Dewatering of Dredged Sludge with Geotubes: Effects of Polymer Additive Type and Amount

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ABSTRACT: In this paper, the findings to understand the effectiveness of laboratory geotube dewatering tests with additives for the dredged sludge taken from the base of the Golden Horn, Istanbul are presented. The dredge sludge used in this study has an extremely high water content. All the tests are performed by using two different cationic and anionic additives to enhance the dewatering, which provided the efficiency of the effect of types and amounts of selected additives on dewatering efficiency of Golden Horn dredged sludge. For this research, a dosage amount of 1.5 kg per ton is used as flocculants solution preparation with distilled water. Moreover, twelve homogeneous sludge-polymer admixtures are prepared by adding 0.1, 0.25, and 0.50% polymers (anionic and cationic) by weight of the dredged material for these tests. The results obtained from the tests on Golden Horn dredged sludge indicate that the use of flocculants increases the retention capacity of geotubes and more specifically that the chemical cationic polymers is more appropriate for Golden Horn dredged sludge rather than the anionic polymers.

Keywords: Geotubes, Dredged sludge, Dewatering, Polymers, Golden Horn

1 INTRODUCTION

In Turkey, especially in recent times, a huge amount of sludge has been dredged from the sea-bottom to deal with the problem of contamination in the Golden Horn, Istanbul, where the dredged material has been stored on-land through pumping or disposed back elsewhere into the water. Dewatering of the sludge pumped to the on-land disposal areas has a potentially important economic contribution. Recent studies have indeed found geotextile tubes (geotubes) to be a convenient method to dewater high-water content materials (Kutay and Aydilek, 2005; Liao and Bhatia, 2005; Aydilek and Edil, 2002). The use of geotubes for this purpose, unfortunately, is little in Turkey. Moreover, an important component of dewatering is chemical additives which may increase the effectiveness. The water-soluble polymers are commonly utilized chemicals for various industries, such as food, pharmaceuticals, paint, textiles, paper, constructions, adhesives, coatings, water treatment. Anionic and cationic ionic polymers were used in this study.

1.1 *Background and Materials*

Geotextile dewatering is a technique of separating solids and water in a sludge using geotextiles as the filter media. Globally, there is a growing need for technologies that efficiently dewater high-water content sediments dredged from canals, harbors, and lakes to decrease its volume for practical and economical disposal considerations (Leshchinsky et al., 1996; Aydilek and Edil, 2002; Kutay and Aydilek, 2005; Liao and Bhatia, 2005; Shin and Oh, 2007; Lawson, 2008; Yan and Chu, 2010; Cantré and Saathoff, 2011; Chu et al., 2011; Malik and Sysala, 2011; Chu et al., 2012; Yee et al., 2012; Yee and Lawson, 2012). The high-water content of the Golden Horn sea-bottom sediments suggests that the use of geotextile tubes can be a viable option for dewatering these materials. Geotextile tubes are efficient for separating and dewatering contaminated high-water content sediments and wastes primarily due to a large contact surface area (Moo-Young et al., 2002; Muthukumaran and Ilamparuthi, 2006; Lawson 2008), and have rapidly emerged as the preferred in-situ method in recent years. In practical applications, liquid slurry is filled into geotextile tubes under pressure, allowed to dewater, and refilled to repeat the cycle two to six times until the throughput is insignificant (Lawson, 2008). Since then many successful applications of geotextile tube dewatering have been reported (Wangensteen et al., 2001; Lawson 2008; Mastin et al., 2008) providing site specific information but no general guidelines, specifications, or observations. High-strength monofilament fibrillated woven geotextile (GT500) is used in testing, which is a common geotextile for dewatering applications. Strength and hydraulic properties of the geotextile including apparent opening size are given in Table 1.

