# Reclamation of an old landfill site using geo-synthetic materials

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ABSTRACT: Some significant results coming from investigations on the possibility of reclaiming with vegetal soil a damaged lining system of an old MSW landfill are hereinafter referred. The lining system was damaged by strong and concentrated rainfall and by consequent nearby river flood. The lining system and slope reinforcement system are described as well the damages caused by the rainfall events. The properties of the vegetal soil are described as well as the works carried out to minimize slope erosion and creeping before the complete taking root of the vegetation cover.

## 1 INTRODUCTION

The old landfill, located in north-eastern Italy, extends over a surface of about 5 ha, with slope steepness up to 35° and height reaching 15 m. The morphology of the slopes is variable from continuous to intermediate terraced slope. The reclamation design foresaw the following operations on the slopes of the old landfill:

1. Laying of polyethylene filaments geocomposite for the drain-age of the leachate escaping from the slopes.
2. Base drain with HDPE pipe, DN 90, from 0.5 to 1.8 $m^2$/m, filled up with 16-64 mm gravel.
3. Waterproofing with HDPE rough membrane, 1.5 mm thick.
4. Reinforcement layer consisting of two welded, jointly liable elements: a filtering welded nonwoven and a high cell-like index 3D-structure made up of HDPE filaments. The layer is designed to support a vegetal soil cover with a minimum thickness of 0.30 m.
5. Filling with vegetal soil, 0.30 m thick; slope hydroseeding.

## 2 CONDITIONS AFTER STRONG RAINFALL EVENTS

Few weeks after hydroseeding a big storm invested the landfill and a first in-situ check was carried out. Ten days later, another rain storm, as strong as the first one but of longer duration, affected the area. This was followed by the flood of a nearby river. In-situ checks allowed to ascertain the following place conditions:

1. Sliding of plates of cover material (each plate having a surface of about 10 $m^2$), saturated with water, either in the higher or in the lower part of the slope.
2. Erosion grooves in the scarp cover soil, particularly evident on the surfaces which were yet uncovered with grass.
3. Erosion at the foot of the landfill southern slope, with local slides, caused by quick recovery of the flood water into the river bed.

Plate sliding is visible in Figure 1. Here, the friction sheet exposure is clearly evident as well as the shallow, uncompleted development of the roots. The erosion grooves are clearly evident on the surfaces still devoid of grass (Figure 2). The different behavior of the slope not yet greened (erosion grooves) and that of the slope already greened but with scarce taking of the roots (plate sliding) are shown in Figure 3.

Figure 1. Plate sliding on the landfill slope

## 3 CHARACTERISTICS OF THE GEOSYNTHETIC

The verification of the geo-synthetic section was carried out with a very prudential approach, by taking into consideration the section of the continuous slope. The maximum in-situ stress of the geo-synthetic is of 2708 kN/m. This value was obtained by using materials with a breaking-load resistance of 5500 kN/m and applying the due safety factors. The section of the geo-synthetic was then verified with the following calculation. The load (Fs) on the geotextile is given by:

$$Fs = Hp/\sin\beta \ (H\ \gamma s + \cos\beta\ S)\ (\sin\beta - \tan\delta \cos\beta) = 1670 \text{ kN/m}$$

where $\beta = 29.7°$ is the slope angle, Hp = 14.10 m is the slope height, H = 0.2 m is the thickness of the cover soil, $\gamma s = 1600$ kg/m$^3$ is the volume mass of the soil, S is a possible snow over-load (here taken as zero), and $\delta = 19.7°$ is the friction angle at the liner-geotextile interface. The required resistance of the geotextile is calculated according to a safety factor of 1.3 and results of 2179 kN/m. The geotextile in-situ stress for unit width (Pex) is calculated from the ultimate breaking-load of the material, applying the due safety factors. In this case the ultimate breaking-load of the reinforcement material (Pult) is equal to 5500 kN/m. The safety factors are: creep safety factor ($f_c$ = 0.65 for 60 years), production tolerance safety factor ($f_{m1}$ = 1.2 for 60 years), damage safety factor ($f_{m2}$ = 1.1 for soils with $\Phi < 2$ mm). The resistance for unit width of the geotextile is given by:

$Pex = Pult \; f_c / \; f_{m1} f_{m2} = 5500 \times 0.65 / 1.1 \times 1.2 = 2708$ kN/m

