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Durability based on resistance tests of geosynthetics submerged in a sulphurous environment

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ABSTRACT: In the present paper the results of the tensile and static puncture tests are shown and discussed. The tests have been applied to three different types of geotextiles (i.e. mechanical, chemical and thermal binding geotextiles) and to a geomembrane type HDPE, considering the fact that the samples had been submerged into running (rw) and still stagnant (sw) sulphurous water for a period of eight months. This procedure was undertaken to test the stability of these materials in the course of time. The final results are then compared to those obtained by the examination of properly stored samples, paying close attention to the chemical composition of the spring water, whether in the case of young or aged water, with or without contact with the geosynthetics. Finally, another issue that is referred concerns to the possible contamination of the spring water as a consequence of the eventual geosynthetic degradation.

1 INTRODUCTION

The geosynthetics, when used in structures of environmental character, may undergo changes in their resistance, especially if they are used in chemically very hostile environments. In Portugal there are many Medical SPA that use sulphurous mineral water obtained from deep wells and whose water quality needs to be preserved. To ensure that the water of the aquifer is not going to be polluted, there has been the necessity of carrying out drainage actions, eventually using geotextiles, to intersect the resurgence of sulphurous mineral water, so that the nearest areas could be kept dry or without any humidity excess. So, it is being prevented the development of situations that might lead to the contamination of the aquifer. The act of placing waterproof canvas, such as the geomembranes, in areas likely to be polluted to prevent the contact among the different superficial fluids and the mineral water, is becoming a common practice. It is necessary to check the way how the geosynthetics behave in these hostile environments in the course of time without harming the quality of the mineral water. If there is any alteration in the geosynthetics, the mineral water may be contaminated and, therefore, the medical spa activity could be jeopardized. The detection of changes in the resistance of the geosynthetics works as valuable indicators of the stability of these materials in the course of time.

2 MATERIALS AND METHODS

The studied geotextiles belong to a nonwoven type and three different types are used, i.e. a geotextile mechanically bonded (A), a geotextile chemically bonded (Q) and a geotextile thermically bonded (T).

The geotextiles A and Q are made of polyester and polypropylene respectively, whereas the geotextile T is made of 15% polypropylene and 85% recycled textile waste, essentially polyester, cotton and wood. The studied geomembrane is made of polyethylene of high density and smooth surface type (HDPE). The mineral water used in this research comes from the Medical SPA located in Unhais da Serra (Portugal).

To carry out this research, the geosynthetics had to be previously cut in specimens (each one with the suitable dimension to fit the purpose of the tests), that can be divided in three groups according to the following criteria:

(i) specimens submerged in vats with mineral water without circulation (stagnant water – **sw**), at a constant temperature of 20°C, inside the laboratory;

(ii) specimens submerged in vats with running water (running water – **rw**), at a natural temperature of 37°C, in the area close to the spring of the Medical SPA, inside a shack that had been especially designed to suit the referred purpose (Figure 1);

(iii) specimens properly stored, protected from any action that might alter their quality, i.e., a shadowy

Figure 1. (a) Geosynthetics in vats with running sulphurous water, near the collecting zone in Unhais da Serra Medical SPA. (b) A close detail of the white residue referred in (a); the white residue (biojelly) correspond to a typical natural product in this situation.

place, protected from light, humidity and dust, at about a temperature of 20°C.

The reason why the specimens have been studied only after having been submerged in vats with sulphurous water is that it is necessary to assess what may happen, in terms of the chemical alteration of the water, after it had been in contact with the geotextiles. In Nature there is a continuous movement of the underground water, as it is usual in a leaky artesian aquifer, such as the current situation, with a permeability coefficient of 2.3 to 3.1 m/day (Ferreira Gomes and Machado Saraiva, 1977). When the water is circulating, and due to its continuous renovation, it is difficult to detect chemical changes in it. Anyway, it can be admitted that the reactive power of the sulphurous water in continuous renovation might be much greater than that of the stagnant sulphurous water; that is the reason why the research was carried out under those conditions.

The specimens (i) and (ii) have been tested for 6 continuous months and on the 8th month. After the samples had been taken off from the vats, they were placed in a shadowy, dry and ventilated place inside the laboratory for a single day; afterwards they were placed for two more days in a ventilated oven at 22ºC. The specimens (iii) were just tested in the beginning, in the middle and at the end of the study, so that their results could be used as a reference.

The tests carried out on the geosynthetics, whose results are shown in this paper, were the following: mass per unit area (EN 965, 1995), static puncture test, CBR-test (EN ISO 10319 (1996), and wide-width tensile test (EN ISO 10319, 1996).