Polymers are natural or man-made, carbon-based macromolecules. Polymers specifically designed for dewatering are available in many different forms in the commercial market today, including solutions, emulsions, and dry forms (Gaffney et al. 2001). Chemical conditioning of the slurry with polymers can provide many benefits to a dewatering project. The category of polymers covers a wide range of chemical additives including flocculants and coagulants. Polymers can dramatically reduce turbidity in the decant water and can bind solid contaminants with the material being retained. In this study, different concentrations of polymers [C1 (cationic), C2 (cationic), A1 (anionic), and A2 (anionic)] are tried to further illuminate the influence on the dewatering behavior of Golden Horn dredged sludge by the conditioner treatment. Four commercially available flocculants with varying charge densities and molecular weights are selected.

Tests performed on the samples from the dredged sludge (classified as high plasticity silt, MH) are summarized in Table 2. The organic matter content is determined to be about 4%.

Table 1. Geotextile properties (from the manufacturer)

Mechanical properties	GT500D
Type of product	High performance filter fabric
Material	Polypropylene yarns
Color	Noir
Minimum tensile strength [EN ISO 10319] (kN/m)	70
Minimum seam strength [EN ISO 10321] (kN/m)	65
Hydraulic properties	
Water flow rate (l/min/m^2)	813
Apparent opening size (AOS) (mm)	0.43
Mass/unit area (g/m^2)	585
Pore size distribution (O95) (Micron)	195
Thickness (mm)	1.8

Table 2. Index properties of the mud used for this study

The amount of additive substance	10%
Liquid Limit (LL) %	45%
Plastic Limit (PL) %	42%
Plasticity Index (PI) %	3%
Specific Gravity (gr/cm^3)	2.52

2 METHOD

2.1 *Geotextile Tube Dewatering (GDT) Tests: Method and Results*

In the tests the process of filling of the geotextiles lasted for two days. In all the dewatering tests, the geotextile filter is placed in a simple PVC container to be able to measure the quality and amount of the water taken from the geotextile filter.

When geotextile tubes are used for dewatering high-water content materials, the dewatering capacity will be the major concern. It includes two aspects: dewatering efficiency (how high final percent solids can be obtained) and dewatering rate (how long the dewatering will take). Obviously, dewatering efficiency and dewatering rate will be controlled by the interaction between the sludge and the geotextile, affected by the sludge properties, geotextile properties, and filtration pressures (Moo-Young et al., 2002; Koerner and Koerner 2006). The GDT was used to evaluate the effectiveness of combinations of geotextile and anionic–cationic polymers (C1, C2, A1, and A2) in dewatering the Golden Horn dredged material (Figure 1).

Figure 1. Geotube Dewatering System (The GDT system)

Tests were conducted with and without polymers to compare their dewatering and filtration efficiency. Polymer slurries consisting of dry polymers and distilled water were added to the sediment slurry based on density of material to enhance the settlement of solid particles within the geotextile tube. Four polymers were mixed with the slurry of Golden Horn dredged material at 0.1, 0.5, and 1.0% concentration by weight of slurry. The polymer solutions were prepared by dissolving the polymer powder in deionized water at specified concentrations. The concentration is defined as the ratio in percentage of the dry weight of polymer to the total weight of the polymer solution. To prevent clumping, the polymer powder was slowly added into deionized water and a hand mixer was used to stir the solution for 10 minutes until a homogeneous solution was obtained. Polymer solutions concentrations of 0.1, 0.25, and 0.5% were used for GDT tests to investigate the effect of polymers on the dewatering with geotubes.

A small-scale geotextile tube was used to conduct the experiments on Golden Horn dredged sludge, which has dimensions of approximately 53 cm by 53 cm and holds approximately 28,000 cm^3. GT 500 geotextile is used along with conventional seams. The small-scale tube was often referred to as a pillow. For the test method, the stand was leveled before testing, and the standpipe was secured to the pillow. A feeding tube (68.5 cm height and 10 cm diameter) was used for the tests. All tests were performed at temperatures on the order of 15°C. Approximately 127 kg of soil slurry was used for all tests. Soil slurry was first blended to achieve a slurry concentration of 10% solids in all GDTs. Also, slurry was allowed to sit overnight, remixed with a hand drill. GDT was used to test the slurries with four types of polymers. To examine the full capacity utilization of the geotextile tube in all experiments, geotextile tubes have been filled with geotextile sludge gradually. Placement inside the geotextile tube has been completed within 2 days depending on the dewatering activities. Within the first 60 minutes of the experiment 75% of the pre-prepared slurry has been placed in the rack and water outflow was recorded. Second, placement process was initiated 24 hours after the start of the experiment and was completed within 27 hours.

