CUT SLOPES AND WATER MANAGEMENT WITH GEOCOMPOSITES

Rabah Arab[1], Pierre Gendrin[2] & Moulay I. Zerhouni[3]

[1] *Afitex. (e-mail: rabah.arab@afitex.com)*
[2] *Georoute. (e-mail: pgendrin@aol.com)*
[3] *Fondasol. (e-mail: moulay.zerhouni@fondasol.fr)*

Abstract: Two road construction projects were carried out near Paris in France. The first project was a 14-kilometer long, 3-lane by-pass road, built to help improve the traffic flow around Beauvais in the north of Paris. The second project was the widening of the existing RN 104 road in the south of Paris.

The most important aspects of these projects were the scope of the earthworks required under complex hydro-geotechnical conditions. They involved temporary cut slopes excavated in fine grained soils with steep slopes greater than 10 meters in height.

Taking into account the presence of water in the soil, a classical weight draining mask was first considered. However, to allow a reduction in the materials and construction time required, a drainage technique using polypropylene needle-punched geocomposite equipped with mini-drains was chosen to be used alongside other techniques.

The aim of the paper is to present the hydro-geological and the geotechnical context of the two projects and discuss the adopted drainage geocomposite solutions used to address the encountered difficulties with ground water and pore pressure management at some key sections of the two projects.

Keywords: cut slope, drainage, filtration, geocomposites, design, landscaping

INTRODUCTION

The greater demand for road developments to improve the traffic flow, particularly around large, cities requires the creation of bypass roads or the widening of the existing highways. These developments present numerous technical constraints to be considered alongside the economic necessity of construction cost and reducing traffic delays. The asset owner is constantly in search of solutions to enable the widening of road carriageways by increasing embankment slope angles.

This paper examines the management of waters in an excavation slope by drainage using geocomposites to reduce the interstitial pressures and to improve the safety factor against failure of the slope and eliminating erosion. In the presented cases, we have used a geocomposite for drainage combined with regularly drilled mini-drains.

CONCEPTION AND DESIGN OF THE GEOCOMPOSITE SOLUTION

Principle of drain mask

Water inflow in natural or man-made slopes considerably reduces stability and often causes failure. Several methods of slope drainage are possible. The traditional drain mask method using stones or coarse materials is one of them. Often a drain mask fulfils two objectives:

- Improves mechanical stability as a result of its weight,
- Improves drainage as a result of the permeability of the material.

A geocomposite solution may be advantageous in replacing the traditional drain mask in the two following cases:

- Where the embankment is stable without additional weight but water infiltration and water inflow may cause instabilities and failure,
- Where the material added can fulfil the mechanical function but not the hydraulic function.

Drainage geocomposite structure

The solution used to replace the traditional system is shown in Figure 1, it consists of a drainage geocomposite with a structure composed of:

- a polypropylene non-woven needle-punched filter layer (filter 1) ;
- polypropylene mini-drains, perforated at regular intervals on two axes at 90° (2 perforations per rib) ;
- a polypropylene non-woven needle-punched drainage layer;
- a polypropylene non-woven needle-punched filter layer (filter 2).

The various components are industrially bonded with needle-punching process.

It is widely used in geotechnical and geoenvironnemental projects (Arab et al., 2002, 2004, 2006) (Gendrin et al. 2002).

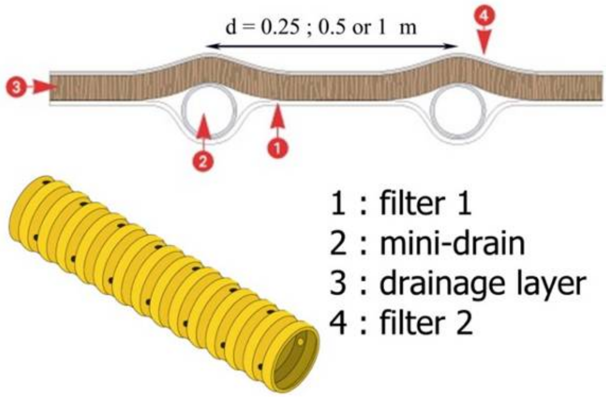

Figure 1. Structure SOMTUBE FTF geocomposite

Design of the drainage system

The design of the drainage system has to take into account the filtration aspects and the in situ discharge capacity of the product and the drain or the trench collector.

Filtration

The filter opening size is 80 µm and is compatible with the underlying beds according to the French standard NF G 38061. The two filters are made of needle-punched, non-woven geotextiles specially adapted to the task of filtering.

