Landfill capping and road runoff basins: functional approach design

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ABSTRACT: lining system covers by organic earth applied to an old landfill and a road runoff basin cover are described in this paper. Functional approach is detailed. Involved geosynthetics are : flexible membrane, drainage geocomposite, reinforcement geotextile. Each geosynthetic is chosen and designed in regard with its function. For instance, no tangential or shear strength stresses must be transferred from the cover soil to the geomembrane to avoid its elongation and the creep of the lining structure. The sliding forces of the cover soil are intercepted by the geocomposite for reinforcement. For the landfill, design solutions that have been found to improved the stability of the cover soil laid on the lining system are presented. Due to the total length of the slope (85 m), it has been decided to built 3 intermediate berms to reduced the tensile strength of the reinforced geocomposite and to make the construction easier.

1 INTRODUCTION

Integration of construction with geosynthetics like old landfill capping or basins inside the natural surrounding landscape become more and more required by public owner. That is why engineers have to design cover systems retaining organic earth. One of the problem of this kind of solution is the stability of soil on a sliding surface like flexible membrane.

The paper describe the functional approach for both :

- geosynthetics choice
- and geosynthetic characteristics calculation

This method was applied to two types of works: an old landfill cover in center of France with a length of 85 m; and a national road runoff basins in west of Paris, France.

These two different works show that a simple similar functional approach design can be successfully employed.

The two works are firstly presented, and then the geosynthetic design.

2 CULHAT LANDFILL CAPPING

2.1 *Description*

The Culhat landfill is an old storage site of municipal wastes. The landfill dome is about 30 m height. The capping has been decided by the public owner with a special requirement concerning the integration of the site inside the natural surrounding landscape. A special organic soil was chosen as cover soil to ensure green aspect of the capping. The total area of the cap is about 100,000 m². The capping has several layers for specific functional purposes. The configuration was the following, from the top to the bottom:

- 30 cm cover soil for vegetation
- geosynthetic for cover soil reinforcement. This fabric is composite between a non woven and yarns.
- HDPE geomembrane for the lining
- Drainage geocomposite for the biogaz
- Municipal waste

The figure 1 shows the principle of the cover.

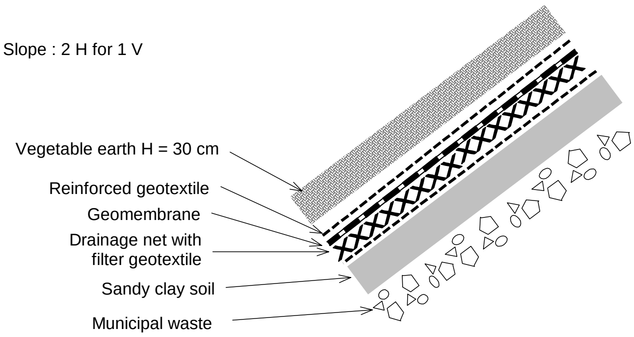

Figure 1. Principle of the landfill cover.

2.2 *Design*

Functional approach concerning geosynthetics and detailed cover design are both combined to obtain correct global design, specially the slopes.

The height of 30 m and the slope angle of 26° conduct to a total length of the slope equal to 85 m. It has been decided to built three intermediate berms to reduce the tensile strength of the geocomposite, figure 2.

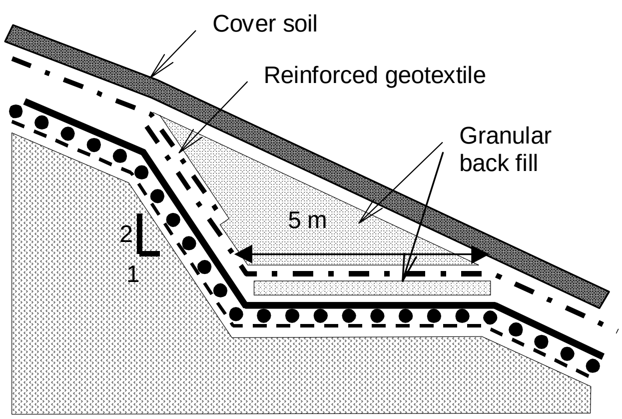

Figure 2. Geometry of the berm.

But the intermediate anchoring of the geocomposite has raised problems of berm stability due to the low friction angle of the geomembrane. The berm geometry should be also as small as possible to reduce the amount of waste to be removed. The berms have been therefore designed with an optimum geometry to secure the geocomposite anchoring with a sufficient safety factor inside the smallest volume, figure 3.

The reinforced geotextile was linear anchored inside the granular material of the berm fill. 10° Reverse slope of berm base was required by the stability calculation. Berm stability was calculated by 2 blocs limit equilibrium.

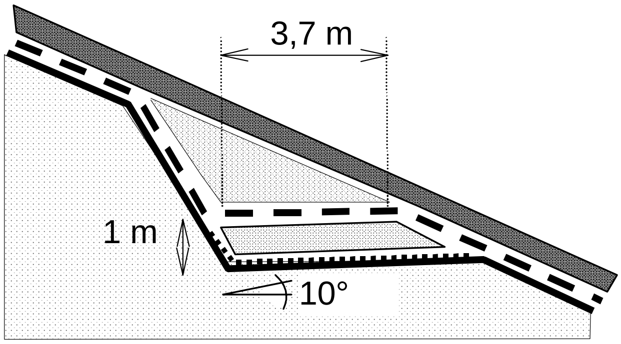

Figure 3. Detail of the reverse slope.