Dewatering efficiency (Moo-Young et al., 2002) is used to describe the dewatering degree in each test, which compares the final percent solids with the initial percent solids:

$$\text{Dewatering Efficiency (\%)} = \left[\frac{PS_{final} - PS_{initial}}{PS_{initial}}\right] * 100 \quad (1)$$

where $PS_{initial}$ is the initial percent solids (%); PS_{final} is the final average percent solids (%). The test results are also evaluated for the average infiltration efficiency (Muthukumaran and Ilamparuthi 2006) which is calculated by,

$$\text{Infiltration Efficiency} = \left[\frac{w_{final} - w_{initial}}{w_{initial}}\right] * 100 \quad (2)$$

where $w_{initial}$ and w_{final} are the initial and final water contents of the sludge, respectively.

After the experiments, the highest filtrate water quality was recorded. The analysis of the filtrate water in this experiment is given in Table 3.

Table 3. The results of filtrate analysis after geotube dewatering test (0.1%-Cationic 1)

Elements (mg/L)	Golden Horn dredged sludge chemical analysis	Water filtrate analysis after GDT (0.1%-Cationic 1)	Sea water quality index criteria for Turkey
Total Cadmium (Cd)	1-30	0.001	0.01
Total Chromium (Cr)	30-240	0.002	0.1
Total Copper (Cu)	50-1660	0.006	0.01
Total Lead (Pb)	20-270	<0.002	0.1
Total Nickel (Ni)	40-800	0.015	0.1
Total Zinc (Zn)	80-1500	0.009	0.1

Flame atomic absorption spectrometry technique is used for the analysis. The chemical analysis of the filtrate water from geotextile tubes, which had been improved with additives, indicates that no harm to the environment is likely. Figures 2-4 show the flow response of tests carried out on Golden Horn dredged material using geotextile tubes with twelve homogeneous sludge-polymer admixtures obtained by adding 0.1, 0.25, and 0.50% polymers (anionic and cationic) by weight of the dredged material. Percent drained water is used to describe the dewatering-time behavior in each test:

$$\text{Percent drained water} = \left[\frac{W_{w\ filtrate}}{W_{w_{initial}}}\right] * 100 \qquad (3)$$

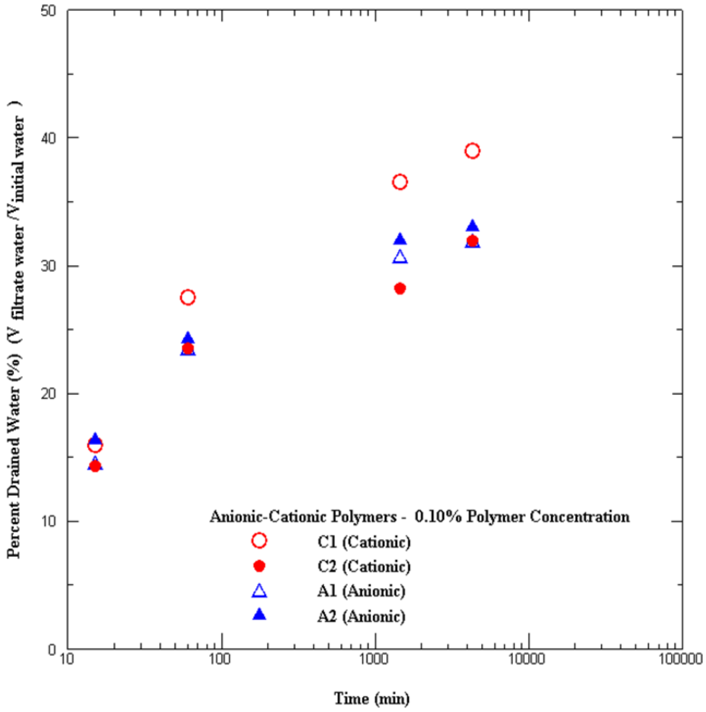

Figure 2. Percent drained water vs. time for 0.1% polymer enhanced slurry in GDTs.