The mechanical bonding of filter and drainage layers helps avoid all risk of slip between the filter and drainage layers and ensures filtration continuity. The flexibility of the geocomposite allows it to adapt to any ground irregularities. The last two characteristics optimise the filtering function by limiting the space in contact with the filter and consequent soil in suspension.

Drainage

The drainage design was conducted using LYMPHEA software (Faure et al. 1993) (Arab et al. 2008) developed in cooperation with Joseph Fourier University of Grenoble and validated together with the Laboratoire Régional des Ponts et Chaussées (LRPC) of Nancy. The software was used to design the appropriate geocomposite.

The assumptions taken into consideration in design of the drainage mask under the embankment were:

- Uniform flow
- The height of embankment
- That the mini-drains are unsaturated
- The number of mini-drains per metre (spacing between mini-drains)
- Flow lengths
- The transmissivity of the drainage layer under stress due to embankment height
- The slope of the flow
- The maximum pressure on the product.

Construction

The drainage geocomposite was unrolled directly on the embankment in the highest inclination direction (Figure 2).

Figure 2. Application of the drainage geocomposite on the slope

For practical reasons (wind resistance, accessibility, etc.), the drainage geocomposite was fastened to the slope using concrete iron rods, for example (Figure 3). Transversal joints (end to end) were not permitted on the slope face. The longitudinal joints were created by overlapping the layers by a minimum of 10 cm.

Figure 3. Drainage geocomposite fixation on the slope

Anchorage trench design

The strains sustained by the geocomposite in the anchoring trench (Figure 4) are function of:

- The shear resistance geocomposite/embankment, τs
- The Shear resistance in situ soil/geocomposite, τi
- The height of the embankment.

The friction angles were measured in a laboratory shear box. They can be also estimated on the condition of adding adapted safety factors.

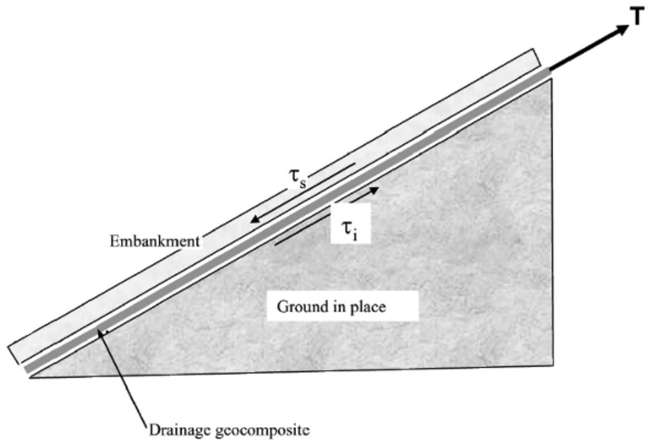

Figure 4. Design profile.

At the top of the slope, the geocomposite drainage is anchored with a traditional anchoring trench (Figure 5).

Figure 5. Mechanical fastening at the summit with anchoring

Trench collector

Trench design consists of dimensioning the geocomposite by determination of the water infiltration rate by linear meter of drain down the slope. This value prescribes the minimum internal diameter for the road drain that requires installation in the drainage trench. The trench collector was constructed using permeable coarse material, usually gravel type 20/40 (grain size distribution), protected by filter geotextile. The connection of the drainage geocomposite and drain collector at the foot of the slope was achieved with a simple hydraulic overlap (Figure 6).

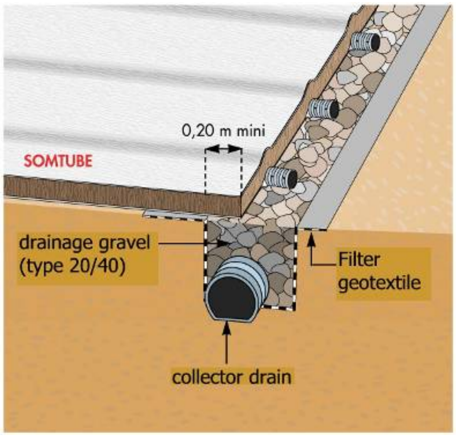

Figure 6. Hydraulic connection drainage geocomposite - drain collector

After installation of the drainage geocomposite, the construction of the anchorage trench and the connection to the drain collector, the resurfacing of the embankments is carried out with selected compacted in situ material.

BEAUVAIS BYPASS – RN31

The RN31 by-pass road around Beauvais is located in the heart of the Bray region. The geology of this area is characterised by the presence of a dissymmetric anticline with an axial surface running northwest – southeast. This anticline is eroded and centred in the sandy-clay soil of the Lower Cretaceous period. The north side has an exceptional dip towards the Paris region of up to 50° from the horizontal. The geological makeup of the land is in narrow strips covered by the chalk of the Upper Cretaceous period. The south side has a lesser dip passing close to the sandy-clay formations encountered in the Lower Cretaceous.

