Evaluation of the confinement technique using a closed geotextile system to the dewatering of dredged sediments in the port of Rio Grande

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ABSTRACT

The southern Brazilian city of Rio Grande received maintenance dredging operations in 2019, with an estimated 16 million cubic meters of sediment deposited in the port access channel. This study aims to evaluate the potential of using the retention technique of dredged material in closed geotextiles (Geobags), aiming at dehydration of dredged sediments, thus allowing the disposal of tailings in land for reuse of the material. The Rapid Dehydration Test was used to evaluate the efficiency of dehydration through the geotextile web. Due to the ease of analysis, fast response time and good correlation with total solids content, the efficiency control parameters used were turbidity, drainage flow and loading time. A complete characterization of the sediments collected during the dredging was also performed, with the objective of evaluating their geotechnical characteristics and the behavior of this material before the proposed technique.

Keywords: Dredged, Dewatering, Efficiency

RESUMO

A cidade de Rio Grande localizada ao sul do Brasil recebeu operações de dragagem de manutenção em 2019, com retirada estimada de 16 milhões de metros cúbicos de sedimentos depositados no canal de acesso ao porto. Este estudo tem como objetivo avaliar o potencial de utilização da técnica de retenção de material dragado em geotêxteis fechados (Geobags), visando a desidratação de sedimentos dragados, permitindo assim o descarte de rejeitos no solo para reutilização do material. O Teste de Desidratação Rápida foi utilizado para avaliar a eficiência da desidratação através do geotêxtil. Devido à facilidade de análise, tempo de resposta rápido e boa correlação com o teor total de sólidos, os parâmetros de controle de eficiência utilizados foram turbidez, vazão de drenagem e tempo de carregamento. Também foi realizada uma caracterização completa dos sedimentos coletados durante a dragagem, com o objetivo de avaliar suas características geotécnicas e o comportamento desse material antes da técnica proposta.

Palavras chaves: Dragagem, Desidratação, Eficiência

1. INTRODUCTION

The city of Rio Grande, located in the extreme south of Brazil, received during 2019 maintenance dredging operations in the port located in the city, with the expected removal of about 16 million cubic meters of sediment that is deposited in its channel. Of access. Due to local hydrodynamic characteristics, port needs frequent dredging to maintain minimum draft depths for access and mooring (BURGUEÑO, 2009). These operations carried out in 2019 aimed to increase the channel depth from 12.8 meters to 14 meters, thus increasing the port capacity to receive larger vessels, allowing vessels up to 365 meters long to have access to the port. The Figure 1 shows the location map of the Rio Grande Port access channel.

During the execution, the works were paralyzed several times due to social and environmental issues such as the emergence of mud in the city spa. Dredging is a necessity not only for implementation, deepening or maintenance, but also for remediation, which aims to clear and recover contaminated sediment areas that, however, generate conflicts (GOES FILHO, 2004). The disposal of dredged sediment in water bodies can be performed in oceans, estuaries, rivers, lakes and lagoons. In some out-of-sea areas, when dredging is effected at ebb tide, the impacts on the coastal region are irrelevant, but when it is flooding, if the material is coarse, it may lead to a cloud of pollution that will direct to the coast and will settle (CDRJ, 2002). Thus, alternatives to the use of dredging sediment and disposal techniques have been evolving to cause less environmental impacts. CONAMA Resolution No. 454/12 identifies as possible types of beneficial uses of dredged sediment its use as elements of engineering works, inputs for civil and industrial construction, increases in agriculture and aquaculture, and environmental improvements. The Figure 2 shows operant suction dredger.

