Assessment of GCL hydration depending on the subsoil height

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ABSTRACT: The influence of subsoil height on the hydration of geosynthetic clay liner (GCL) was investigated in this study. For this purpose, subsoil gathered from Aydın municipal solid waste (MSW) landfill liner was compacted at 2% wet side of optimum water content in compaction molds with different thicknesses (H:5.9 cm, 11.6 cm, 17.4 cm). Then, a local GCL was hydrated over these compacted subsoils for 7 days to 62 days using flexible wall permeameters. After termination of hydration process, GCL was removed from the permeameter and the water content of GCL bentonite was determined. Regardless of the height of the subsoil, the final bentonite water contents increased from 53% to 72% as the hydration time was increased from 7 to 62 days. However, at any hydration duration, it is found out that the final bentonite water contents changed depending on the height of the subsoil. The water content distribution across the subsoil after hydration showed similar trends with each other. That is, the water contents of the layers in contact with the GCLs were less than the water contents of the rest of subsoil body. However, small deviations in the initial compaction water contents became larger through the bottom of the subsoil, indicating the influence of subsoil height on the bentonite water content, hence suction performance of GCL.

Keywords: Geosynthetic clay liners, hydration, subsoil, subsoil height, water content

1 INTRODUCTION

Geosynthetic clay liners (GCLs) have been used in so many areas due to their low hydraulic conductivity and easy installation. Especially, landfill liners, pond liners, channel seams and ponds of mine tailings are the most common applications of GCLs (Bouazza 2002; Katsumi et al. 2008).

GCLs are factory-manufactured hydraulic barriers that are composed of thin bentonite layer sandwiched between two geotextiles. The hydraulic performances of GCLs are controlled by the mineralogy and the physicochemical properties of bentonite in GCLs. It is reported in the literature that the hydraulic conductivity of Na rich GCLs were about 2.0×10^{-9} cm/s to water (Lee & Shackelford, 2005; Shan & Lai, 2002, Jo et al., 2001, 2005).

Besides, initial water content of bentonite has an important role on the permeability of GCLs. Previous studies reported that increase in the GCL water content decreases the hydraulic

conductivity (Meer & Benson, 2007; Scalia & Benson, 2011). Similar results were also reported for exhumed GCLs. Benson et al. (2007) reported lower hydraulic conductivities for exhumed GCLs whose water contents were high above 59%.

GCL water content is related to the amount of water that is taken from the subsoil by suction. Swelling of bentonite by water suction from the subsoil is referred to as “hydration”. Recent advances in geoenvironmental engineering showed that the hydration phase of GCLs after installation is one of the most important issues governing the hydraulic conductivity (Katsumi et al., 2008; Rowe and Abdellaty, 2012). To simulate this phenomenon in the laboratory, GCLs are placed over the compacted subsoils and left to hydration for different time periods. The effect of hydration time on the final water content of GCLs has been investigated so far by many researchers (Rayhani et al., 2011; Anderson et al., 2012; Barclay and Rayhani, 2013; Bradshaw et al., 2013; Chevriet et al., 2013; Sarabian and Rayhani, 2013). However, there is no information about the influence of compacted subsoil height (thickness) on the hydration of GCLs. Thus, this study presents and discusses the effect of subsoil height on the hydration experiments in terms of GCL water content.

2 MATERIALS AND METHODS

2.1 *Materials*

In the content of the study, a local needle-punched GCL was used. Bentonite in the GCL was in granular form and the initial water content of bentonite was 11%. In order to determine the particle size distribution of bentonite, wet sieving method was applied (ASTM D422-63). The particle size analysis showed that the GCL bentonite contains 17% sand size grains. The fine content and clay content of the GCL were 83% and 57%, respectively. The liquid limit of the bentonite was also determined as 102% and 97% with fall cone and Casagrande methods, respectively.

Silty sand from the foundation soil at Aydın MSW Landfill was used as the subsoil for the hydration processes. According to ASTM D 2487-11 (USCS), the subsoil from Aydın is classified as silty sand (SM). The liquid limit of the subsoil was determined as 30.7%. However, there was no plasticity for Aydın silty sand.

Hydrations were performed in flexible-wall permeameters which are capable of testing GCL samples with 15 cm in diameter (Figure 1a). In order to simulate the loads acting on the covers, GCLs were hydrated under 10 kPa cell pressure. This pressure was applied directly connecting the influent lines (i.e. burettes) to the cell pressure port of permeameters. Then, burettes were filled with water to the levels that allow 10 kPa cell pressure (Figure 1b).

Figure 1 Flexible-wall permeameters that were used for the hydration of GCLs in this study.

