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BEAUVAIS BY-PASS – RN 31
DRAINAGE OF CUT SLOPE – DRAINING MASK

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ABSTRACT: A 14-kilometer long, 3-lane by-pass road was constructed to help improve traffic flow around the city of Beauvais. The particularity of this project was the scope of the earth moving work required under difficult hydro-geotechnical conditions. In this article, we will present the geolgical, hydro-geological and geotechnical context of the project, followed by the drainage geocomposite solutions adopted to deal with the difficulties encountered in the D5 section which is the longest and highest section requiring management of ground water and pore pressure.

1. Introduction

The RN31 by-pass road around Beauvais is located in the heart of the Bray region. The geological constitution in this area is marked by the presence of a dissymmetric anticline with an axial surface running North-West – South-East. 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 which attains up to 50°. The geological makeup of the land is in narrow strips covered by the chalk of the High 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 and cutting across small valleys. In addition to the anticline axis, starting from Frocourt and going beyond Berneuil, the project quickly, and more abruptly, crosses the northern anticline slope to reach the crest of the plateau and the Senonian clay layers of the Allonne section.

2. Geological formations crossed by this project

The main geological formations crossed by this project are the following :

– The quartzy formations created by the Alluvia encountered to the right of the valley and cutting almost perpendicularly across the silt top soil and silex clay layers mostly located on the chalk plateau east of the project.

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- The tertiary formations corresponding to Thanet sand are located to the East along the final section of the road.

- The High Cretaceous layer is mainly composed of chalky deposits forming the plateau and which distinguishes itself from the Senonian period composed of white chalk, the Turonian period which is also composed chalk with a greater or lesser marl content and the Cenomanian period composed of grey chalk in slabs at the summit followed by glauconeous chalk (greyish green), which is sometimes silicified. This level ends with a fine sandy layer with a very high glauconite content. This High Cretaceous formation extends over the eastern section of the project along the north eastern slop of the anticline in the Bray region.

- The Lower Cretaceous is the main formation encountered along this route, in particular on the west side along the slop of the anticline in the Bray region. These layers are of a clay-sandy character

3 Hydrogeological 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.

1. The Alluvia layer, right of the Alluvia 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.

2. The Lower Albian green sand layer, which rests on an impermeable face of Barremian clay. It is freed when the Lower Albian surfaces and is trapped when the Gault clay forms an impermeable cover. The layer is present in the D5 section.

3. 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 level and are greatly influenced by seasonal changes as is the case for the Alluvia layer.

4. The chalk layer present in the chalky formations of the High Cretaceous. Its face is composed of Cenomanian formations or the Gault clay layers of the Lower Cretaceous.

4 Geotechnical characteristics

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

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

Formations	Passes as 80 µm (%)	Water content w (%)	Pasticity 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°

5. 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 which is different in clay layers and in sandy layers (photos 1& 2). 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.


Photos 1 & 2. View of clearance D5 after earth moving work

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

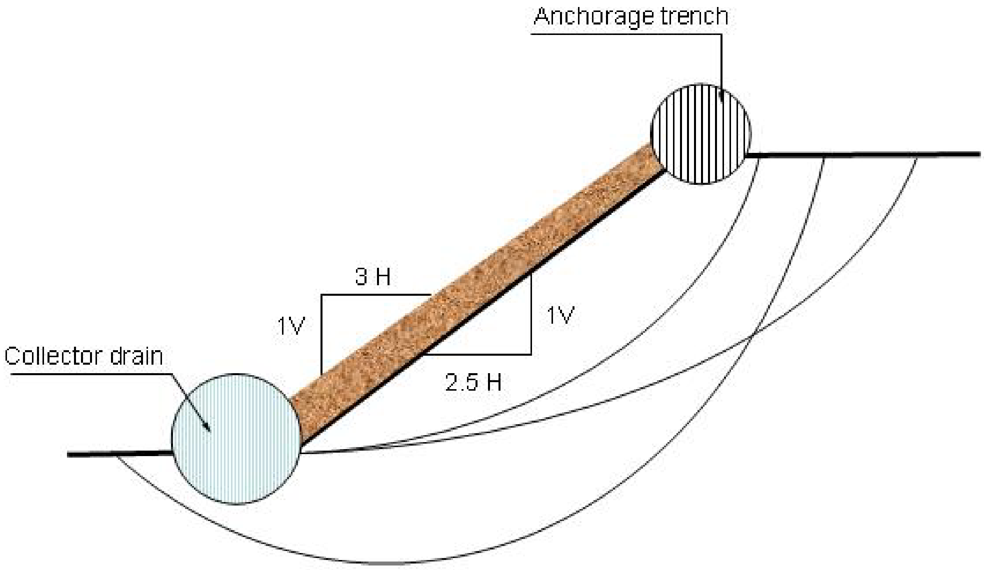

Fig. 1. Analysis of slope stability during and after the work phase

6. Dimensioning of the drainage system

6.1 Filtration

The filter opening size is 80 µm and is compatible with the underlying beds. 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/drainage layers and thus ensures filtration continuity. The flexibility of the somtube 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.