In relation to the mineral water, classic physical and chemical tests were carried out (Riscado Santos et al., 2002), in the following situations: (1) young water, (2) aged water after having been in contact with the samples of the geosynthetics and also in situation (3) aged water without contact with the samples of the geosynthetics, so that the results could be used as a reference. In nature these waters usually show a pH > 7, SiO_2 > 10% (in relation to the total mineral contents), F^- > 5 mg/l, reduced forms of sulphur not too stable (HS^- and $S_2\ O_3^{2-}$), and the presence of HCO_3^- and Na^+, respectively, as dominant anion and cation. There are also other important elements, such as Cl^-, SO_4^{2-} , CO_3^{2-} and $H_3SiO_4^-$ on anions, and Ca^{2+}, K^+, Mg^{2+}, and Li^+ on cations. Some gases like CO_2 and ^{222}Rn, and some other minor elements like Mn^{2+}, Br^{2-}, B_3O_3,W, Zn, Sb, and Mo are also present. It must be emphasised that this type of water, when in continuous circulation, tends to form a whitish gelatinous residue (biojelly) which is typical of sulphurous waters (Figure 1).

3 RESULTS AND INTERPRETATION

The results obtained in the tests of mass per unit area, static puncture test and wide-width tensile test, in terms of mass per unit area (μ_A), maximum plunger force (F_p) and tensile strength (α_f), respectively, in specimens kept in a dry environment, are shown in Table 1. It must be emphasised that these results were obtained in three tests (months 0, 4th and 8th).

Table 1. Results obtained from physical and mechanical tests of geosynthetics in a dry environment in terms of average values.

Geosynthetics	μ_A - (g/m^2)	F_p (kN)	α_f (kN/m)
Geotextile A	157.76	1.53	6.81
Geotextile Q	158.95	2.10	8.92
Geotextile T	595.25	0.26	2.08
Geomembrane G	979.05	3.13	19.11

The results of the several tests, relatively to running water (rw) and stagnant water (sw), carried out throughout the 8 months are illustrated in Figure 2.

From the results obtained for the mass per unit area it can be taken the general notion that in the environments rw and sw, this parameter generally decreases throughout the eight months for the majority of the geosynthetics, being the geomembrane an exception. Anyway, the situation that arises from the development of the referred biojelly on the geosynthetics makes the evolution of μ_A vary in different tendencies in the course of time.

The residues became well visible in the rw environment, mainly from the 5th month onwards. In the sw environment the appearance of the biojelly was much lighter.

This situation has been analysed in detail in Riscado Santos et al. (2002), when the evolution of the permeability throughout the time was presented in relation to the same materials as those studied in this research. In that paper it has been clearly shown that the permeability of the geosynthetics has increased during the first five months, which can be attributed to the degradation of these materials due to the contact with sulphurous water, but after the biojelly has been detected, the geotextiles became obstructed, occurring something like a compensation relatively to the mass per unit area, although generically the degradation went on.

Through the static puncture tests it can be emphasised the particularity that all results of the submerged geomembranes show values of F_p always inferior to those carried out in a dry environment. Throughout the time there is a clear tendency of the F_p for the geomembrane and for the geotextile Q to decrease, either in stagnant or running water. Based on the equations of the variation of F_p occurred throughout the time, it can be testified a loss in the resistance of the geomembrane of about 1.0% a month, either in sw or rw, and 0.5% and 1.4% for the geotextile Q, respectively in a rw and a sw environment. The geotextiles A and T do not show a so significant degradation as the other materials; in particular the geotextile A shows some kind of stability and even a slight improvement in its resistance; such situation is believed to result from the effect of the biojelly that not only sticks to the geosynthetics but also reinforces the bonds between the fibres.

Relatively to the results of the tensile tests, a slight parallelism can be established with what happens in terms of F_p, i.e., there is a general tendency for α_f to decrease in the course of time, being this situation more significant on the geosynthetics G and Q. It can be detected a decrease of 2.3% a month in G in a rw environment and of 1.4% a month in T in a sw environment. The geosynthetics Q and T show a better stability than G and Q, with a very low degradation and even a tendency to improve their resistance due to the effect of the biojelly referred above.

In what concerns the results of the physical and chemical analysis of the mineral water, it can be said that there are significant differences between the results of the young and of the aged water, even when the latter is not in touch with the geosynthetics. Those results have been studied by Riscado dos Santos et al. (2002) and the main conclusions are presented in this paper. Considering the several parameters analysed, the aged water increases its total mineralization, mainly when it is in contact with the geotextile T (highly significant), followed by Q, A, and finally by G. A similar situation occurs with the conductivity, that shows a higher amount in the aged waters with the geotextile T, followed by Q, A, and finally by G.