Figure1. Location Rio Grande Port Access Channel

Among the methodologies and disposal technologies of dredged sediments is the sediment conditioning in geotextile pipes. In environmental applications, geotextile pockets have been used for dewatering and controlled disposal of sediment and contaminated offshore soils (LAWSON, 2008). According to Avancini (2017), geotextile bags or tubes, also called closed geotextile systems, allow the control of affluent and effluent material and are produced in high permeability filtering fabric with small pore openings. According to GRI (2009), closed systems in geotextile can be classified according to their dimensions. And by ISO 10318-1: 2015 (ISO, 2015) geotextile is a type of geosynthetic, a polymeric material (synthetic or natural), planar and permeable, can be woven or non-woven. The use of a closed geotextile system began in the 1970s, with the initially structural purpose in coastal works and from the 1980s onwards it was used to contain dredged sediments (PIEPER, 2008). According to Souza (2018) Nowadays, besides the use for retention of dredged material, this closed geotextile system technology has grown exponentially in the last years and can be used from small to large installations. According to Pereira (2012) the excess water resulting from the dredging process is drained through the geotextile pores, resulting in an effective dehydration process, with consequent reduction in water volume, such reduction allows each geobag to be filled, until considerable portion of the available volume is occupied by the solid fraction in the dredged sediment.

The technique of dewatering through geotextile is the separation between solids and water, having the geotextile as a filter medium. Therefore, the dewatering process in geotextile pipes aims to reduce the volume of mud, which helps in the transportation, disposal and reuse of this material. Some testing is required to ascertain the holding capacity of dredged material. For these dewatering systems, the retention of suspended solids is sought, and the rate of dewatering, the use of polymers is indicated. Polymer conditioned sludge tends to have higher dewatering rates and higher retention of fines and contaminants (KHACHAN et al., 2011). The selection and dosage of the polymer directly influences the sludge dewatering, so it is necessary to seek the optimal chemical conditioning point, because the lack or excess of chemical conditioning can compromise the system efficiency (GUIMARÃES; URASHIMA; VIDAL, 2014


Figure 2. Operant suction dredger

Geotextile Dewatering Cone test or GDC is a simple and fast run test, allowing quick results, so it is a very useful test giving evidence of filtration efficiency and dewatering rate. of the system. The aim of this study is to verify from the dewatering performance evaluation indices a comparative analysis, in order to select the most appropriate geotextile for the sludge discharge in question. These results will help in the sizing of the closed geotextile system aiming at dehydration of the dredged sediments of the Rio Grande Port. The sediment analyzed was removed from the canal in April 2019 and was removed from a suction dredger with a very fluid consistency.

2. MATERIALS AND METHODS

Dewatering test in the cone test it is possible to analyze some system efficiencies between the geotextile and the soil. And to perform the cone test it is necessary to divide the analysis process into several:

- Sediment Characterization
- Choice Geotextile
- Choice Of Polymer
- Observed Efficiency Parameters
- Dewatering Cone test

2.1 *Dredging sediment characterization*

Firstly, the geotechnical characterization of the dredging mud sample was performed through sedimentation tests and Atterberg boundaries. The determination of the particle size curve was obtained through the sedimentation test, performed by the densimeter method and sieving of the material washed and retained in sieve # 200, as described in NBR 7181 (ABNT, 2016). In this process it was necessary to determine the specific mass of the grains that was obtained by means of a test using the odometer. The sedimentation test is based on the principle of Stokes law.

For the determination of Atterberg limits, which represent the soil moisture content, and distinguish the different states of its consistency, and are divided into two limits: Plasticity Limit (LP) which represents the limit moisture content between the states. semi-solid and plastic; and the Liquidity Limit (LL) which represents the moisture content limit between the plastic and liquid states.

2.2 *Geotextiles Characterization and Polymer*

For the cone dewatering test, woven geotextile supplied by Huesker company was used. Table 1 presents the characteristic properties of the geotextile used in the test.

Table 1 - Characteristic properties of geotextile

Properties	Test Method	Geotextile 1 105/105 DW	Geotextile 2 55/55 DW
Feedstock	-	Polypropylene	Polypropylene
Mass per unit de area	NBR ISO 9.864	440 g/m³	270 g/m³
Density	-	1,38	0,92
Rated Flow Speed	NBR ISO 11058	20x10³	$15x10^{-3}$
Filtration opening	NBR ISO 12956	0,20 mm	0,20 mm
Color	-	Black	Black
Nominal exposure			
Resitance longitudinal	NBR ISO 10319	105 kN/m	55 kN/m
Cross Direction	NBR ISO 10319	105 kN/m	55 kN/m

For the preparation of the polymer solution, the process was carried out from the weighing of 0,5 g of the polymer powder, after which 500mL of distilled water was separated in a volumetric flask that I will place in a Becker with capacity of 1000mL. This solution was stirred and mixed by a hand shaker until the solution had a homogeneous solution.