6.2 Drainage geocomposite

The drainage geocomposite used in this project is SOMTUBE FTF, it is widely used in geotechnical projects (Arab and al., 2002, 2006) (Gendrin and al. 2006), Its structure is (Fig. 2) described below:

- a needle-punched, non-woven polypropylene filter layer (filter 1),
- a needle-punched, non-woven polypropylene drainage layer,
- Polypropylene mini-drains diameter 20 mm, perforated at regular intervals,
- a needle-punched, non-woven polypropylene filter layer (filter 2).

The different components are assembled by the needle-punch process

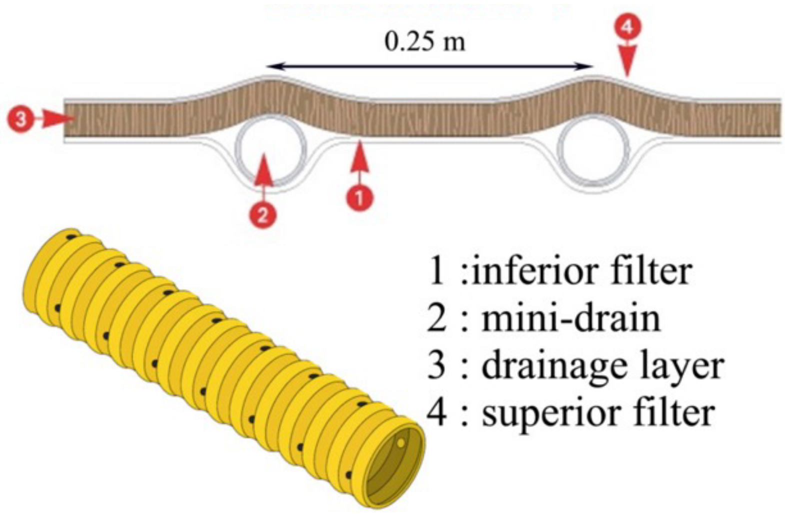

Fig. 2. SOMTUBE FTF structure

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

The mini-drains system incorporated in the drainage product allows a quick exhaust for hydraulics streams resulting from the slope. Water collected this way is released towards a collector drain at the bottom of cut slope.

The assumptions taken into consideration to design the drainage mask under the embankment are:

- uniform flow
- height of embankment: 2 m
- mini-drains unsaturated
- four mini-drains per metre (spacing: 0.25 m)
- flow lengths: 29,6 m
- transmissivity of the drainage layer under stress due to 2 m of embankment: 7 10^{-5} m^2/s
- slope: 40%
- maximum pressure on the geocomposite: 0.003 m.

The slope geometrical characteristics (maximal height, hillside, thickness of the fill material) allow to figure out an exhaust stream of 1.4910^{-5} m/s with maximal pressure between mini-drains about 3 mm in height of water. The result obtained is shown on figure 3. The value of hydraulic flow is much higher in comparison to the permeability of grounds in place.

6.3 Trench collector

Trench design consists of dimensioning the geocomposite allows us to define the water exhaustion capability by linear meter of drain down the slope. This value prescribes the minimal internal diameter for the road drain to be set up in the drainage trench collector. The trench collector is constructed using permeable coarse material, it's a traditional use with gravel type 20/40 (grain size distribution), protected by filter geotextile.