Photo 1. View of the lined slopes before laying of the reinforced geocomposite.

2.3 *Anchoring methods*

Both linear and trench anchor system were employed. They are described hereunder.

2.3.1 *Linear anchor*

Linear anchors were used on the berms. The equation used to calculate the geometry is the following:

$$Lancr \geq Tserv \cdot (\cos\beta - \sin\beta \cdot \tan\varphi_g / F\varphi_g) / (H \cdot \gamma \cdot \tan\varphi_g / F\varphi_g)$$

Where Lancr is the linear anchor length.
Tserv is the service tensile strength.
β is the slope angle, here 1 V for 2 H.
φ_g is the friction angle between reinforced geocomposite and the beneath geomembrane, about 10° degrees. In the case of friction with backfill soil, φ is the friction angle of the backfill, and is equal to 35° degrees.
$F\varphi_g$ is the safety factor on this friction angle : it is conventionally equal to 1,25.

2.3.2 *trench anchor*

Trench anchor were used on the top the landfill hill, figure 4. The equation used is the following: H and L are the result.

$$\text{Tserv} = 2\,.\,\gamma\ .\text{H}\left[\frac{\text{L}\,.\text{tg}\varphi g/\text{F}\varphi}{\cos\beta\ \text{-}\ \sin\beta\ .\text{tg}\varphi\text{g}/\text{F}\varphi} + H(1-\sin\varphi)\right]$$

where Tserv is the service tensile strength.
H is the height of the cover soil.
γ is the volumic weight of the cover soil.
H the depth of the trench.
L the length of the trench.
β is the slope angle, here 1 V for 2 H.
φ_g is the friction angle between reinforced geocomposite and the beneath geomembrane, about 10° degrees.
$F\varphi_g$ is the safety factor on this friction angle : it is conventionally equal to 1,25.
φ is the friction angle of the backfill, about 35° degrees.
Iterative calculus give the height and the length of the trench anchor.

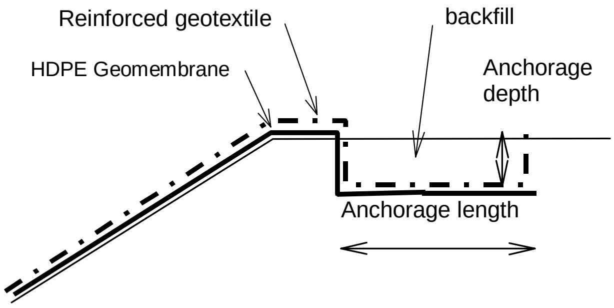

Figure 4. Trench anchor schema.

More over, in situ trial tests on organic soil were carried out to verify the stability of the cover soil on the reinforced geotextile. Artificial rain was imposed to simulate exceptional rainfall. After the test, the soil remained stable.

Low infiltration soil was also chosen to avoid use of upper drainage product : the drainage is only provided by the non woven part of the reinforced geocomposite.

3 PONTCHARTRAIN ROAD RUNOFF BASINS

Road runoff Basins have been during a long time built without care of integration in the landscape. This kind of work is now more and more designed with green aspect solution. Anti erosion or reinforced geosynthetics are obvious involved in this application. In our case, a reinforced geotextile was used for the same above mentioned function : intercept the tensile strength above drainage and lining system, figure 5.

During the general design, a drainage geocomposite was calculated: minimum transmissivity and tensile strength were determinate. But HDPE based product conduct to a high Safety Factor : so it was decided to use a reinforced geocomposite instead of the geotextile filter of the drainage product. This is a typical example of functional design. This geocomposite is a similar product than previous example: the non woven part of the reinforced geocomposite act as filter geotextile where as reinforced yarns provide the tensile strength and modulus required.

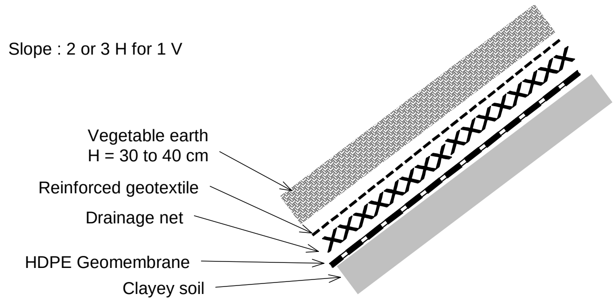

Figure 5. Basins green system.

4 GENERAL FUNCTIONAL APPROACH

Today's design with geosynthetics conduct to define specific geosynthetics in regard to their function.
The general functional approach define:

- first the type of the work. Here green aspect of a landfill cover and basins is presented
- second the function of geosynthetics connected to the work. Here the paper deals with reinforced and drainage geocomposites.
- And third, specific characteristics of the geosynthetic are defined and calculated.