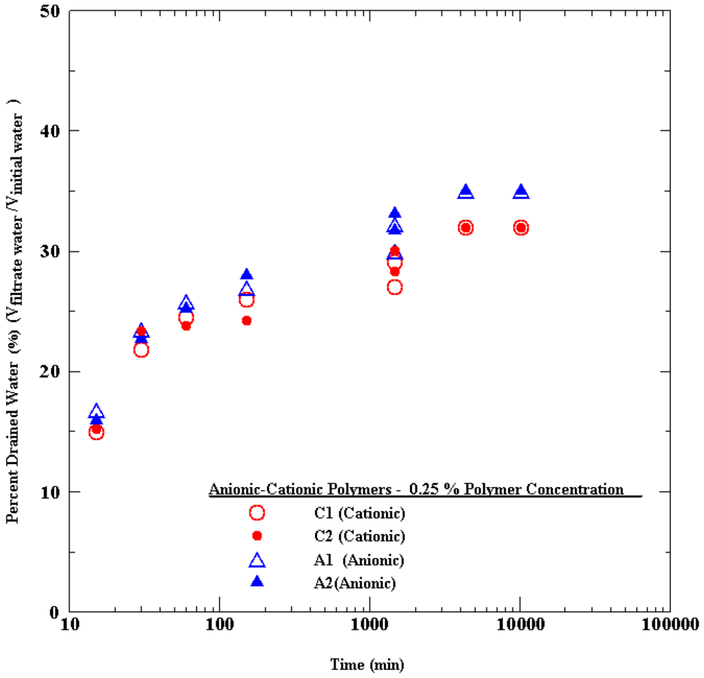

Figure 3. Percent drained water vs. time for 0.25 % polymer enhanced slurry in GDTs.

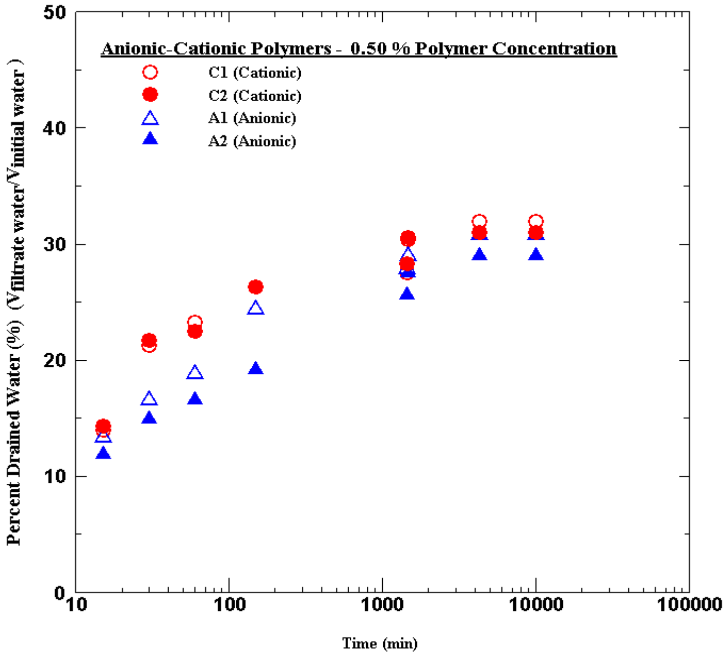

Figure 4. Percent drained water vs. time for 0.50% polymer enhanced slurry in GDTs.