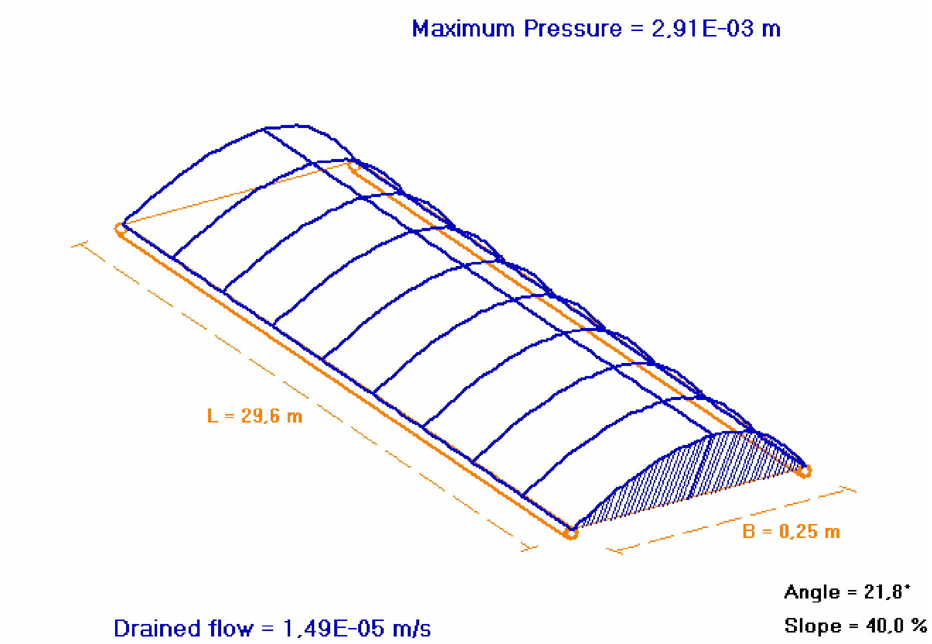

Fig. 3. Lymphea Software results

6.4 *Anchorage trench design*

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

- shear resistance geocomposite/top soil τs
- shear resistance in situ soil/geocomposite τi
- thickness of the top soil.

The friction angles are measured in laboratory in shear box. Sometimes, they can be also estimated on the condition of adding adapted safety factors.

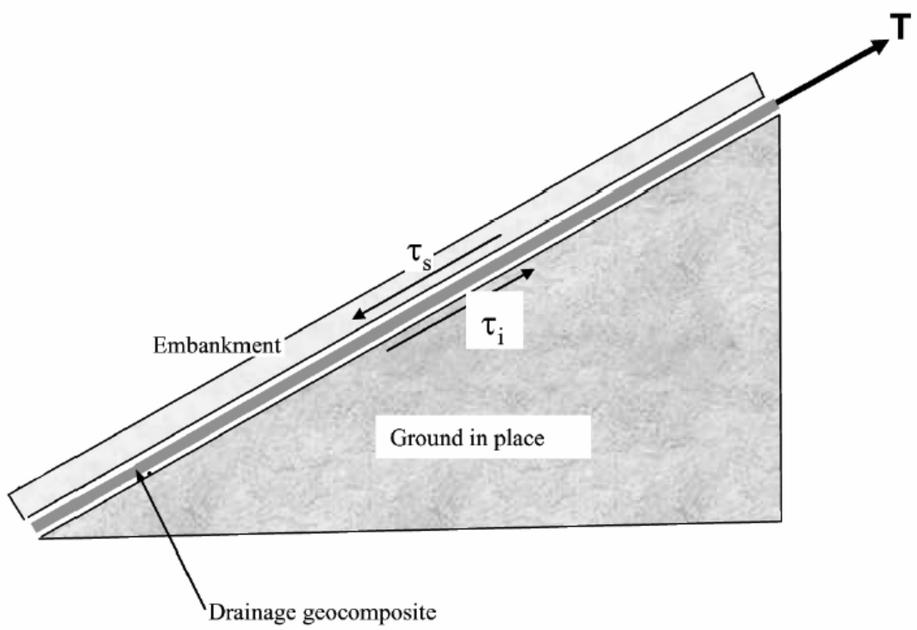

Fig. 4. Design profile.

7. Methodology installation of the drainage geocomposite SOMTUBE FTF

The geocomposite is unrolled generally from the top of the slope (photo 3). Once anchored in the trench up the slope, which will be filled later the geocomposite is batched off down the cut slope, ensuring there was no stop until footer trench.

Photo 3. Géocmposite SOMTUBE FTF unrolling

To prevent any movements due to the wind or refilling, the geocomposite drainage layers are fixed together using metallic U shaped bindings (photo 4).

Photo 4. Géocomposite SOMTUBE FTF fixation on the slope

The flow collected by the geocomposite is discharged in the drain collector at the bottom of the slope. The Connection with the collector drain is achieved by simple hydraulic overlap (photo 5).

Photo 5. Geocomposite SOMTUBE FTF connection to the collector drain

At the top of the slope, the geocomposite drainage is anchored with a traditional anchoring trench (photo 6).

Photo 6. Mechanical fastening at the summit with anchoring.

After installation of the drainage geocomposite, the resurfacing of the embankments is done with compacted in situ material (Photo 7).

Photo 7. Filling, resurfacing and under-steeping the slope embankment.

The completion of the cut slope is shown on photos 8 and 9.

Photo 8. Completion of the cut slope

Photo 9. Vegetalisation and intérgation of the cut slope in the landscape

8. Conclusion

The construction was completed in May 2005. The readings taken until now are conform to predictions. Drainage geocomposite equipped with mini-drains was used successfully to achieve the long term stability of a high cut slope. Comparatively to the traditional solutions with permeable coarse material, SOMTUBE FTF offers great guarantee on regularity performance, saving time work and earthwork. It also allows the integration the cut slope in the landscape.

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