4.1 *Geotextile choice*

In the case of a slope, no tangential or shear strength stresses must be transferred from the cover soil to the geomembrane to avoid its elongation and the creep of the lining structure. The sliding forces of the cover soil are intercepted by the structure above the geomembrane.

This structure has to be calculate as a reinforced geosynthetic, specially for characteristics like polymer creep behavior and tensile strength calculation.

Beneath and above geomembrane, waste gas and runoff water have to be collected and evacuated. The function of the geotextile is drainage, and transmissivity is the essential characteristic.
In our case, the following geosynthetics were chosen:

- reinforced geotextile was ***bidim*® *Rock PEC***. It is a geocomposite made with polyester high tenacity yarns providing reinforcement knitted on a polypropylene needle punched continuous filament non woven geotextile. This geocomposite have mainly two advantages: the non woven participates to the pore pressure dissipation and protects the yarns when the product is installed; the tensile strength in the yarns are mobilized directly.
- Drainage net was a high compressive resist HDPE net associated with one or two filter non woven geotextiles.

4.2 *Characteristic calculations*

Any geotextile used in a structure has a well-defined function, which means that a number of very specific characteristics have to be carefully determined. These are conventionally grouped into three categories according to role, as shown in figure 6.

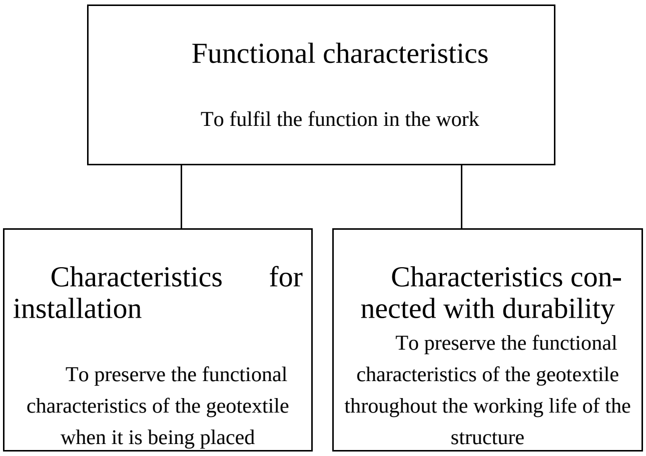

Figure 6. General procedure for designing geosynthetics : the role of the 3 groups of characteristics

4.2.1 *Reinforced geocomposite*

The reinforced geotextile is placed on geomembrane, beneath organic earth. Its characteristics are
- functional characteristics are:

- tensile strength
- stiffness modulus
- soil friction behavior

- characteristics for installation are:

- static puncture resistance (pyramidal piston)
- dynamic puncture resistance (cone drop)

- characteristics connected with durability are:

- UV resistance
- Creep behavior

The tensile strength necessary to intercept cover soil is calculated with bidim method, according to Rigo calculations. Limit equilibrium can also be used Koerner (1990), Feki (1997).
The tensile strength is given by the following equation:

$$Tgtx = Fgtx .Fw. W (\sin \beta - \cos\beta \tan\varphi_{gs}/F\varphi_{gs})$$

Where Tgtx is the ultimate tensile strength of the reinforced geocomposite.
Fgtx is the safety factor of the reinforced geotextile. It combine four partial factors, the main concerning the creep behavior.
Fw is the safety factor on the earth weight, in principle equal to 1,5.
W is earth weight.
β is the slope angle, here 1 V for 2 H.
φ_{gs} is the friction angle between reinforced geocomposite and the beneath geosynthetic. In the case of the landfill, it is the geomembrane, about 10° degrees, in the case of the basins, it is the geonet, the angle is about 16°.
$F\varphi_{gs}$ is the safety factor on this friction angle : it is conventionally equal to 1,25.

The earth weight is given by :

$$W = H \times \gamma \times L$$

Where H is the height of the cover soil, γ is the volumic weight of the cover soil and L the length taken into account in the calculus.

4.2.2 *Drainage net*

The drainage net is placed on geomembrane, in contact with a filter geotextile. Its characteristics are:

- functional characteristics are:

- transmissivity under given vertical stress and gradient
- opening size of the filter
- permittivity of the filter
- creep behavior under load

- characteristics for installation are:

- static puncture resistance (pyramidal piston)
- dynamic puncture resistance (cone drop)
- tensile strength

- characteristics connected with durability are:

- long term drainage capacity
- UV resistance

The main characteristic is the transmissivity. It is calculated for a given rainfall. The drainage capacity calculated with correct safety factor has to compared with transmissivity of the manufactured product as placed on the site: if our case, the fabric transmissivity taken into account is the one measured with the filter.

5 CONCLUSION

General functional approach allows correct choice of geosynthetics regarding to its function. This approach conduct to specific products. Thus specific calculus are necessary to determinate the characteristics. The paper shows also different aspects of a cover design : a dialogue between contractors, consultants and geosynthetic manufacturer is important to taken into account the geosynthetic solutions during the design. This have been permit in our case a good behavior of the works.

Photo 2. Berms laid by geomembrane and reinforced geocomposite.

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