Table 2 – Property of Polymer (Kemira, 2004)

Polymers Superfloc	A -120 HMW
Relative charge	Median
Molecular weight	Very High
Apparently density (kg/L)	0.78
pH solution at 0,5% (25°C)	7-9
Viscosity a 25°C (cp/mPa.s)	
0.10%	250
0.25%	550
0.50%	1000
1.00%	-

2.3 *Observed Efficiency Parameters*

The first parameter considered was the efficiency of the polymer effectiveness, which was calculated in two ways, as indicated by Avancini (2017), relating the polymer effectiveness to the material retention and relating to the flow rate according to Equation 1 and 2:

$$Effciency\ Polymer\ (retention) = \frac{P\ sludge - P\ sludge\ c/polymer}{P\ sludge} X\ 100\ (\%) \qquad [1]$$

Where,
P sludge = dry weight of the polymer-free percolate, in grams.
P sludge c/ polymer = dry weight of the percolate using the polymer, in grams.

For the Filtration Efficiency (EF) analysis, Moo-Young, Gaffney and Mo (2002) state that it can be obtained by comparing the amount of Total Suspended Solids (SST) of the filtrate, ie the effluent, with the amount of Total Solids (TS). However, in this study the TSS were replaced by final Total Solids (final TS), due to the fact that in the dewatering process the passage of sedimentable solids must be taken into account. For this research, we also considered the solids dissolved in the effluent as indicated by Tominaga (2010). Thus, Equation 2 calculated the equation:

$$EF = \frac{ST\ initial - ST\ final}{ST\ initial} X\ 100\ (\%) \qquad [2]$$

Where,
EF = Filtration Efficiency, in%.
Initial ST = Initial Total Solids, in mg / L.
Final ST = Final Total Solids, in mg / L.

The same authors also present the Dewatering Efficiency (ED) and indicate that it can be obtained in a similar way, comparing the final solids percentage with the initial solids percentage, being calculated through Equation 3:

$$ED = \frac{ST\ final - PS\ initial}{PS\ initial} X\ 100\ (\%) \qquad [3]$$

Where,
ED = Dewatering Efficiency, in%;
Initial PS = Initial Solid Percentage.
Final PS = Final Solid Percentage.

Another similar index is the infiltration efficiency (EI) also presented as a percentage (%) this refers to the sludge moisture before and after the dewatering process and is calculated by Equation 4:

$$EI = \frac{W\ initial -\ W\ final}{W\ initial} X\ 100\ (\%) \qquad [4]$$

Where,
EI = Infiltration Efficiency, in%;
Initial W = Initial sludge humidity (%);
Final W = Final moisture of sludge cake (%).

Finally, the last calculated efficiency refers to the passing particles (PP), in the particle loss per unit area (g / m²). According to Satyamurthy and Bhatia (2009), this efficiency is the loss of particles along the geotextile surface, being calculated through Equation 5.

$$PP = \frac{ST\ final}{A} \qquad [5]$$

Where
Final ST = total solids passing through the percolate, in grams.

A = effective dewatering area, in m².

2.4 *Dewatering Cone test*

After choosing the best flocculated polymer with the mud in the jar test, the cone test was done. For the test a glass cone was used to support the geotextile cones, a beaker to collect the effluent at the time of draining, a scale, and a cylindrical ring to secure the cone. The assay was performed in triplicate and divided into with and without polymer, therefore the cones were identified as 1C, 2C, 3C, 1S, 2S and 3S. The geotextile cones are 30 cm in diameter and were carried in the oven for two hours at 65 ° C to remove moisture before testing. Figure 3 shows the structure at the time of the test.