For different polymer additions, the flow is exponential on a logarithmic scale up to certain time and thereafter changes its slope. Having examined the test results, the most effective outcome in dewatering process was with 0.1% by weight C1 additive. In this regard, the water content of the sludge at the beginning has been realized as maximum 40% in drainage. The initial flow rate decreased with an increase in polymer concentration, which increased filtrate viscosity. The success or failure of a dewatering project often hinges on how much a particular sludge will dewater to an acceptable dryness (usually defined in terms of percent solids).

The dewatering rate of GDTs is defined as the slope of a curve of percent solids and the polymer concentration by weight (Figure 5). It can be seen that the results changes within a 39–52% range and the best result for percent solid content was reached at 51% for the cationic polymer CI which was added to the sludge in a 0.10% polymer concentration by weight. Also it is clear that anionic polymers used in this research do not have an efficient impact on Golden Horn dredged sludge compared with cationic polymers.

Dewatering efficiency in the GDT results is given in Figure 6 with varied concentrations (0.1, 0.25, and 0.5%) of four different polymers (C1, C2, A1, and A2). The GDT results show that the cationic polymer C1 has the most positive impact on the dewatering process.

Infiltration efficiency in the GDT results is given in Figure 7 with polymer concentrations for four different polymers (C1, C2, A1, and A2) in the slurry. Infiltration efficiency at polymer concentration varies within a narrow range irrespective of the polymer type. This value is around 87% for cationic polymers (C1 and C2) and 85% for anionic polymers (A1 and A2).

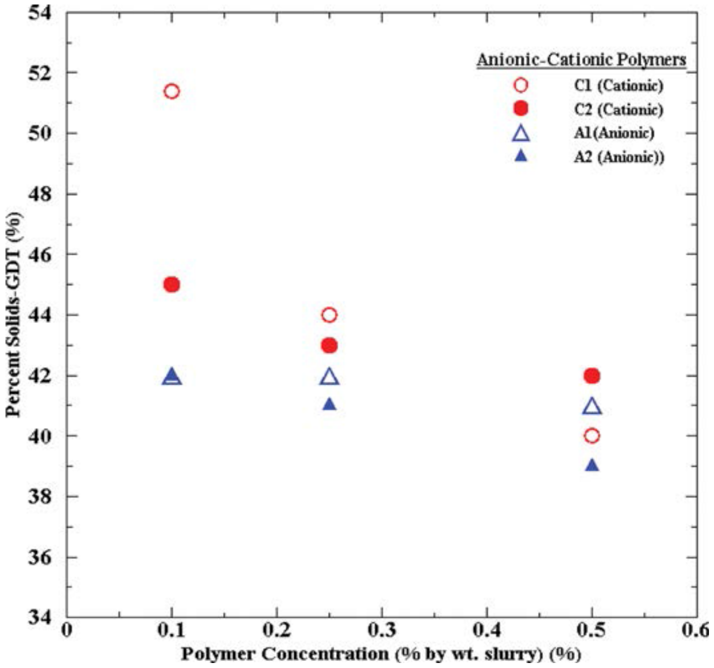

Figure 5. Percent solid with different polymer types and concentrations enhanced slurry on GDTs.

