dewatering time, periodic collections were carried out, and turbidity was measured, as shown in Figure 3a. In this study, the dewatering phase was completed prematurely due to problems with pump availability. In the Consolidation phase, 17 days after the last filling, geotextile and sediment samples were collected (Figure 3b). A reference sediment sample was collected directly from the stream bed. Specific gravity and granulometry tests were performed on each sediment sample. Tensile strength tests, seam strength tests and permittivity tests were carried out on the exhumed geotextile according to ISO 10319 (2015), ISO 10321 (2008) and ASTM D 4491 (2020), respectively.

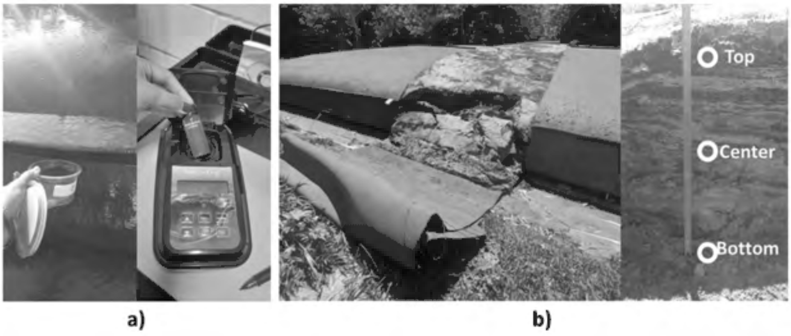

Figure 3. Sample collection. a) percolated collection, and equipment used for turbidity measurement. b) geotextile exhumation and sediment sampling.

3 RESULTS AND DISCUSSION

3.1 *Hydraulic performance*

Monitoring was carried out for approximately 110 consecutive days. However, due to problems with the pump operation, only fillings were carried out for 56 days. During this period, approximately 156 m^3 of sediments were stored. Moreover, a maximum height of 1.40 m was reached at the central point of the tube (39% lower than the expected height). The inlet flow was measured using an ultrasonic meter, and it was observed that the pump worked at a maximum of 70% of its capacity. The decrease in pump flow may be associated with the presence of the sediment that forced the flow's transport. Due to the limited availability of the ultrasonic flow meter, only readings were taken during three periods, and the recorded values "Measurements" are presented in the graph in Figure 4. The maximum output flow, measured in the Parshall flume, was 40 m^3/h.

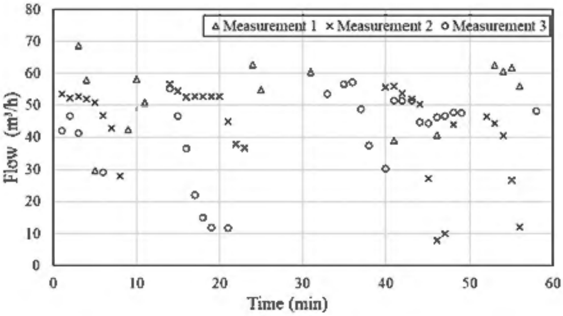

Figure 4. Inlet flow measurements performed at different periods.

The importance of compatibility between the pump capacity and the volume available inside the geotextile tube can be observed. In this remediation project, the tube dimensions were selected according to the expected storage volume (offered by the manufacturer), and the pump capacity was not verified. This indicates that the design was made according to trial and error, as Heilman *et al.* (2003) mentioned.

3.2 *Sediment distribution*

The specific gravity was 2.57 g/cm^3, 2.70 g/cm^3 and 2.68 g/cm^3 for the bottom, center and top samples (Figure 3b), respectively. Figure 5 presents the granulometric distribution of the samples collected at the bottom, center and top of the Geotextile tube and the reference sample. It can be observed that the curves of the bottom and top samples showed similar behavior with percentages in the sand fraction close to 50%. In the granulometric curve of the center, it can be observed that the fraction of sand was higher, close to 77%.

Figure 5 shows that the reference sample collected directly from the stream bed does not represent the material dredged by the pump, which had high variability. The sediments pumped to the geotextile tube were pumped directly from the stream, involving operational variations such as suction height and stream dynamics affected by environmental conditions (rain and wind).

For this specific study, a sedimentation pattern cannot be identified, as the pumped material was not homogeneous. It did not come from an equalization tank. The granulometric distribution in the different heights of the geotextile tube depended on the pump

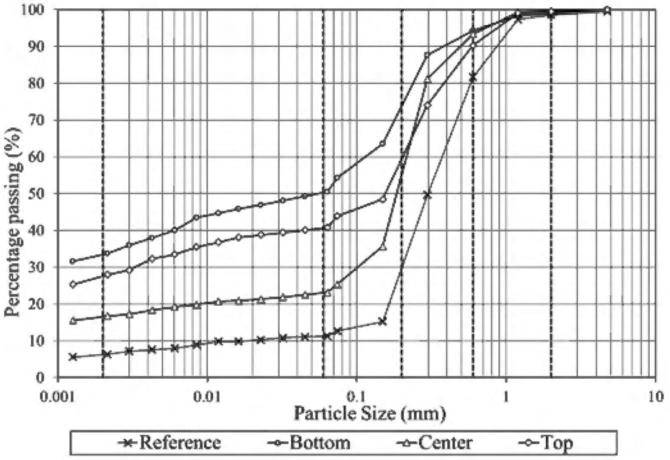

Figure 5. Particle size distribution curve of the sediment samples.

operation, which explains the different granulometric distributions in the three analyzed points (bottom, center and top).