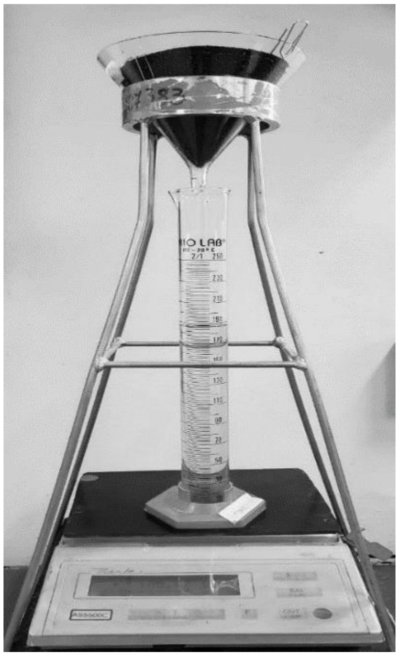

Figure 3. Cone Test

Initially, the sediment was homogenized; During the test, an initial subsample of sludge was removed before being placed in each cone with that subsample. We can identify the initial values of solids. 30 minutes were stipulated for the complete test. In the preparation of the polymeric solution, a concentration of 0.5% of polymer was used, the concentration of 1% was also tested, but this one presented a very large and difficult to work characteristic. Thus, 0.5 g of polymer were dissolved in 500 mL of distilled water, the solution was homogenized manually until the polymer was of good consistency and without fluctuation in the water.

For polymer cone tests, a sediment volume of 336 ml was used, and 64 ml of polymer solution was added, totaling a 400 ml sample. For tests without polymer it was added in a backer of 336 ml of sediment and 64 ml of water, in order to maintain a standardization in the test. The end of the test all material was weighed, the cone sample was removed, called cake for analysis of solids, moisture and polymer efficiency, as well as the material from the beaker for analysis of effluent, passing solids (percolated) and turbidity. All material was baked at 100 ° C for at least 24 hours to obtain the results of the dry sample values.

3. RESULTS

The granulometric distribution found in the studied sample is shown in Figure 4. through the granulometric curve, obtained by the sedimentation and sieving tests. Table 3 shows the percentages of each granulometric fraction performed as indicated in NBR 6502 for classification (ABNT, 1995). The pycnometer test resulted in a specific grain weight (γs) of 24.19 kN / m³, and the average moisture content obtained using the greenhouse method with homogenized and saturated samples was 137.76%.

The results obtained corroborate in part with the results found by Machado (2019), which presents approximate values for the granulometric fractions in a sample also of the dredging material taken from the access channel of the Port of Rio Grande. Machado (2019) in his analysis found that Coarse Sand equal to 1%, Medium Sand 7%, Thin Sand 32%, Silte 33% and Clay

27%. Thus, the clay fraction of both samples has a practically equal value, and the fraction of fine sand with higher values. However, in the analysis of the same, its sample showed a greater uniformity between the granulometric fractions.

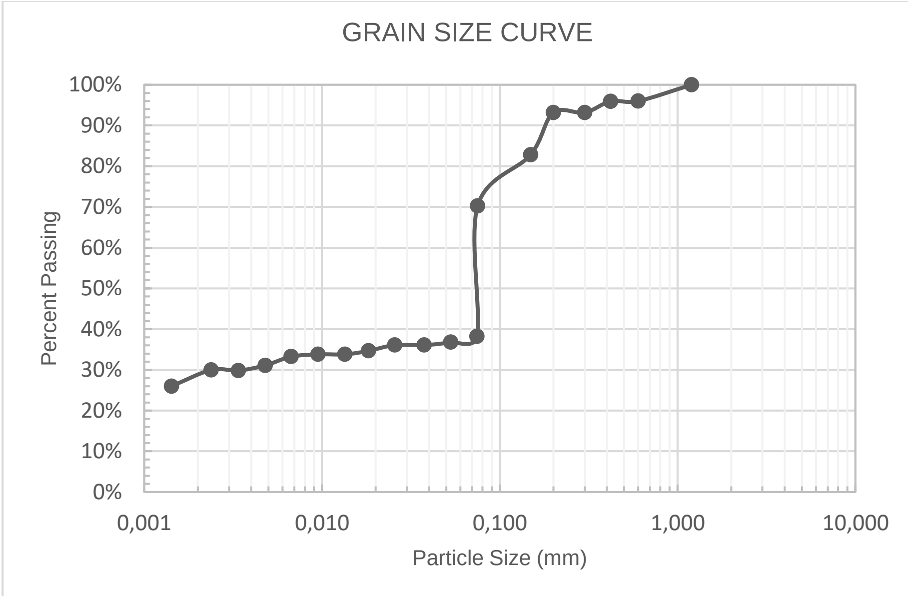

Figure 4. Grain size curve the ABNT classification

Table 3 - Percentages of clay, silt and sand fractions according to NBR 6502 classification (ABNT, 1995).