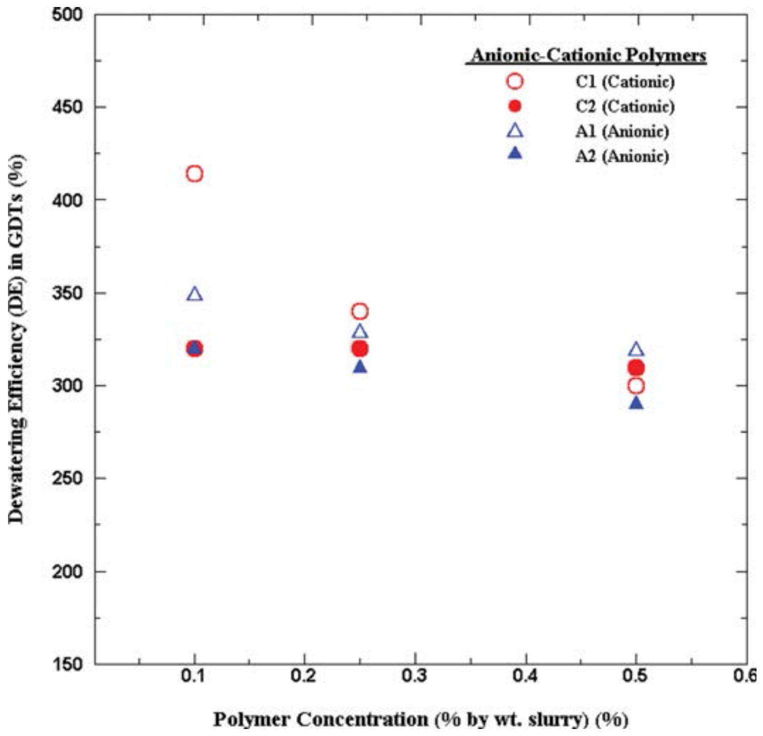

Figure 6. Dewatering efficiency with different polymer types and concentrations enhanced slurry on GDTs.

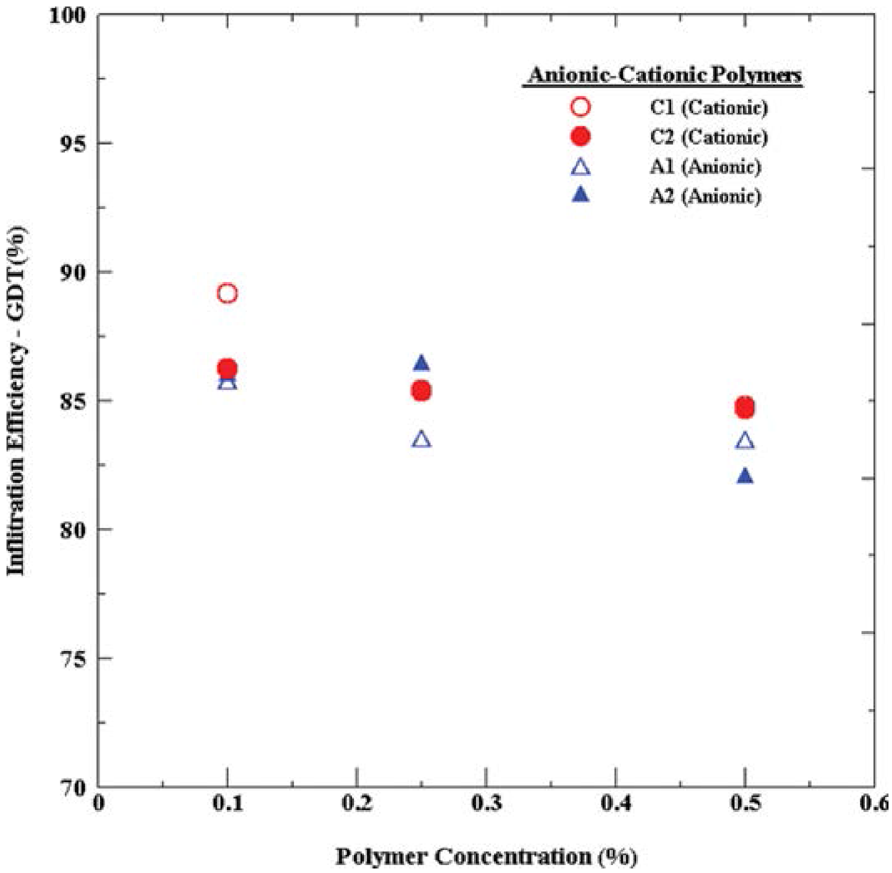

Figure 7. Infiltration efficiency with different polymer types and concentrations with on GDT.