2.2 *Methods*

2.2.1 *Compaction of subsoils*

Compaction parameters of the Aydın MSW subsoil was (i.e. maximum dry density and optimum water content) determined in accordance with ASTM D698-07. Samples were compacted in a 10 cm diameter mold (H= 11.6 cm) under Standard Proctor energy by using an automatic compactor. The compaction curve of the subsoil is shown in Figure 2. As seen from Figure 2, the maximum dry density ($\rho_{d,max}$) and optimum water content (w_{opt}) were obtained as 1.86 t/m^3 and 12%, respectively.

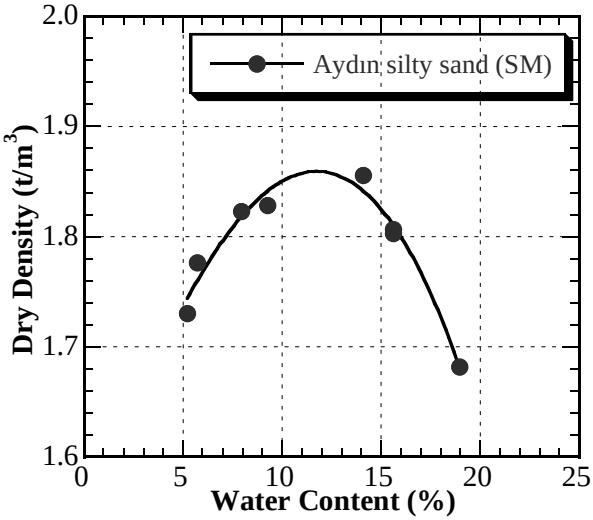

Figure 2 Compaction curve for the subsoil used in hydration of GCLs.

Since flexible wall permeameters had an ability to test 15 cm diameter samples, subsoils were compacted within molds with 15 cm diameters, but having different heights (Table 1). Thus, blow counts and number of layers were arranged for 15 cm diameter mold to achieve the same dry density as was obtained in 10 cm compaction mold (1.845 t/m^3).

Table 1. Subsoil dimensions and blow counts applied for each layer while compacting the subsoil.

Subsoil Diameter D (cm)	Subsoil Height H (cm)	Number of layers	Blow counts per layer
15.3	5.9	2	36
15.2	11.6	3	56
15.3	17.4	5	52

Subsoils which were used in GCL hydration process were compacted at 2% wet side of the optimum water content (14%) in three different heights (Table 1). Before compaction, subsoils were left to hydration in plastic bags for 24 hours to achieve homogeneous water content. Then, the soils were mixed once more and then, compacted.

2.2.2 *Sample Preparation for GCL hydration*

GCL hydrations were performed in flexible-wall permeameters. For this purpose, 15 cm diameter circle was drawn on the middle of a 30 cm × 30 cm square GCL sample. The circumference of the drawn circle was hydrated with DI water to prevent the bentonite loss while cutting. In order to simulate the landfill liner systems in the laboratory, GCL specimen was placed on the compacted subsoil in the flexible-wall permeameters. A geomembrane, a nonwoven geotextile disk and the top plate were also placed in that order over the GCL sample. Note that the nonwoven side of the GCL was in contact with the subsoil. Then, the system was covered with latex membrane and three O-rings were placed to each top and bottom plates. The cell was filled with water and 10 kPa cell pressure was applied.

2.2.3 *Water content determination of GCLs and subsoils after hydration*

At the end of the hydration period, GCL final water content was determined by detaching fibers in between the geotextiles. After that, all bentonite was taken with a spatula and dried in an oven at 105 °C to determine the water content.

The subsoil water contents were determined by layering the compacted soil samples. For this purpose, subsoils were divided into 4, 5 or 7 layers by spatula depending on the heights of the sample. The water contents of these layers were determined after 24 hours of drying in an oven at 105 °C.

3 RESULTS

The hydration behavior of the GCL is evaluated in terms of the final GCL water contents. GCL samples were initially hydrated over compacted silty sand with 5.9 cm height for 7 days, 30 days and 62 days. The final GCL water contents are shown in Figure 3 as a function of hydration duration. As seen in the Figure 3, the GCL water content increased from 12.6% to 72% in time.

To determine the influence of the subsoil height on the GCL hydration, GCL samples were also hydrated over compacted silty sands with H: 11.6 and H: 17.4 as well. Due to limited number of permeameters were available in the laboratory, hydration durations were chosen as 7 days and 62 days for these samples to represent the short and long term hydration performances of the GCLs. There were no significant changes in the GCL hydration profiles while changing the subsoil height from 5.9 to 11.6 or 17.4 (Figure 3).

