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Influence of subgrade, temperature and confining pressure on GCL hydration

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ABSTRACT

Geosynthetic Clay Liners (GCLs) are often used in waste disposal facilities. In order to act as a barrier as cover or bottom liner, GCLs must hydrate and swell under a confining pressure. According to the French Committee for Geosynthetics (Fascicule n 12, 1998), the gravimetric water content of the bentonite must be at least 100%. GCLs are commonly installed at their initial bentonite water content (around 10–15%), for practical reasons and ease of installation. Therefore, the duration of the hydration period (vapour and liquid migration from the subgrade) appears to be an important issue in terms of confining performance. This question was addressed during laboratory and field experiments performed on a natural sodium bentonite GCL and aimed at examining the influence of several parameters: subgrade (sand versus clay), temperature and confining pressure.

Results illustrate the high influence of the subgrade permeability and water content on the bentonite final water content level and hydration kinetic. As could be expected, sandy soils allow a faster hydration and higher water content than clayey soils for a same period of observation. The hydration rate and the final gravimetric water content at equilibrium both increase significantly when temperature rises. But a low temperature, such as tested during the experiments (5 °C), drastically slows down the rate of hydration but also the final water content, whatever the material. The vertical stress also appears to influence the hydration rate by providing a better contact between the GCML and the soil. The water content at equilibrium appears to be not improved by that confining stress whatever the materials and the temperature.

1. Introduction

Geosynthetic Clay Liners (GCLs) are used in landfill liner systems in bottom, slope or cover applications. In order to fulfil their sealing function, GCLs need to be confined under normal stress and hydrated with water in order to achieve very low hydraulic conductivities. Initial hydration, with a non-chemically aggressive hydration fluid, is particularly important in order to confer the hydraulic performances of the GCLs subjected to a prolonged contact with leachate (von Maubeuge, 1995; Ruhl and Daniel, 1997; Didier and Comeaga, 1997; Shackelford et al., 2000; Guyonnet et al., 2005). Indeed, the most detrimental situation for a GCL used in a landfill bottom liner system would be a direct contact with landfill leachate (Guyonnet et al., 2005; Rowe, 2007) before enough hydration has operated. Several methods for achieving this initial hydration are possible. An active wetting process can be ensured by rainfall or controlled moistening before or after installation of the confining layer. But if GCLs are installed at their initial bentonite gravimetric water content (typically 10–15%) and then covered by a geomembrane, as is the most common practice, there is a passive hydration of bentonite by water vapour transfer from the subgrade to the bentonite (Kröhn, 2005; Rowe, 2007).

Although GCL water content is known as an important parameter for its hydraulic behaviour, only a few studies have been performed on the hydration process and its influencing parameters. Among the available studies, Eberle and von Maubeuge (1997) show that the gravimetric water content of a given, initially dry, GCL placed on a 10% wetted sand is 100% after 24 days, and 140% after 60 days. For Rayhani et al. (2011), the water content of several GCL samples placed on a 16% wetted silty-sand reaches 88–104% within 6–22 weeks, depending on GCL manufacturing. In the case of a landfill bottom liner, hydration rate is one also an important parameter. Rayhani et al. (2011), show that, for the first 6 weeks of tests, hydration rate is quite similar for all GCL samples,

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Table 1
Cation exchange capacity and cation concentration of bentonite (meq/100 g).

CEC	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}
75.5	16.7	54.6	10.0	1.5

Table 2
Geotechnical properties of bentonite.

Plastic limit (%)	Dry density	Specific gravity	Optimum dry density	Optimum gravimetric water content (%)
34	1.14–1.35	2.64	1.55	23.5

but a vertical load of 2 kPa accelerates hydration rate of bentonite because of a better contact between the geosynthetic and the material.

In this paper we present the results of several series of tests performed to determine the stabilised water contents and hydration rates of a GCL in contact with various subgrades. The study addresses the influence of soil water content and grain size, confining pressure and ambient temperature. Experiments were performed in the laboratory and at a field scale in order to reproduce a real outside conditions.

2. Material properties

2.1. Geosynthetic clay liner

The GCL tested in this study is a needle punched GCL containing 4.80 or 5.90 kg/m^2 of a granular natural sodium bentonite encapsulated between a 200 g/m^2 bottom non-woven polypropylene carrier geotextile and a 100 g/m^2 top polypropylene woven geotextile. Geotextile fabrics connection is needle punched and not thermally treated. Swell index of the bentonite is 24 ml/2 g, initial average grain size is 1 mm. Cation exchange capacity (CEC) and exchangeable cations concentrations of the bentonite of GCL are summarised in Table 1, geotechnical properties are shown in Table 2.

