Geotextiles and Geomembranes 44 (2016) 515–533

Contents lists available at ScienceDirect

Geotextiles and Geomembranes

journal homepage: www.elsevier.com/locate/geotexmem

Performance of geotextile filters after 18 years' service in drainage trenches

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A R T I C L E I N F O

Article history:
Received 6 September 2014
Received in revised form
19 January 2016
Accepted 15 February 2016
Available online 19 March 2016

Keywords:
Geosynthetics
Geotextile filter
Drainage trenches
Hydraulic properties
Mechanical properties
Chemical clogging

A B S T R A C T

This study evaluates the long-term performance of two types of geotextiles that were used for 18 years in drainage trenches to stabilize slopes in the French Alps. The flow rate analysis of each trench enabled estimating an average permittivity at trench scale of between 10^{-5} and 10^{-6} s^{-1}. After exhuming the geotextiles, their hydraulic and mechanical properties were assessed. The hydraulic tests performed on geotextiles alone gave permittivities greater than 10^{-3} s^{-1}. Gradient ratio tests were performed on undisturbed soil/geotextile/drainage specimens and gave results in the order of 10^{-8} s^{-1}. The aged specimens were examined using scanning electron microscopy. Quantifying the overall performance of the geotextile filter is complicated because of the brittleness of the calcite crust and the subsequent difficulty of characterizing undisturbed interfaces. Various possible explanatory mechanisms involved in the deterioration of trench performance were reviewed: filter cake blinding, internal clogging and downstream chemical clogging. Existing analytical models were used in order to predict the loss of hydraulic performance due to each of these clogging mechanisms. By comparing the measured permittivities to the calculated permittivities, we demonstrated that chemical clogging due to calcite precipitation on the downstream face of the geotextiles was probably the preponderant mechanism responsible for the poorer performance of geotextile filters at trench scale.

1. Introduction

Geotextiles are used worldwide in geotechnical and geoenvironmental works for filtration in drainage systems. The performance of geotextiles has been demonstrated in classical geotechnical applications by many authors (Giroud, 1982; Leflaive, 1988; Gourc and Faure, 1990; Bhatia et al., 1991; Fannin et al., 1994; Lafleur, 1999; Palmeira and Gardoni, 2000; Narejo, 2003; Palmeira et al., 2010). In particular, geotextiles are known to be an effective alternative to conventional granular filters, particularly in regions where granular materials are not available (Degoutte, 1987; Christopher and Fischer, 1992; Giroud, 1996). However, whether geotextiles can guarantee the long-term durability of installations such as hydraulic structures or drainage systems remains to be demonstrated.

The durability of geotextile filters is related to variations in the properties that allow them to perform one or more of the following functions: separation, reinforcement, filtration, drainage, protection (Koerner, 1994). Methods are now available to evaluate the durability of geotextiles in terms of the durability of their constituent fibers, which may be altered by physicochemical reactions (Cassidy et al., 1990; Mathur et al., 1994; Duvall, 1995; Hsuan et al., 2008; Van Schoors et al., 2009). However, even if the geotextile fibers themselves are undamaged, the performance of geotextile filters may be reduced in terms of filtration and flow capacities.

The main mechanism affecting the durability of geotextile filters used in drainage systems is clogging, which occurs on the scale of the entire geotextile filter. A geotextile filter is composed not only of the geotextile itself but also includes the interface between the geotextile and the natural soil (filter cake or bridge) and between the geotextile and the drainage material (downstream crust). A

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http://dx.doi.org/10.1016/j.geotexmem.2016.02.002
0266-1144/

geotextile filter should thus be considered as a filtering zone that evolves over time (see Fig. 1), and its clogging can be caused by physical, biological, and/or chemical processes (Koerner et al., 1988; Rollin and Lombard, 1988).

The mechanism behind physical clogging is the accumulation of fine particles within the geotextile or upstream of the geotextile filter (Giroud, 1996; Palmeira and Gardoni, 2000). Internal physical clogging results from the accumulation of material within the voids between the geotextile fibers. The subsequent decrease in effective porosity and in the interconnectedness of the pore network reduces the hydraulic conductivity of the geotextile, which may reduce filtering and draining efficiency. External physical clogging, or “blinding” as described by Faure and Fry (2004), is caused by the formation of a granular filter cake (or filter bridge) upstream of the geotextile, which may progressively clog the geotextile by retaining increasingly finer particles (Christopher and Fischer, 1992). Intensive research on this phenomenon led to the development of models (Faure et al., 2006) and standardized tests (Luettich et al., 1992; Mlynarek, 1998). The design guidelines are generally based on empirical approaches and are expressed in terms of retention and permeability criteria (Christopher and Fischer, 1992; Heerten, 1993; Lafleur et al., 1992; Giroud, 1996; Lafleur, 1999). Applying these methods requires assessing the properties of the filtrated soil or bedding material (Giroud et al., 1990; Wu et al., 2006; Palmeira et al., 2012) and examining in situ conditions such as confining stress (Palmeira and Gardoni, 2002). However, although the physical clogging of geotextiles can significantly degrade the hydraulic performance of drainage systems, their drainage and filtration properties generally remain acceptable. For example, Faure et al. (1999) filter geotextiles used for 21 years in the Valcros embankment dam (France) were exhumed and studied. The authors main conclusion was that the geotextile properties had not been significantly altered. The most severe degradation in mechanical performance had occurred when installing the geotextile and biochemical effects were negligible. Despite particle impregnation ranging from 15% to 30%, the geotextile still performed its filtration and drainage functions.