Fractions of the granulometric composition	
Boulder	0,00%
Coarse Sand	3,99%
Medium Sand	2,84%
Thin Sand	58,38%
Silte	10,78%
Clay	26,01%

With the results of the sedimentation and sieving test indicating the values of the granulometric fractions, it was possible to perform the soil classification through the methods of Unified Soil Classification System (SUCS), and HRB Classification System (AASHTO, 1973). Therefore, the material was classified as a “SC” soil, through SUCS, being above line A and framing as Clay Sand. Through the HRB, the soil is classified as an A-7-6 soil (4). Table 4 presents the quantitative parameters of texture and plasticity of the sample.

Table 4 – Soil Texture and Plasticity Parameters

Indices		Resulted
Cu	53,21	Uneven soil
CC	0,05	Poorly graduated soil
LL (%)	43	
LP (%)	20	
IP (%)	23	Highly Plastic
IC	-4,12	Soil with liquid behavior
IL	5,12	>1 Extra sensitive clay
IA	0,88	Normal activity soil behavior
Organic matter content (%)	1,45	Low organic matter content

Observing the determination of Atterberg limits, the sediment presents the behavior of a liquid and is classified as a highly plastic soil also confirmed through IP. As for the consistency index (Ic), the sediment is classified as very soft, presenting a liquid soil behavior. For Machado (2019) the LL obtained was 64%, LP 25%, IP 39%, and Ia of 1.44 these would be the values corresponding to the dredged material in the access channel, which differ from the values found in this study. Therefore, it is possible to observe variation between both samples of the dredging material, this result is attributed to several factors, among them the type of dredge, the height of the sediment removal, as well as the organic matter content presented in each sample.

After the geotechnical characterization of the sediment, the cone test was carried out with the sediment density of approximately 1.1 (kg/m³) with the attempt to represent the fluidity of the sample under field conditions, that is, conditions of the sediment taken from the dredge. First, for the cone test, it was necessary to choose the polymer that best flocculated with the sediment and its concentration to be used.

During the test, it was observed that the polymer that best flocculated with the sludge was Superfloc A120 HMW, of all the polymers tested only 4 presented flocculation condition with low concentration from 160 ppm to 200 ppm. The material was homogenized until the sludge flocculated with polymer as shown in Figure 5. The polymer chosen was the one that presented the best conditions tested the lowest value of ppm. Figures 6 and 7 show the cone with polymer and without polymer, during the test and after drying in the oven. It can be seen that polymeric cones have a smaller wetted area than non-polymeric cones. The flocculation of the sludge with the polymer is clear and after drying the material showed a good ridicule.

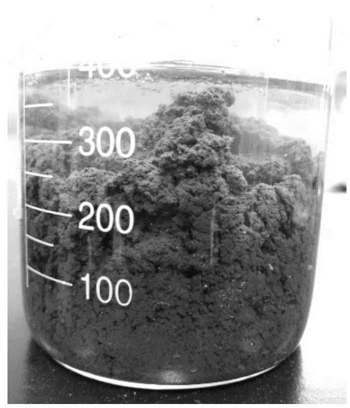

Figure 5. Flocculated with polymer

Figure 6. Polymer material a) during the test b) after drying in the oven.

After drying the material in the oven, the difference in solids in the percolated material was observed, the ones with polymers had a more whitish and granular appearance than the solids present in the percolates without polymers, in Figure 6 shows this difference between percolated materials. The variation between the materials is clear, those with polymer have the same amount of passing solids as those without polymers, but the passing solids have the appearance of polymer in natura.