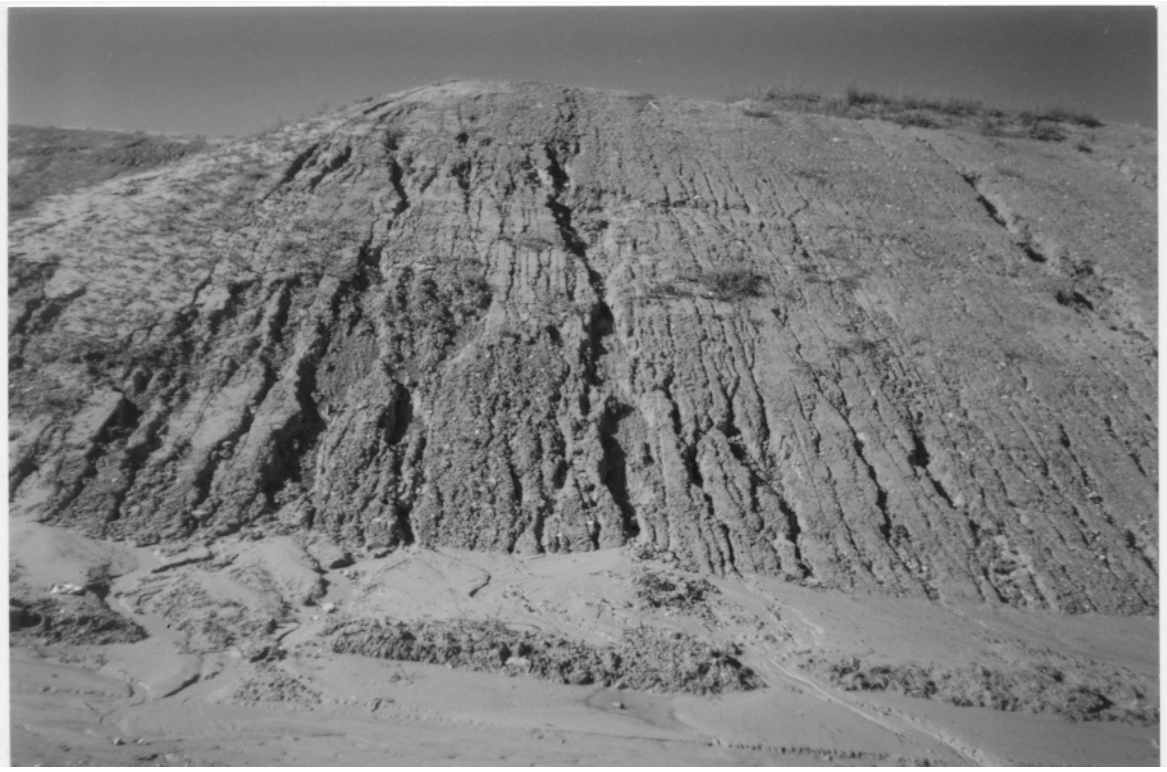

Figure 2. Erosion grooves

## 4 CHARACTERISTICS OF THE COVER SOIL

Fourteen samples were collected to assess the geotechnical characteristics of the cover soil. Sampling was carried out in the areas affected by sliding and groove erosion phenomena. The following lab tests were carried out: Atterberg limits, grain-size, and slow-consolidated drained shear test (CD).

The terrain materials are substantially homogeneous under the grain-size point of view: the clayey-silty fraction varies from 42% to 65%, the sandy fraction varies from 30% to 35%; gravel is present in small amount: less than 5%.

Pure clay is absent in most samples; in few samples it is present in a percentage of no more than 6-7%. The samples are in class A4, sandy-clayey silt, according to the CNR-UNI-10006 classification. CD shear tests gave values of friction angle from 24° to 30° and values of cohesion from 6 to 15 kN/m$^2$. The greater values of friction angle (> 27°) are relevant to samples with higher sandy-gravelly fraction and lower water content. The lower values of friction angle and cohesion are relevant to samples whose water natural content is not far from the liquid limit (WL). These materials are scarcely plastic (0<IP<5), due to the higher sandy-silty fraction.