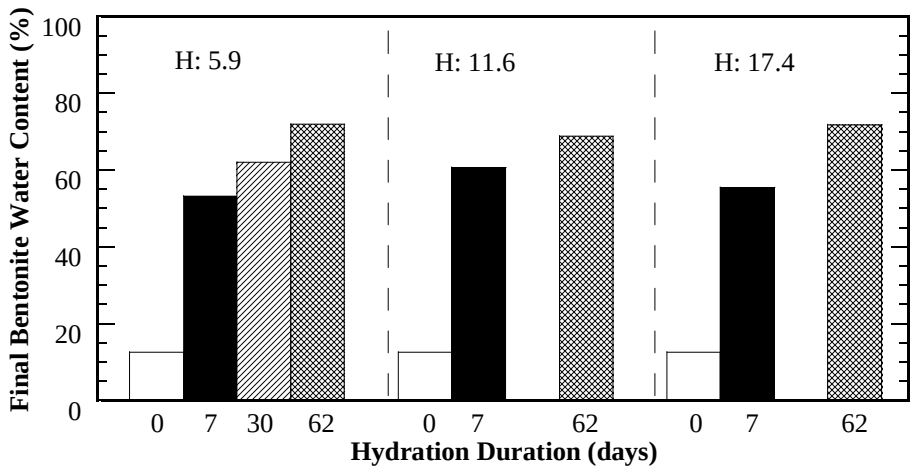

Figure 3 Influence of hydration duration on the final bentonite water contents.

The comparison of the final GCL water contents as a function of subsoil height is shown in Figure 4. In the case of 7 days of hydration, the final bentonite water content from H: 5.9 cm was less than that from H: 11.6 cm (53.1% vs. 60.6%). However, the final bentonite water content decreased to 55.4% when the subsoil height was increased to 17.4. The water content differences were 7.5% at most. In contrast, the final bentonite water contents changed rather negligibly in the case of 62 days of hydration. At this time, the final bentonite water content at H: 11.6 cm was less than those of at H: 5.9 cm and H: 17.4 cm. The differences in the water contents were around 3.2% depending on the subsoil heights.

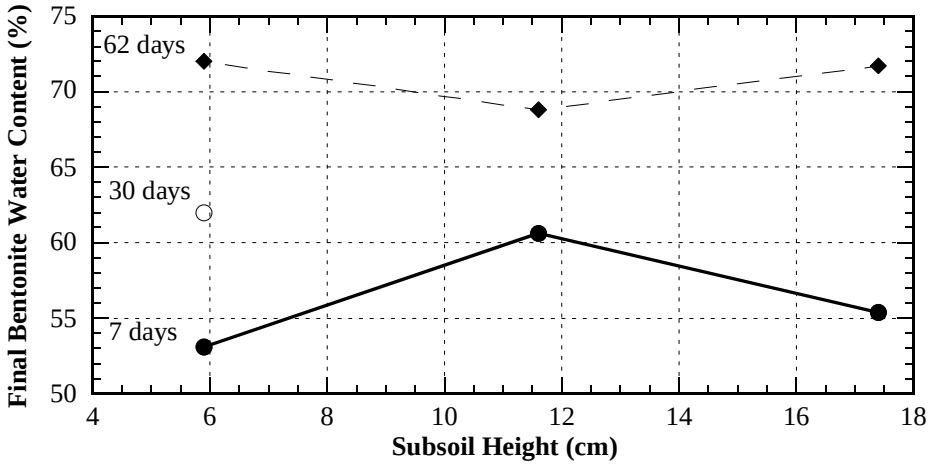

Figure 4 Influence of the subsoil height (H) on the final bentonite water content

The reason of these differences may possibly be resulted from small deviations in the subsoil initial compaction water contents. Thus, subsoils were divided into sub-layers (4 to 7 layers) after hydration so as to determine the water content changes across the soil profiles (Figure 5). Note that the water contents in Figure 5 are shown from the midpoints of the sub-layers. The water content profiles of the subsoils are demonstrated in two ways. In the first demonstration (Figure 5a and Figure 5c), final subsoil water contents are drawn by considering the actual sample heights. In the second demonstration, subsoil heights are normalized by dividing the sub-layer height to corresponding subsoil height (Figure 5b and Figure 5d).

Regardless of the hydration duration and subsoil height, general tendency of water content distribution across the subsoils were the same. That is, water content of the subsoil decreased in the first layer where GCL was overlying the subsoil. This reduction in the water content can be attributed to the high suction potential of bentonite. In the proceeding layers, water contents of the subsoil slightly increased but still almost the same with the initial compaction water content. The migration of the pore water due to gravity led to have greater water contents through the bottom of the samples (Chevrier et al., 2012; Barclay and Rayhani 2013).