In relation to the ions of the main elements, the major alterations are found in the aged waters with the geotextile T, being relevant the increase of HCO_3^-, Ca^{2+}, Cl^-, F^-, Na^+ and K^+, in addition to a highly significant decrease of SO_4^{2-}. In the other

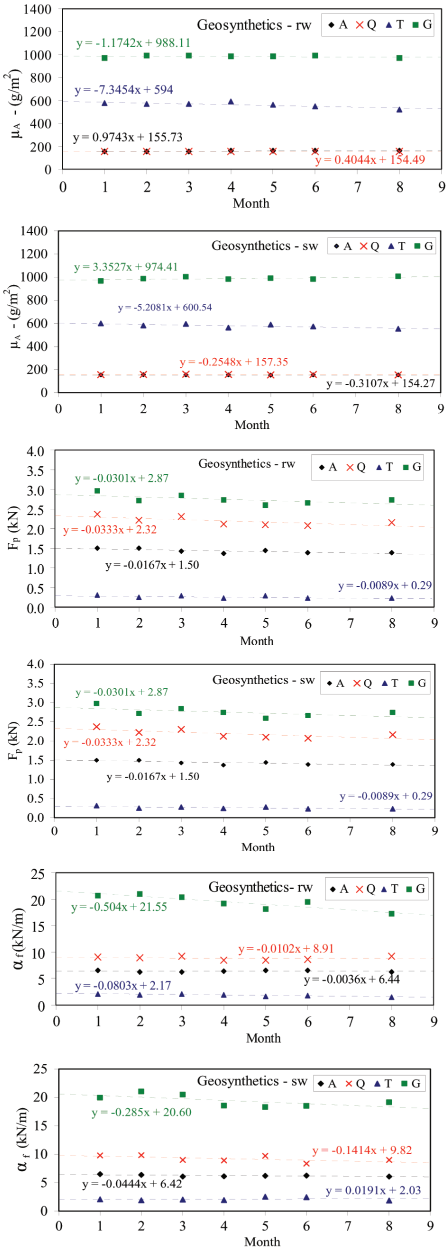

Figure 2. Results of mass per unit area (μ_A), maximum plunger force (F_p) and tensile strength (α_f), of geosynthetics tests, in running water environment (rw) and stagnant water environment (sw), for a period 8 months.

geosynthetics it is interesting to confirm the increase of SO_4^{2-} in the whole of the aged waters, with a higher significance on the geotextile Q. Increased emphasis should be placed on the fact that the aged water with the geotextile Q shows quite a relative increase of Ca^{2+} and Li^{+}, moreover, the anion NO_3^- was present in the waters with the geotextile A and with the geomembrane. Finally, it must be emphasised that Fe^{2+} shows an increase on geotextiles A, Q and especially on T.

4 CONCLUSIONS

The following conclusions could be drawn from the present study:

(i) Throughout the entire research and in particular after the first four months, it was quite visible, within the rw environment, the appearance of a whitish jelly residue (biojelly), not expected at first, that stuck itself on the surface of the geomembrane and of the chemical textile, as well as inside the structure of the thermal bonded and needled geotextile, mainly in this last one.

(ii) The analysis of the values of the mass per unit area shows that in the majority of the situations the geosynthetics, particularly the geotextiles, have lower mass per area values during the first months; this situation becomes clearer when it is analysed in terms of the permeability indexes that had been carried out in previous studies. This fact allows us conclude that due to the aggressiveness of the water in an early stage, the mineral water makes the geotextiles more permeable. However, this tendency is reversed after a certain amount of time due to the appearance of the biojelly, which besides clogging the geotextiles externally, acts also internally and as a consequence they become denser.

(iii) Relatively to the mechanical tests, it can be confirmed that the mineral water affects the resistance of some geosynthetics; the tendency to decrease the resistance throughout the time is stronger in the geomembrane and in the geotextile Q, being it more evident in a sw environment; in a rw environment the situation is not so serious, with the particularity that the geotextiles with the mechanical bonding keep a reasonable stability, becoming even more resistant in the course of time.

(iv) It is important to emphasise the fact that both the geomembrane and the chemical geotextile, when submerged in mineral sulphurous water, have lost resistance in the static puncture tests (F_p) by 1.0% and 1.4% a month respectively. From the moment of the tensile test onwards the degradation level was even more significant. The resistance to traction (α_f) kept decreasing both in the geomembrane and in the chemical geotextile at a pace of 2.3% and 1.4% a month respectively. These results point out to a complete loss of resistance in a period of 4 years (traction) and 9 years (puncture) for the geomembranes and 6 years (traction and puncture) in the case of the chemical geotextile.

(v) Regarding the physical-chemical analysis of the mineral water, after comparing the results of the young and the aged water, it could be concluded that there are significant changes in the chemism of the waters, particularly with the appearance of nitrate in the aged waters when in touch with some geosynthetics (G and A). If that situation happened in a medical spa, it would be an indicator that the mineral water was polluted. However, it is necessary to carry out a more detailed research, especially taking into account the minor elements as well as the heavy metals and other products like hydrocarbons, to clarify all aspects that might be involved in the degradation of the geosynthetics.

The results obtained justify a deeper study about the durability of the geosynthetics. Moreover, only a small variety of materials have been used in this research. The thermal binding geotextile used in this study has been an attempt to test recyclable materials, for this reason the conclusions should not be taken as universal or definitive.

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