The same samples underwent to agro-pedological analysis. The following parameters were determined: pH, organic content, cation exchange capacity, K, Mg, Ca, Na and total carbonate. The physico-chemical characteristics show up an alkaline soil (average pH value of 8.2), with high carbonate content (average value of 68%), fairly enriched with organic matter (average value of 1.7%). Such parameters show that the soil is fairly suitable for vegetal growth. The grain-size characteristics show that the soil material is of the sandy-silty type, with high erodibility and scarce permeability: in absence of a grass root apparatus this soil may give rise to small surfaces affected by hydromorphous phenomena. Such phenomena preferably develop in zone of anomalous slope conditions due to MSW settlement.

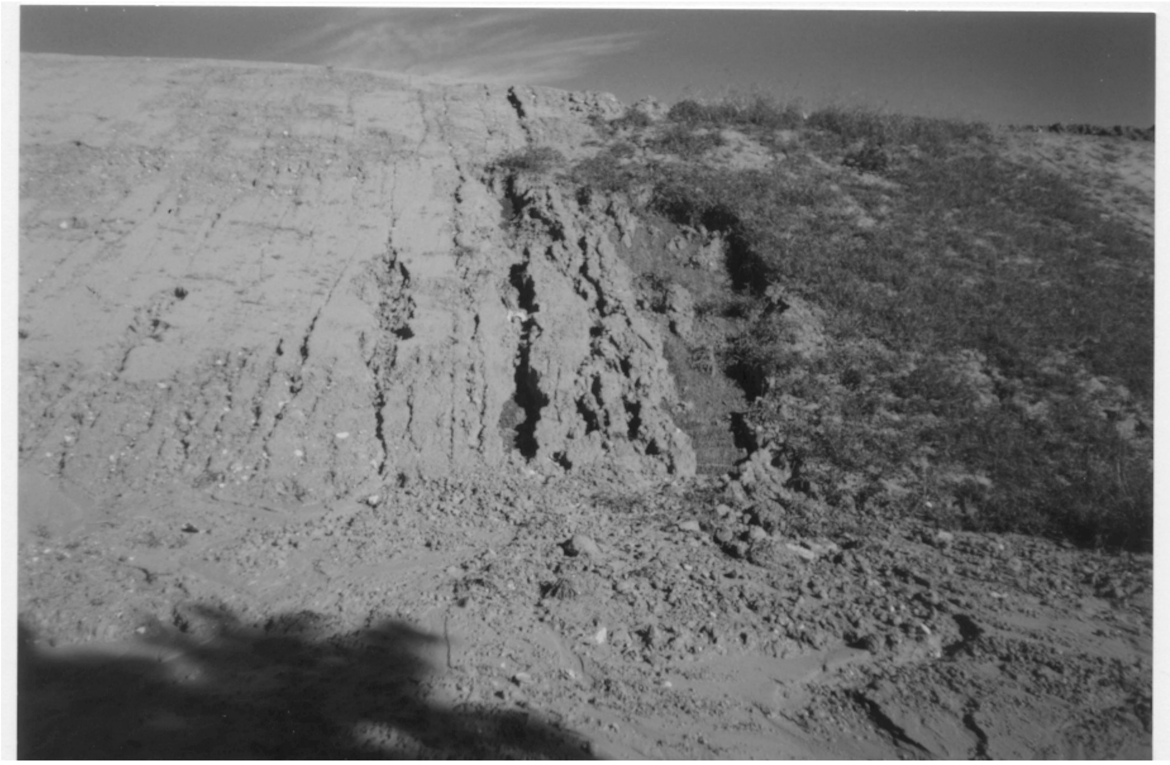

Figure 3. Different behavior on the slope

## 5 SLIDING DYNAMICS

The geotextile dimensions resulted to be properly designed: no evidence of damage or failure, neither incipient, was revealed by the accurate analysis of their conditions, unless the thickness of the filling soil was locally higher than the values scheduled in the verification calculus.

The cover terrain comes from local landfill area due to the high costs of supplying materials with better characteristics from remote locations. High sandy and silty fraction confer scarce geotechnical characteristic to this material: low internal angle of friction and very low cohesion. Many samples showed high natural humidity, very close to the liquid limit, with percent difference from 3% to max 10%.