In contrast, although the tendency of water content distribution is the same for all subsoils, the water content profiles are somewhat different within each other. There are small differences in the initial compaction water contents of the subsoils. However, these differences are being more pronounced in the proceeding layers. In other words, water content profiles are apart from each other but almost parallel within each other. Thus, the differences in the final bentonite water contents of GCLs can be attributed not only to the initial compaction water content of subsoil, but also to the height of the subsoil. Thus, subsoil

height can be accepted as one of an important factor that influences the hydration of GCLs while performing such tests in the laboratory.

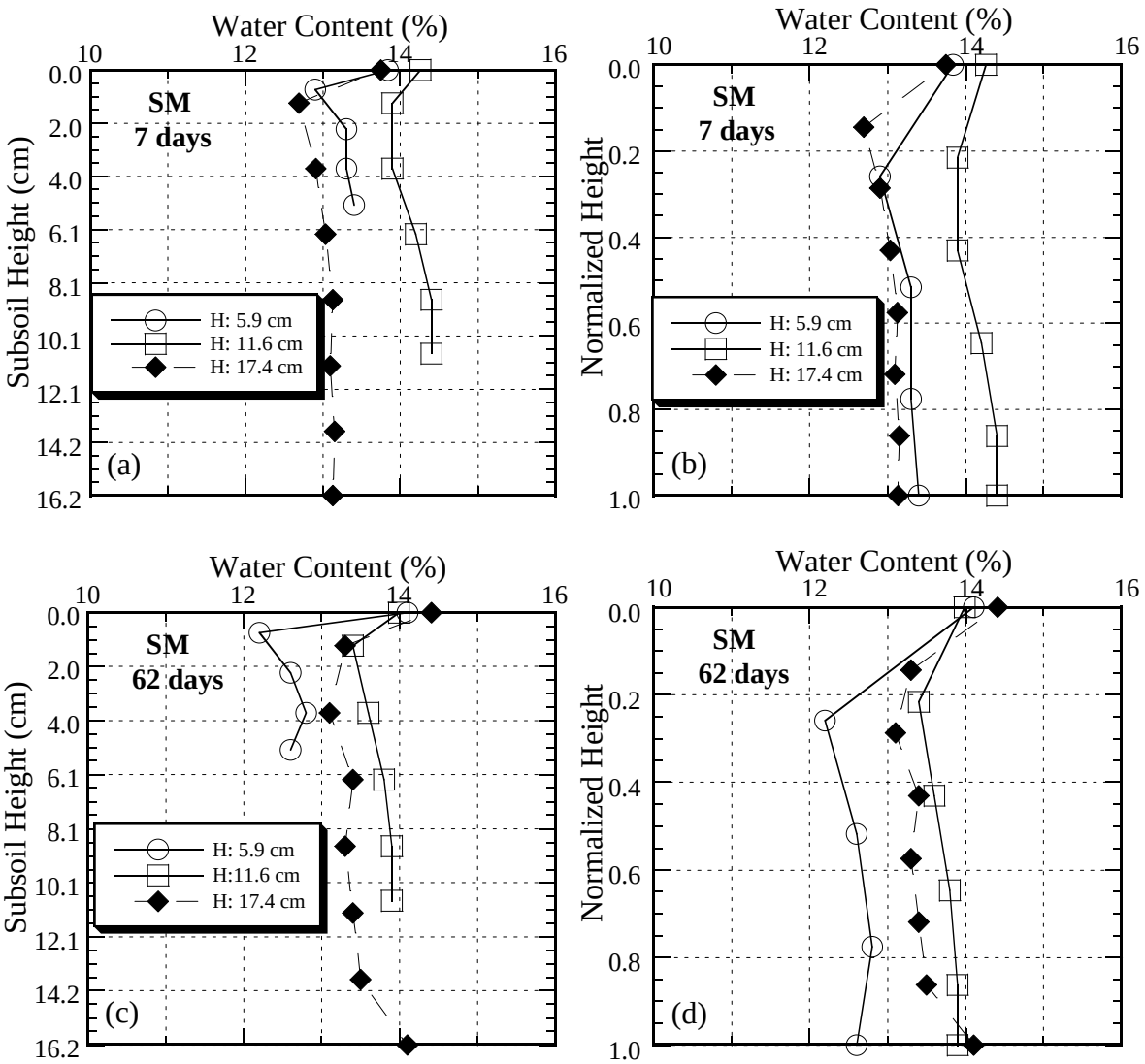

Figure 5 Water content distributions across the subsoil in terms of: a) total height and b) normalized height for 7 days of hydration; c) total height and d) normalized height for 62 days of hydration.