The project is centred around Saint Paul and Frocourt, on the south anticline slope and passes perpendicularly over slightly rough terrain, cutting across small valleys. In addition to the anticline axis, starting from Frocourt and going beyond Berneuil, the project crosses the northern anticline slope to reach the crest of the plateau and the Senonian clay layers of the Allonne section.

Hydrogetechnical context

The succession of the geological layers sand and clay results in the presence of ground water at the base of the sandy formations over the clay layers which allows identification of four ground water levels based on the stratigraphy.

- The Alluvium layer, right of the Alluvial valleys which are subjected to seasonal changes, the amplitude of which may be relatively high. The piezometric level of this layer, in particular during high water seasons, is extremely close to the surface.
- The Lower Albian green sand layer, which rests on an impermeable face of Barremian clay. This is unconfined when the Lower Albian surfaces and confined when the Gault clay forms an impermeable cover. The layer is present in the D5 section.
- The surface layers formed by water penetrating into the top soil layers (silt or sandy-clay), corresponding to the changing terrain conditions or the layers resting in the impermeable soil layers (plastic clay). These layers are generally close to surface and are greatly influenced by seasonal changes in common with the Alluvium layer.
- The chalk layer is present in the chalky formations of the Upper Cretaceous. Its face is composed of Cenomanian formations or the Gault clay layers of the Lower Cretaceous.

Geotechnical characteristics

The global geotechnical characteristics in accordance with the GTR 92 classification for the various formations passed through by the project are summarised in Table 1. The intrinsic mechanical characteristics of the formations are also indicated in Table 1.

Table 1. Classifications to GTR 92 and geotechnical characteristics of the formations

Formations	Passes as 80 µm (%)	Water content w (%)	Plasticity index	Soil blue values VBS	Classification GTR	Cohesion c'(kPa) Friction angle φ' (°)
Sandy clay	23 - 37	11 - 29	14 – 20	0.4 – 1.6	A1/A2/B5	c' = 1.2 kPa φ' : 33°
Silt and marl clay	58 – 96	10 - 31	12 -24	-	A1/A2	c' = 15 - 23 kPa φ' : 19 - 31°
Green sand Albian	4.7 – 45	4 - 38	-	0.3 – 3.1	B5/B2	c' = 14 kPa φ' : 30°
Plastic and sandy clay	58 – 99	14 -28	22 – 39	-	A3/A2/A1	c' = 9 kPa φ' : 21°
Sand and clay clump mix	51 – 91	9 – 32	5	1.2	A1	c' = 17 kPa φ' : 25°

Characteristics of the D5 section

The earth clearance section D5, with a length of 800 m and a maximum height along its axis of 11m, passes through formations with alternating layers of plastic clay and sand. This is part of the green sand layer of the Lower Albian. The linear hydraulic rate depends on the surface soil layout that is different in clay layers and in sandy layers (Figure 7). Due to this hydrogeotechnical context, the embankment stability is only guaranteed if the water and pore pressure are correctly managed with the installation of a drainage cover over the clay layers. The drainage layer is also used to protect the clay layers during the frost/defrost expansion/retraction cycles.

Stability studies were carried out to establish the most unfavourable profiles in the clay layers. The slope stability calculations were carried out taking into account a slope of 1V/2.5H during the work phase and a slope of 1V/3H during the final phase after installation of the drainage layer and resurfacing of the embankments with selected site materials (Figure 8).

Figure 7. View of clearance D5 after earth moving work

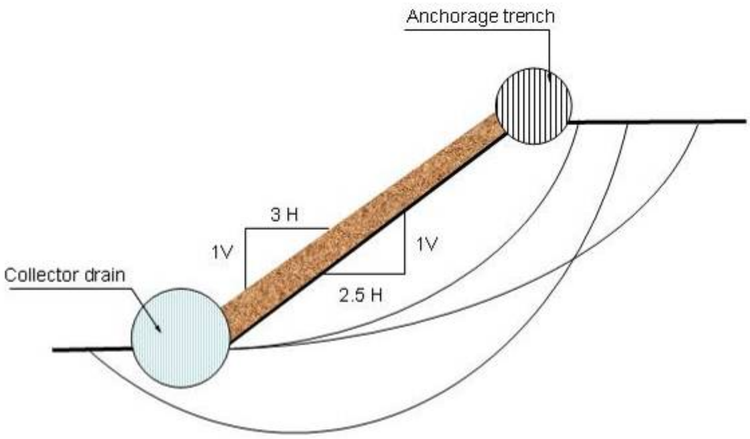

Figure 8. Analysis of slope stability during and after the work phase

The construction phase and completion of the cut slope is shown on Figures 9 and 10.