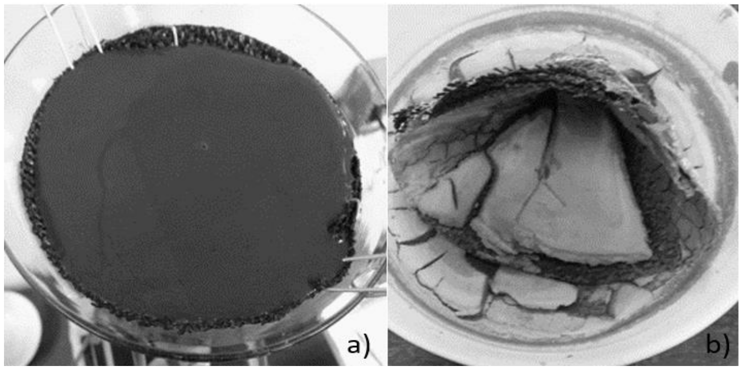

Figure 7. Polymer-free material a) during testing b) after oven drying.

In Table 5 presents the other efficiency values. The results obtained for the filtration efficiency of both polymers are noteworthy, as both presented satisfactory results, mainly that of geotextile 1 which was more than 90% both with polymer and without the addition of the polymer in the sediment. During the test it is possible to clearly observe the difference between the effluent at the time of filtration with and without polymer, in tests without polymers it is possible to observe that the effluent passes with a lot of fine material. Polymer efficiency for Geotextile 2 showed a value above 100% which differs considerably from geotextile 1 which showed a polymer efficiency of 28%. Therefore, due to these results, we can observe that both geotextiles are efficient for dewatering the studied sediment, however geotextile 2 ends up standing out more when the polymer is added to the sediment.

Table 5 – Efficiency Results

Efficiency	Geotextile 1		Geotextile 2	
	With Polymer	Without Polymer	With Polymer	Without Polymer
EP (%)	28,89	-	178,50	-
EF (%)	99,14	96,75	99,26	87,66
ED (%)	38,23	172,63	50,53	99,02
EI (%)	22,49	20,76	38,63	36,15
PP	0,00	0,00	0,00	0,00

The polymer tested flocculated at a high ppm concentration so we conclude that this factor may influence the system efficiency. Figure 8 and 9 shows the relation mass, volume by test time for tests with and without polymer, on geotextiles 1 and 2 respectively During the test we can observe that in the initial 30 seconds the effluent passes quickly through the polymeric geotextile compared to the polymer-free geotextile. Another factor that can be observed at the time of drainage is the appearance of the effluent in the polymer cone all the effluents visually presented a low solids passage, while in the unpolymerized cones the solids passed along with the liquid.