2.2 *Atterberg Limit Test Results After Geotextile Tube Tests (GDT)*

Atterberg limit tests were repeated on the samples obtained from the dewatering tests which were carried out by using additives. The values of liquid limit, plastic limit and plasticity index (Figures 8-10) are presented based on the percentage of the additives of polymer below. As seen from the figures below, the values of liquid limit, plastic limit and plasticity index obtained from the samples without additive before the process of dewatering did not exhibit significant differences. As a result, all the values are observed to be very close to each other.

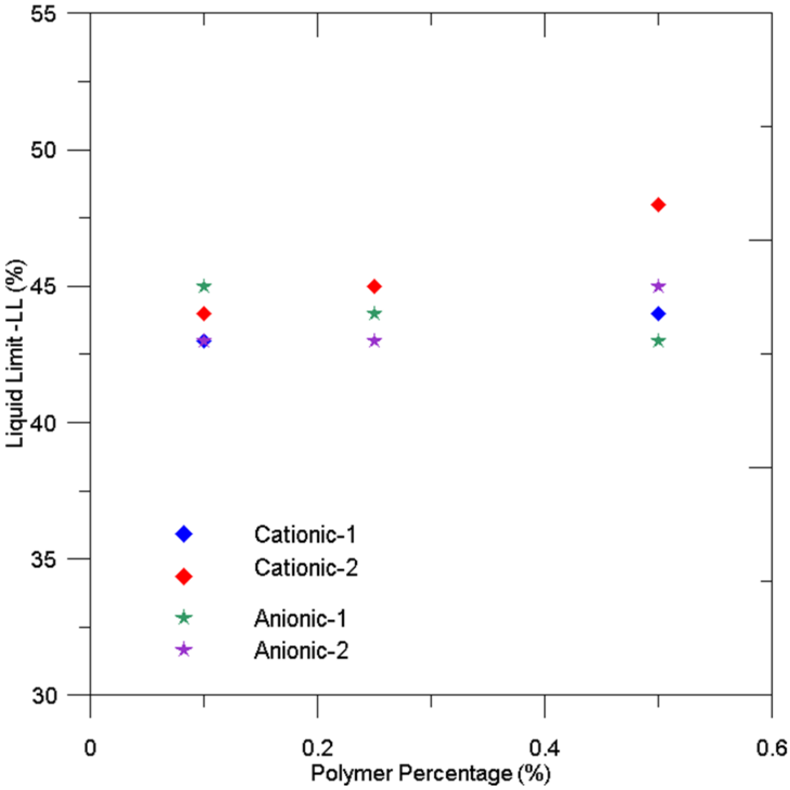

Figure 8. Liquid limit (LL) test results after GDT tests

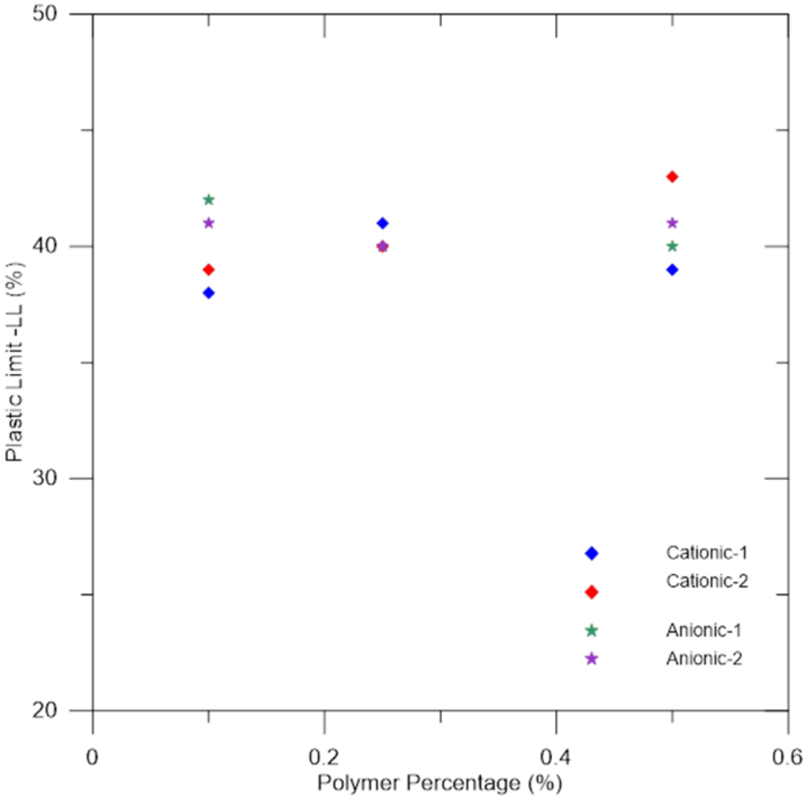

Figure 9. Plastic limit (PL) test results after GDT tests

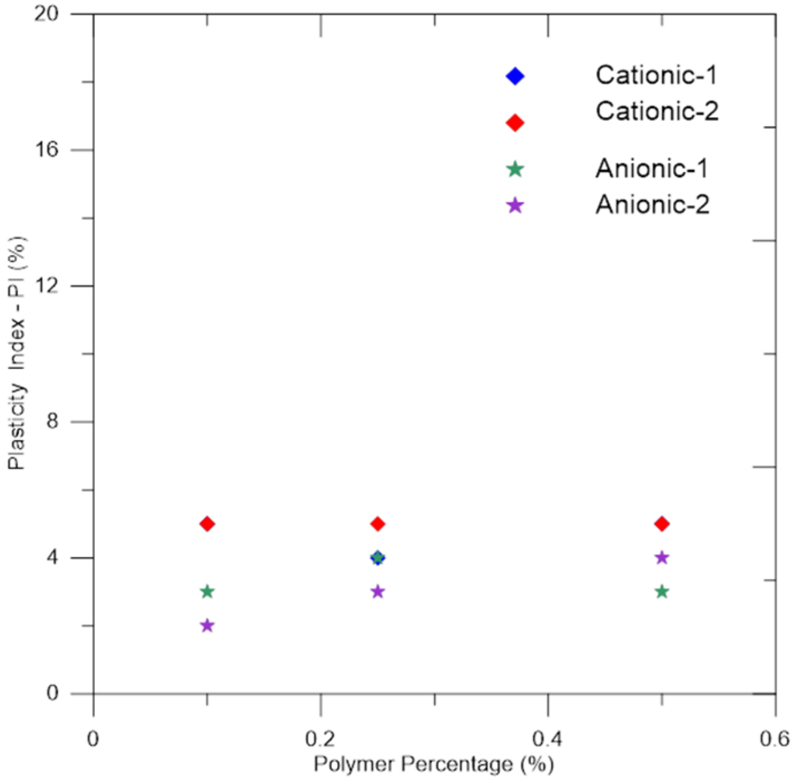

Figure 10. Plasticity index values after GDT tests

3 CONCLUSIONS

The purpose of this study is to investigate the use of geotextile tubes for high-water content Golden Horn dredged sludge dewatering with anionic and cationic polymers, evaluate its feasibility and possible affecting factors. Twelve GDTs were conducted. The following conclusions can be drawn based on the findings:

1. Dewatering efficiency is low at lesser water content (less than 800%) and greater percent solids (more than 10%) of Golden Horn sludge than those having a higher water content and lower solid content.
2. Polymer addition increases the dewatering efficiency and infiltration efficiency. Especially cationic rather than anionic polymers are recommended for the dredged material from the Golden Horn,
3. Any design for dewatering should be made considering that the amount of additive substance (economy), the quality of the infiltration water, the ease and duration of filling.

Transportation and disposal of dewatered material with higher density (i.e., lesser volume) provides significant economic gains. Further environmental benefits may be obtained if a dewatering process involving appropriate additives more in line with the chemical and physical profile of the sludge can be utilized. Possible effects and toxicity of polymeric additives present in the filtrate water should also be investigated.

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