Biological clogging requires very specific physicochemical conditions in terms of temperature, alkalinity (Halse et al., 1987), and concentrations of minerals and organic substances (Fleming and Rowe, 2004). Extensive analysis of the mechanisms involved has led to the identification of the relevant parameters and to models of the physicochemical processes (Cooke et al., 1999; Cooke and Rowe, 2008; Yu and Rowe, 2012). Geotextile clogging seems to occur with the following stages: formation of surface biofilms, generation of slimes, and the growth and interconnection of bioconcretions. These structures can be stabilized by the precipitation of low-solubility sulfide and carbonate minerals, and the subsequent decrease in the geotextiles porosity is accelerated by the entrapment of fine particles from the soil being drained (Rowe, 2005; Rowe and Yu, 2010). For geotextiles used in leachate-collection systems, field studies (Koerner and Koerner, 1995; Junqueira et al., 2006; Fleming et al., 2010) and laboratory experiments (Koerner and Koerner, 1992; Mendonca and Ehrlich, 2006; Palmeira et al., 2008) demonstrated the importance of biological clogging in the degradation of drainage systems, showing that this type of clogging is a major concern for drainage in leachate-collection systems. However, in conventional drainage systems, organic acids in water are generally present only at low concentrations, so biological clogging is not expected to be a significant factor.

Very few full-scale experiments or field studies have found chemical clogging of geotextile filters to be a determining phenomenon. McIsaac and Rowe (2006) simulated full-scale collection systems permeated with real municipal solid-waste leachate. They allowed these systems to evolve for six years and studied how different filter designs influenced the clogging process and the extent of clogging under full-scale and real-time conditions. Based on laboratory measurements and microscopic-scale analyses, they showed that the clogging of nonwoven needle-punched geotextiles was primarily due to the development of chemical clogs within the fibrous structure of the geotextile and that the loss of hydraulic conductivity (more than 90%) did not cause leachate ponding. Testemale et al. (1999) studied the geotextile installed between the original embankment and the downstream reinforcement berm at

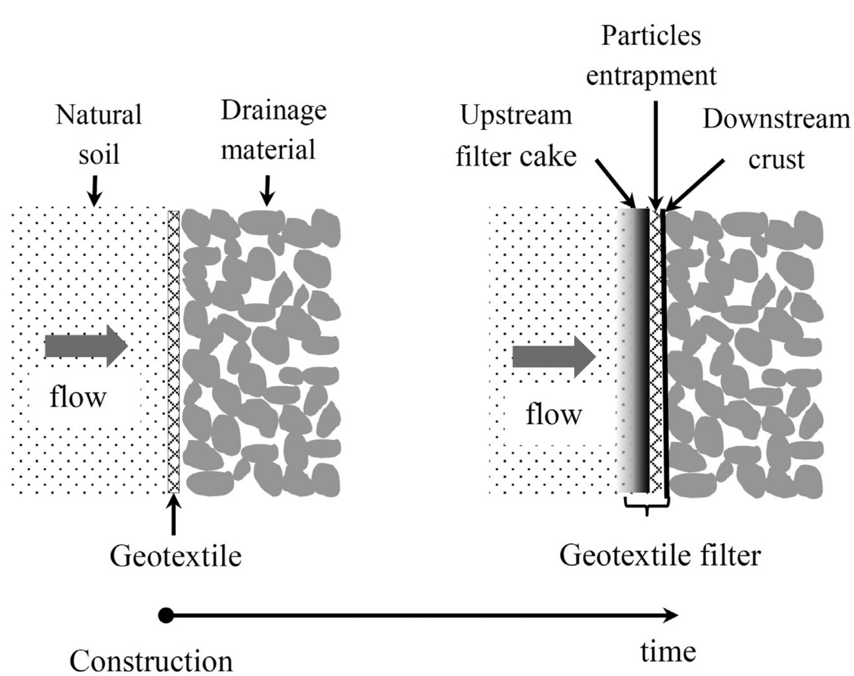

Fig. 1. Evolution of the geotextile filter structure over time.