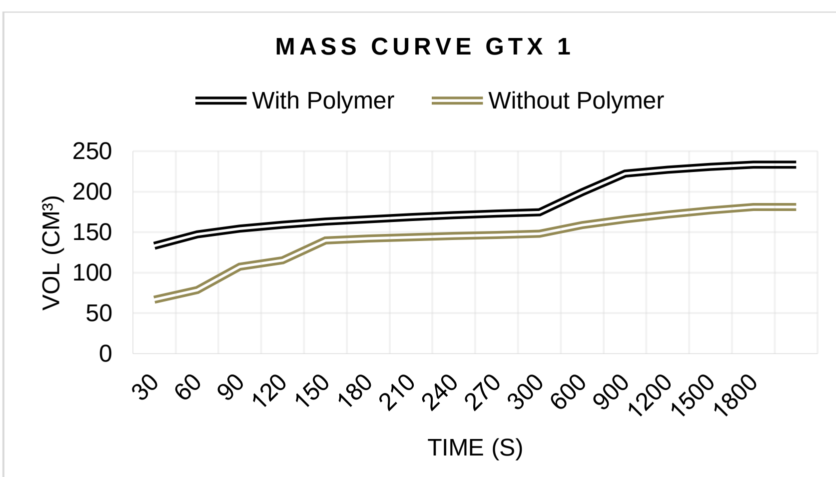

Figure 8. Mass Curve Geotextile 1

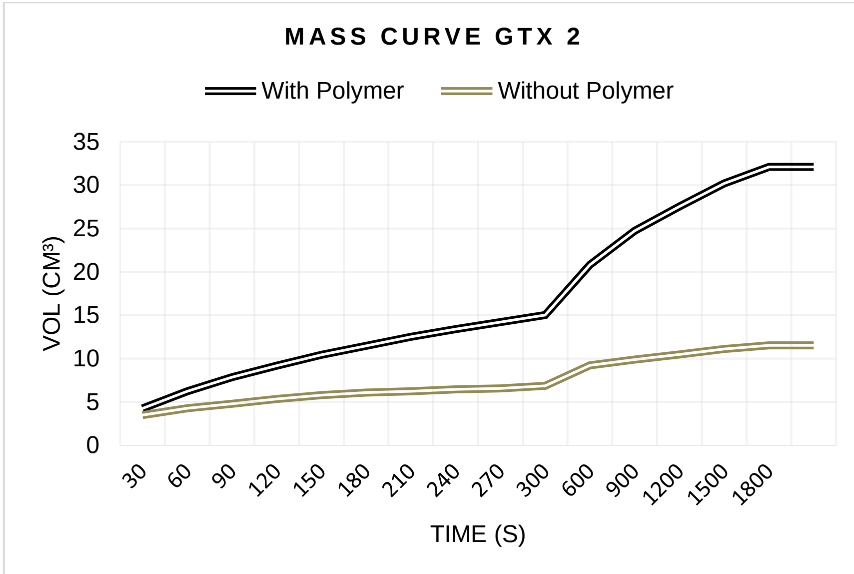

Figure 9. Mass Curve Geotextile 2

It can be observed that between these two geotextiles the mass curve of the effluent without polymerization is below the line of the effluent with polymerization. In Figure 8 it is observed that the difference in drainage in the initial 30 seconds is approximately 66 cm^3/s, in Figure 9 that represents geotextile 2 the difference in initial drainage value is approximately 1 cm^3/s, being very small compared to geotextile 1. In geotextile 1 we have the final dewatering rate equal to 233.39 cm^3/s of the polymer test and in geotextile 2 the final value of the same rate is 32,10 cm^3/s, ie geotextile 1 filters the effluent much faster than geotextile 2 in the same test time.

It is possible to observe that in the test of geotextile 2 without polymer that the dewatering volume varies little in relation to the time, the same geotextile tested with polymer started to have a greater dewatering volume only after the first 5 minutes of the test. As for geotextile 1 without polymer, the variation was greater up to approximately 180 initial seconds, with a drainage volume variation of 70 cm^3 / stabilizing over time, and in the polymer test the volume rate remained uniform throughout of the test having an increase until the first 15 minutes and stabilizing afterwards.

4. CONCLUSION

The dredged sediment from the port of rio grande, Brazil was characterized as clay sand by SUCS, and A-7-6 (4) by HBR. The sediment presented a large amount of fine sand and clay in its geotechnical characteristics, as well as a high plasticity and a low organic matter, characteristics of poorly graded and uneven soil, with highly plastic and liquid behavior. What was expected because it is in a fluid state with a density of 1.1 (kg / m^3). From these characteristics of the material and its density it was possible to select the best polymer that flocculates with the material. Among 10 tested polymers, only 4 flocculated with the material in concentrations between 160 and 200 ppm, the polymer chosen for the test was the one with the lowest concentration and that best flocculated with the material.

As well, it was possible to observe with the cone test that the difference between the tested geotextiles is small, however the geotextile 2 showed better results regarding the efficiency of the polymer. The results of the mass curve, directly influence the drainage efficiency of the cone test, therefore the ED in geotextile 1 with polymer is less than the ED without polymer indicates that the passage of the effluent volume is better without the addition of polymer because it is more constant when over time, the same applies to geotextile 2.

However, when choosing the geotextile to be used for conditioning the sediment, the efficiencies should not be analyzed individually, but together, therefore, firstly, geotextile 1 with the addition of polymer fits better for the filtration of effluent without sediment in less time. To fill the geobags with the dredged material, more tests and other tests are necessary in order to better quantify the study.

5. ACKNOWLEDGEMENTS

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