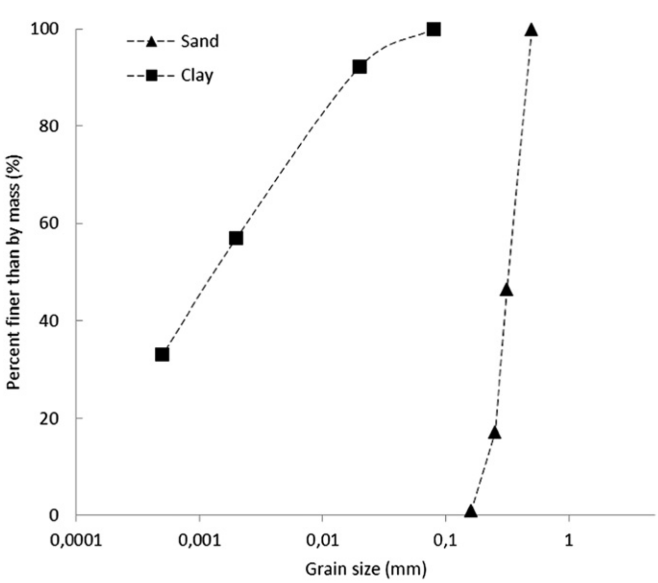

Fig. 1. Grain size distributions for subgrades examined.

Table 3
Cation concentration in subgrade hydration water.

Cation	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}
Concentration (mg/l)	61.9	12.2	5.7	3.8

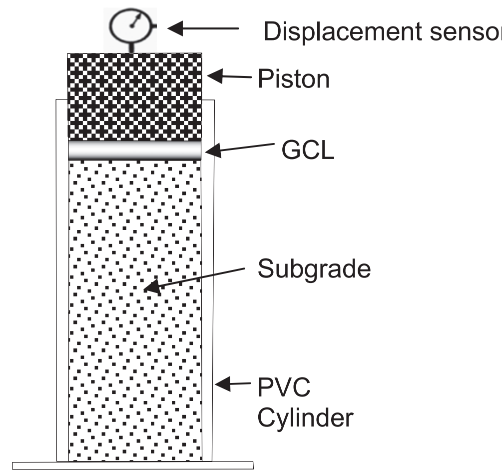

Fig. 2. Apparatus for monitoring the water content in GCL in equilibrium with the subgrade.

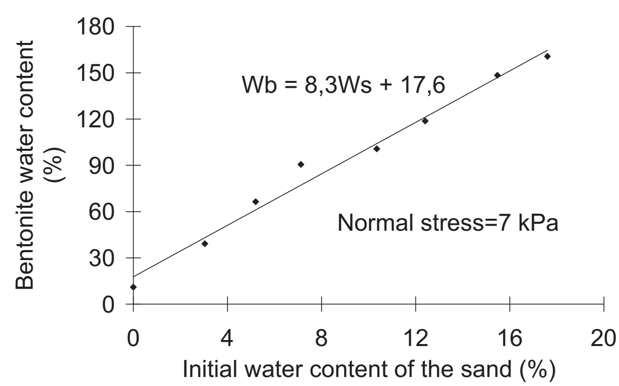

Fig. 3. Final water content of the bentonite (w_b) versus initial water content of the sand (w_s).

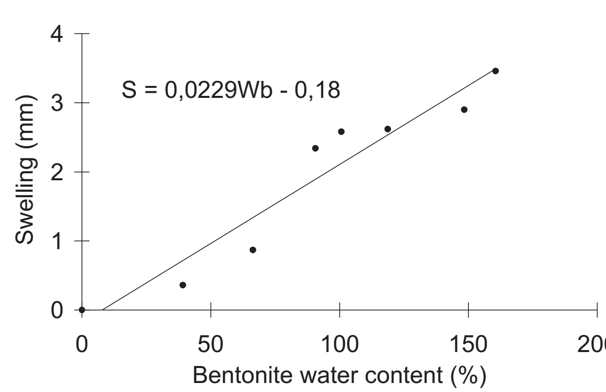

Fig. 4. Swelling (S) versus water content of the bentonite (w_b).