EMBANKMENT ACCESS ROAD TO A CIVIL RAILWAY STRUCTURE ON SOFT SOIL

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ABSTRACT: A new road is to be constructed in order to improve road traffic conditions in the Lille metropolitan area. In this article, the authors present the geosynthetic solutions used on the one hand for drainage at the base of the construction and on the other hand to reinforce the embankment on the side of the railway line.

1 INTRODUCTION

A new road is to be constructed in order to improve road traffic conditions in the Lille metropolitan area. The specificity of this project is the construction of an embankment on soft soil providing access to a bridge passing over the railway line and reinforcement of the embankment for consolidation of the soil close to the railway line.

The geosynthetic solutions used for drainage at the base of the construction and reinforcement of the embankment on the side of the railway line are described in this article.

2 GEOTECHNICAL CONTEXT

The soil studies carried out have revealed that the mechanical characteristics of the soil on site are mediocre and the free ground water level is at a depth of –1 m under the natural surface.

On average, from –1 to -10 m, the soil contains sandy silt, from –10 to –22 m, a grey-green plastic clay referred to as ″Flanders clay″ and beyond this depth the soil is composed of green sand

Due to the low mechanical resistance of the foundation soil and the height of the earthwork of approximately 8 m, the theoretic subsidence is estimated to be 40 cm over a settling period of 20 years; this is not compatible with the bridge working requirements. The main contractor has therefore chosen to employ the vertical drainage techniques to help decrease the consolidation time

3 TREATMENT OF COMPRESSIBLE ZONES

To meet the requirements of the main contractor who imposes a consolidation time of 1.5 years and a maximum residual settlement of 5 cm, a flat vertical geosynthetic drainage mesh will be incorporated at a depth of 22 m (Figure 1). The calculated mesh is 1.5 × 1.5 m.

The vertical drainage is combined with a horizontal drainage (Figure 2) to ensure the flow of drainage water to the lateral trenches

Figure 1 Installation of the geosynthetic vertical drains

Figure 2 Horizontal drainage combined with the vertical drains

The horizontal drainage system is composed of a SOMTUBE FTF geocomposite. The geocomposite structure is illustrated in figure 3. It is created by mechanical bonding of the following elements.

- A needle-punched, non-woven polypropylene filter layer (bottom filter),

- A needle-punched, non-woven polypropylene drainage layer,
- Polypropylene mini-pipes diameter 20 mm, perforated at regular intervals along two axes at 90°,
- A needle-punched, non-woven polypropylene filter layer (top filter).

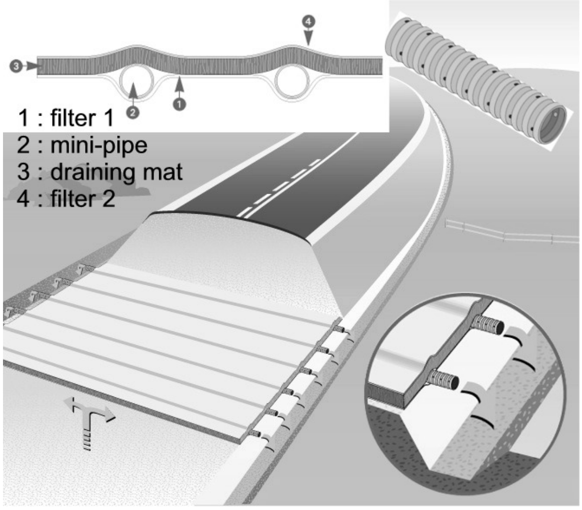


Figure 3 Horizontal geocomposite drainage structure

The space between the mini-pipes varies from 0.25, 0.5, 1 and 2 m depending on the drainage flow rate and the geometric characteristics of the construction

4 DIMENSIONING OF THE HORIZONTAL DRAINAGE GEOCOMPOSITE

4.1 *Filtration*

The filter 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 spaces in contact with the filter and consequent soil in suspension.

4.2 *Drainage:*

The water evacuated by the vertical drains is collected by the non-woven drainage layer and transported to the mini-drains after having passed through filter 1.

The geocomposite dimensions must take into consideration:

- the head loss when passing through filter 1,
- the head loss when flowing through the drainage layer,
- the head loss when entering the mini-pipes,
- the head losses when flowing through the mini-pipes.

4.2.1 *Hypothesis*

The head losses when passing through filter 1, already taken into consideration in the filter criteria, are not taken into consideration when calculating the drain dimensions. This is generally the case for all drainage facilities.

The non-woven layer is placed horizontally and it is therefore considered to be totally saturated. The characteristic parameter retained is the transmissivity. For simplicity, it is assumed that flow in the layer is straight and perpendicular to the direction of the mini-pipes. The flow Q_1 transported per unit of width is given by equation 1.

$$Q_1 = V_1 T_g = \theta i_1 \tag{1}$$

Laboratory tests have been carried out to establish the head loss when entering the mini-pipes. These tests illustrated that the head loss is negligible and corresponds at the most to several millimetres of flow in the non-woven layer.

For this application, the mini-pipes are placed horizontally. To evacuate the water collected over a great length, they are considered to be completely saturated. There is not sufficient slope to consider a free surface flow inside the mini-pipes. It is even quite likely, considering the difference in subsidence which is greater in the central segment, that they may even be under pressure.

The laboratory results indicate that the flow rate in the mini-pipes may be characterised by the following form relationship.

$$Q_2 = q_d i = \alpha i^{(n+1)} \tag{2}$$

where

- qd : discharge capacity of the mini-pipe,
- i : hydraulic gradient in the mini-pipe
- α, n : experimental constants

4.2.2 *Calculation of the maximum pressure inside the drain*

A uniform flow of intensity V is assumed to enter the drainage layer perpendicularly over a width of 2B, corresponding to the distance between mini-pipes as illustrated on figure 4.