4 CONCLUSIONS

In the content of this study, the influence of the subsoil height on GCL water uptake was investigated. The summary of the results are given below:

- The water content of GCL bentonite increased when the hydration duration was increased at each subsoil height conditions.
- The impact of subsoil height on the final bentonite water contents is more pronounced at lower hydration duration (i.e. 7 days). Depending on the subsoil heights, the differences between the final bentonite water contents were about 7.5%. This influence is less pronounced when the hydration duration was 62 days where the

difference in the final bentonite water contents reduced to 3.2%. These differences possibly resulted from the initial water content conditions of the subsoils.

- Subsoil height has significant effect on the subsoil water content profile. Although water content distributions across the subsoils were the same regardless of hydration duration and subsoil height, the subsoil water content profiles were apart from each other. This can be attributed not only to the small deviations in the initial compaction water contents but also to the height of the subsoils.

REFERENCES

Anderson, R., Rayhani, M. T. and Rowe, R. K. (2012), Laboratory Investigation of GCL Hydration from Clayey Sand Subsoils, Geotextiles and Geomembranes, 31, 31-38.

Barclay, A. and Rayhani M.T. (2013), Effect of Temperature on Hydration of Geosynthetic Clay Liners in Landfills, Waste Management & Research, 31 (3), 265–72.

Bradshaw, S.L., Benson and C.H., Scalia, J. (2013) Cation exchange during subgrade hydration and effect on hydraulic conductivity of Geosynthetic clay liners, Journal of Geotechnical and Geoenvironmental Engineering, 139 (4), 526-538.

Bouazza, A. (2002). Geosynthetic clay liners. *Geotextiles and Geomembranes, 20*, 3-17.

Chevrier, B., Cazaux, D., Didier, G., Gamet, M. and Guyonnet, D. (2012), Influence of Subgrade, Temperature and Confining Pressure on GCL Hydration, Geotextiles and Geomembranes, 33, 1-6.

Jo, H. Y., Katsumi, T., Benson, C. H. and Edil, T. B. (2001). Hydraulic conductivity and swelling of nonprehydrated GCLs permeated with single-species salt solutions. *Journal of Geotechnical and Geoenvironmental Engineering, 127 (7),* 557-567.

Jo, H. Y., Benson, C. H., Shackelford, C. D., Lee, J. M. and Edil, T. B. (2005). Long-term hydraulic conductivity of a geosynthetic clay liner permeated with inorganic salt solutions. *Journal of Geotechnical and Geoenvironmental Engineering, 131 (4),* 405-417.

Katsumi, T., Ishimori, H., Ogawa, A., Maruyama, S. and Fukagawa, R. (2008). Effects of water content distribution on hydraulic conductivity of prehydrated GCLs against calcium chloride solutions. *Soils and Foundations, 48 (3),* 407-417.

Lee, J-M. and Shackelford, C.D. (2005). "Impact of bentonite quality on hydraulic conductivity of geosynthetic clay liners." *Journal of Geotechnical and Geoenvironmental Engineering, 131 (1):* 64–77.

Meer, S.R. and Benson, C.H. (2007). Hydraulic conductivity of geosynthetic clay liners exhumed from landfill final covers. *Journal of Geotechnical and Geoenvironmental Engineering, 133 (5),* 550-563.

Rayhani, M.T., Rowe, R.K., Brachman, R.W. and Take, W.A., Siemens, G. (2011), Factors Affecting GCL Hydration Under Isothermal Conditions, Geotextiles and Geomembranes, 29 (6): 525–533.

Rowe, R.K. and Abdelatty, K. (2012), Effect of Calcium rich soil on the performance of an overlaying GCL. *Journal of Geotechnical and Geoenvironmental Engineering, 183 (4),* 423-431.

Sarabian, T. and Rayhani, M.T. (2013), Hydration of Geosynthetic Clay Liners from Clay Subsoil Under Simulated Field Conditions, Waste Management, 33 (1): 67–73.

Scalia, J. and Benson, C.H. (2011). Preferential flow in geosynthetic clay liners exhumed from final covers with composite barriers. *Canadian Geotechnical Journal, 47*: 1101-1111.

Shan, H.Y. and Lai, Y.J. (2002). Effect of hydrating liquid on the hydraulic properties of geosynthetic clay liners. *Geotextiles and Geomembranes, 20 :* 19–38.