Figure 9. Filling, resurfacing and under-steeping the slope embankment

Figure 10. Completion of the cut slope

CORBEILLE ESSONNE – RN104 WIDENING

The RN 104 widening at the level of PARIS area takes place in a significant cut section. The length of the section is about 900 m and its height is 12 m.

Geotechnical characteristics and slope stability analysis

The main geotechnical formations encountered by this project are marl and clay witch are very sensitive to water content (Figure 11).

Figure 11. Soil crossed by the project.

The excavation required a complete reshaping of the existing cut slope to obtain one final slope of 1H/1V. The natural soil consisting of materials classified A1 A1/A2 (French standard GTR 92), slope stability of a 1H/1V slope cannot be guaranteed in the long term. Therefore, It was decided to increase the slope to 1H/1V, and then to install a drainage geocomposite on the slope linked to a collector drain at the bottom of the slope. For the final phase after installation of the drainage layer and resurfacing of the embankments with selected site materials to obtain a slope of 3H/2V (Figure 12). For reasons of stake works and of aesthetics the total height (12m) was to be divided into 2 parts.

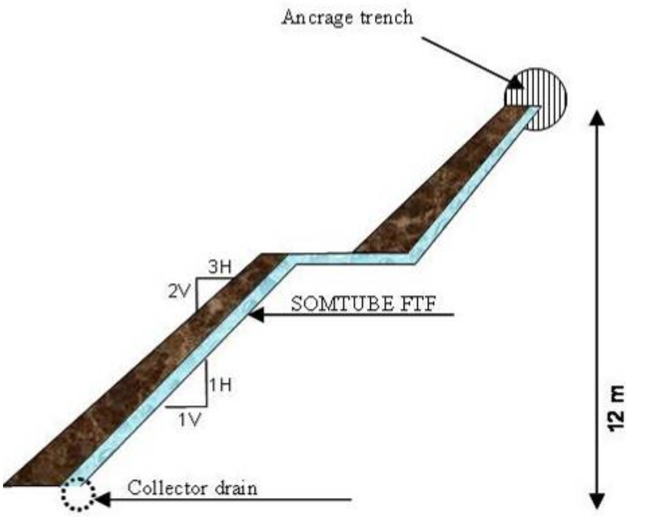

Figure 12. Cross section

The stability studies conducted considering a cut slope of 1H/1V to achieve the short term stability during the work stage have shown a safety factor greater than one. The final configuration with a slope of 3H/2V after the installation of the drainage geocomposite and the refill material with silt, allow reaching a safety factor greater than 1.5.

Figures 13 and 14 show respectively the construction phase and completion of the cut slope.

Figure 13. Filling, resurfacing and under-steeping the slope

Figure 14. Completion of the cut slope

CONCLUSION

The readings taken so far conform the predictions for both projects. A drainage geocomposite equipped with mini-drains was used successfully to achieve the long term stability of a high cut slope. In comparison with traditional solutions using a layer of permeable coarse material, the use of a drainage geocomposite with incorporated mini-drains offers repeatable proven performance and gives savings in earthworks volume and construction time while allowing integration of the cut slope into the landscape.

REFERENCES

Arab, R., Fourmont, S. & Gendrin, P. 2008. Lateral and capping landfills drainage with geocomposites. 1st Middle European Conference on Landfill Technology, February 6 – 8, Budapest ; Hungary

Arab, R., Faure, Y.H., Ung, S.Y. & Michaud, B. 2006. Motorway Embankment on soft soil – Monitoring and Analysis. 8IGS September, 921-924

Arab, R., Faure, Y.H., Lecendre, V., Gendrin, P. & Douillat, M. 2004. Embankment access road to a civil railway structure on soft soil. Eurogeo 3, Munich, 35-38

Arab, R., Gendrin, P. & Durkheim, Y. 2002. Landfill Drainage Systems, 7IGS September 2002, Nice, France, 745–748

Gendrin, P., Arab, R. & Faure, Y.H. 2002. Drainage under embankment –Somtube geocomposite solution. Revue Travaux (786), 23-26

Faure, Y.H. et al. 1993. Experimental and Theoretical Methodology to Validate New Geocomposite Structure for Drainage, Geotextiles and Geomembranes (12), 397-412.

French Standard NFG 38061 : Norme Françaises Recommendation pour l'emploi des geotextiles et produits apparentés

Réalisation des remblais et des couches de forme, SETRA-LCPC, Septembre 2002 (2 fascicules)