In such conditions, infiltration of the meteoric water contributed to the reaching of the liquid limit. In facts, the silty-clayey fraction favors water adsorption and retention and the presence of water favors the fall of friction and cohesion forces. The consequence was the annulment of the friction and cohesion forces (which are very low even under normal conditions) and the fluidization of the material. The analysis confirms the above statement. By using the most prudential parameters obtained from the tests, i.e. friction angle $\varphi = 25°$, cohesion $C = 6\ kN/m^2$, volume mass $\gamma = 2\ kN/m^3$, by considering an average thickness of the cover layer equal to 0.50 m, one obtains values of the safety factor of the slopes (F) varying with the slope inclination ($\beta$), but always higher than the normal minimum ($F = 2.13$ with $\beta = 30°$; $F = 1.59$ with $\beta = 40°$). When, in the same calculations, the cohesion C is set to zero, the safety factors fall to values <1, missing the stability conditions of the cover layer.

Furthermore, in this case the stabilizing function of the root apparatus was missing; in facts, at the time of the rain storm the hydroseeding had been carried out only on a part of the slope and the time elapsed after hydroseeding was too short to allow proper development of the root apparatus.

## 6 STABILISATION: DESIGN AND RESULTS

The most urgent and efficient intervention was the planting of the grass cover, after reclaiming the original design profile with soil of better characteristics in the damaged sectors.

Stolonipherous species were utilized. These normally show better anti-erosion properties than tap-root species, due to the formation of a shallow net-shaped root-apparatus that confer a high stability to the soil layer. So, the mix was selected among the following pioneer and frugal species:

- *Agrostis stolonifera L. (25%)*
- *Festuca partense L. (20%)*
- *Medicago lupulina L. (20%)*
- *Trifolium partense L. (10%)*
- *Dactilis glomerata L. (5%)*
- *Brachypodium pinnatum P.B. (o Brachypodium arundinacea R. et S.) (5%)*
- *Bromus erectis Huds (o Bromus inermis Leyss) (5%)*
- *Lolium perenne L. (5%)*
- *Lotus cornicolatus L. (5%)*

Precautionary measures were taken in order to prevent from strong rain damaging before the complete taking root of the grass. A drainage network for the control of surface water was realised aiming at preventing (or reducing) slope runoff and groove erosion. Independent sections of canal, 25 x 25 x 75 m, were designed. These were coated with a jute geocomposite to prevent from erosion during the first year of exercise. Prefabricated concrete descendants, aiming at linking the top canal to the ground level drainage network, were set at a distance variable from 20 to 30 m according to the slope length and inclination, and to the catchment basin.

An anti-erosion geocomposite, made up of cocoa fiber, was laid in the sectors of slope that were affected by severe failure, where rain water is expected to concentrate. This biodegradable material will disappear after 12-24 months but, in the meanwhile, it will favor the complete taking root of the green species.

Twelve months after the realization of the proposed interventions, unless other strong rainy events took place, no further significant damage was noticed on the slopes of the landfill. For the future, it is recognized that the slopes, lacking of an adequate bottom drainage-system, will require particular attention and local maintenance operations.

## 7 CONCLUSIONS

The above mentioned events clearly showed the importance of the quality of the soil to be used for vegetal cover in order to guarantee the esthetical results of the stabilisation obtained with the reinforcement geotextiles. This aspect is particularly important when the design doesn't foresee a drainage layer between the membrane and the reinforcement layer.

The waterproofing and naturalization works must be adequately designed; dimensioning of the geo-synthetics must be carried out according to tested criterions of calculation and to opportune safety factors. Even after the proper dimensioning of the structural elements, a multidisciplinary design staff is required in order to verify the optimal characteristics for vegetal covering and hydroseeding.

The vegetal soil, when this is possible and compatible with the relevant costs, should be accurately selected in the design phase with particular reference to the meteo-climatic conditions of the place. Soils with fair draining capacity and good cohesion should be preferred as well as planting of stolonipherous species, characterized by quick taking and growth of the roots.

Whenever intense rainfall events are foreseen, even during summer, and good quality soils can't be found at sustainable costs, it is to be foreseen, at least, the followings:

1. Hydroseeding as far as possible contemporaneous to the slope covering, with characteristics such to allow a quick taking root (stolonipherous species).
2. Soil fertilizing interventions, even with compost.
3. Proper drainage of runoff water for minimizing the presence of water on the slopes.

The use of a draining geocomposite between the geomembrane and the reinforcement layer, or (when the last is missing) between the geomembrane and the vegetal soil, is always to be suggested, apart from the case of slopes with moderate height and low inclination.