Turbidity is an indirect measure of the amount of sediment/particles passing through the geotextile tube (Aparicio-Ardila *et al.* 2020). During the monitoring, it was observed that the turbidity after dewatering decreased, ranging from 600-700 NTU (Nephelometric Turbidity Units) values to 200-300 NTU. This indicates that the water returned to the stream (percolated) had a better quality.

3.3 *Degradation*

Table 1 presents the geotextile tube property results after the dewatering application. As expected, a decrease can be observed in all the properties in the exhumed sample compared to the virgin one, in which the exhumed sample was exposed for 110 days. After exposure, this behavior was observed in other applications where the geotextiles were exposed to the weather conditions, such as Carneiro *et al.* (2018) in marine environments, Aparicio-Ardila *et al.* (2021a) in the application of erosion control and Aparicio-Ardila *et al.* (2021b) in weathering panels.

Table 1. Geotextile virgin and exhumed properties and variation regarding the virgin sample.

Properties	Test Method	Virgin	Exhumed	Variation (%)
Tensile strength per unit CD (kN/m)	ISO 10319 (2015)	106.5	95.2	10.6
Tensile strength per unit MD (kN/m)	ISO 10319 (2015)	78.2	73.8	5.6
Seam tensile strength CD (kN/m)	ISO 10321 (2008)	75.5	52.86	30.0
Permittivity (s^{-1})	ASTM D 4491 (2020)	0.35	0.27	22.9

The mechanical degradation measured by the tensile strength of the geotextile and the seam showed a more significant decrease in the resistance of the seam indicating the importance of the quality of the seam for the dewatering application. Another essential characteristic evaluated was the hydraulic performance, measured by the permittivity. Permittivity presented a more significant decrease when compared in percentage terms with the resistance of the geotextile.

4 CONCLUSION

A trial-and-error process is not a design method. Using geotextile tube technology requires preliminary planning and testing to take advantage of the application's potential fully. Despite the operational limits for the execution of the presented environmental remediation project, the technology contributed to the solution of the operational problem in the catchment and returned water with better quality to the stream. Identifying a sedimentation pattern is impossible when the pumped material is not homogeneous.

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REFERENCES

Aparicio-Ardila, M. A. A., Souza, S. T., Silva, J. L., Valentin, C. A., Dantas, A. D. B., 2020. Geotextile Tube Dewatering Performance Assessment: An Experimental Study of Sludge Dewatering Generated at a Water Treatment Plant. *Sustainability*, 12, No.19, 8129.

Aparicio-Ardila, M. A., dos Santos Junior, R. D., Kobelnik, M., Aparecido Valentin, C., Silva Schliewe, M., Teixeira Coelho, A., da Luz, M.P., 2021a. Semi-Rigid Erosion Control Techniques with Geotextiles Applied to Reservoir Margins in Hydroelectric Power Plants, Brazil, *Water*. https://doi.org/10.3390/w13040500

Aparicio-Ardila, M. A., Pedroso, G. O. M., Kobelnik, M., Valentin, C. A., da Luz, M. P., Lins da Silva, J., 2021b. Evaluating the Degradation of a Nonwoven Polypropylene Geotextile Exposed to Natural Weathering for 3 Years. *International Journal of Geosynthetics and Ground Engineering*, 7(3), 1–11.

ASTM D4491, 2020. *Standard Test Methods for Water Permeability of Geotextiles by Permittivity*. ASTM International, West Conshohocken, PA, USA.

Carneiro, J. R., Morais, M., de Lurdes Lopes, M., 2018. Degradation of Polypropylene Geotextiles with Different Chemical Stabilisations in Marine Environments. *Construction and Building Materials*, 165, 877–886.

Folwler, J., Sprague, C.J., Toups, D., Engler, R.M., 1994. *Dredged Material-filled Geotextile Containers, Environmental Effects of Dredging Technical Notes*. U. S. Army Engineer, Waterways Experiment Station, Vicksburg, MS.

Heilman, D.J., Hauske, G.J., Melby, J.A., 2003. Advances in Geotextile Tube Technology, in: CoastalStructures 2003: *Proceedings of the Conference*. Portland, Oregon, USA, pp. 1001–1012.

ISO 10319, 2015. *Geosynthetics — Wide-width Tensile Test. International Organization for Standardization*, Geneva, Switzerland.

ISO 10321, 2008. *Geosynthetics — Tensile Test for Joints/seams by Wide-width Strip Method*. International Organization for Standardization, Geneva, Switzerland.

Lawson, C. R., 2008. Geotextile Containment for Hydraulic and Environmental Engineering. *Geosynthetics International*, 15, No. 6, 384–427.

Leshchinsky, D., Leshchinsky, O., Ling, H.I., Gilbert, P.A., 1996. Geosynthetic Tubes for Confining Pressurized Slurry: Some Design Aspects. *J. Geotech. Eng*. 122, 682–690.

Müller, M., 2018. Efeito de Diferentes Configurações no Deságue de Lodos Em Sistemas de Confinamento de Resíduos em Geotêxtil. Instituto Tecnológico de Aeronáutica. (in portuguese)

SABESP - NTS 301, 2015. *Saco Geotêxtil Para Desaguamento de Lodo*. Norma Técnica SABESP, São Paulo, Brasil (*in portuguese*)

Silva, V.L., Almeida, M.G.G., Pimentel, K.C.A., 2021. Numerical Modelling of Geotextile Tubes Filled with Gold Mine Tailings. *Geosynth. Int.* 28, 574–583.