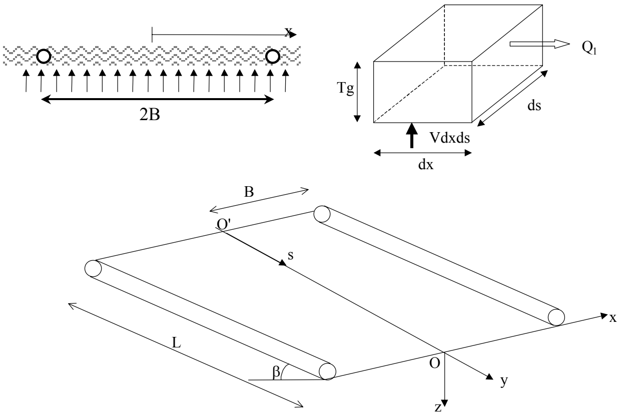


Figure 4 Flow modelisation

The flow dQ_1 which enters perpendicularly via a surface element (dx.ds) of the non-woven layer is:

$$dQ_1 = V\,dx\,ds \tag{4}$$

Where the volume through the layer element (ds T_g) is:

$$Q_1(x,s)\,ds = V_1 T_g\,ds = -\theta \frac{dh_1}{dx} ds \tag{5}$$

with :

- Q_1 : flow in the non-woven layer plane,
- T_g : thickness of the layer

- θ : transmissivity of the layer
- V : flow entering the layer
- V_1 : flow transported by the layer
- h_1 : hydraulic head in the layer.

Consequently:

$$\frac{d^2h_1}{dx^2} = -\frac{V}{\theta} \tag{6}$$

Furthermore, the volume collected in an element of length «ds» of mini-pipe is given by:

$$dQ_2(s) = 2VBds \tag{7}$$

with

$$Q_2(s) = q_d\, i = \alpha\, i^{(n+1)}$$

where:

- Q_2 : flow transported by the mini-drain
- q_d : discharge capacity of the mini-drains
- i : hydraulic gradient in the mini-drain
- α, n : experimental constants.

i.e. :

$$\frac{dh_2}{ds} = -\left[\frac{2VB}{\alpha}s + C_1\right]^{\frac{1}{n+1}} \tag{8}$$

h_2 : hydraulic load in the mini-drains.
but C_1 = 0 as for s=0, i = 0 (Q_2 is zero at s = 0) :

$$h_2(s) = -\frac{n+1}{n+2}\times\left(\frac{2VB}{\alpha}\right)^{(1/n+1)} s^{(n+2)/(n+1)} + C_2 \tag{9}$$

which gives

$$h_2(s) = -\frac{n+1}{n+2}\times\left(\frac{2VB}{\alpha}\right)^{(1/n+1)}\left[s^{(n+2)/(n+1)} - L^{(n+2)/(n+1)}\right] \tag{10}$$

The maximum head is obtained for s = 0

$$(h_2)_{max} = \frac{n+1}{n+2}\times\left(\frac{2VB}{\alpha}\right)^{(1/n+1)} L^{(n+2)/(n+1)} \tag{11}$$

The maximum load h_{1max}, inside the mini-pipes is:

$$(h_1)_{max} = \frac{VB^2}{2\theta} + \frac{n+1}{n+2}\times\left(\frac{2VB}{\alpha}\right)^{(1/n+1)} L^{(n+2)/(n+1)} \tag{12}$$

4.2.3 *Use of LYMPHEA software*

A software design (LYMPHEA) has been developed in co-operation with the Laboratoire Interdisciplinaire de Recherche Impliquant la Géologie et la Mécanique (LIRIGM) of the Joseph Fourier university of Grenoble and validated together with the Laboratoire Régional des Ponts et Chaussées (LRPC) of Nancy. It is used to process this type of configuration : horizontal ground and saturated mini-pipes. However, it may also be used for other configurations:

- sloping ground with free flow in the mini-drains,
- constant load imposed for a certain drain distance,
- evacuation of gas,
- drainage layer with or without mini-drains.

In the software, the flow in the drainage layer is considered to be uni-directional and perpendicular to the mini-drains.

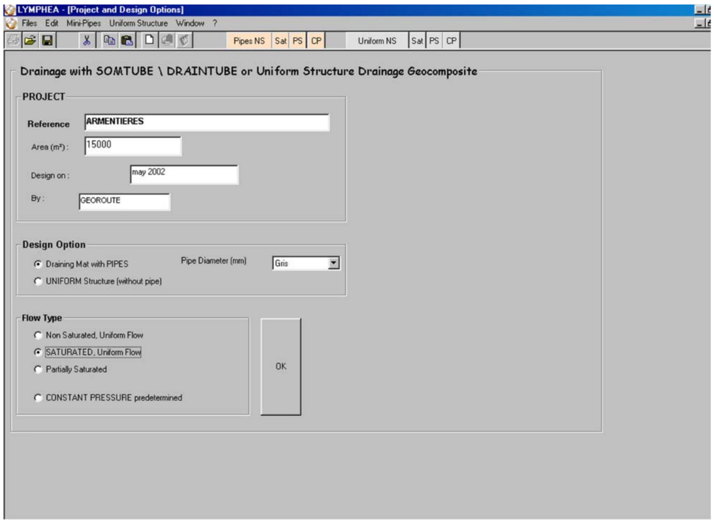
The software takes the following parameters into consideration:

- the transmissivity of the drainage layer under compression,
- the flow length in the mini-pipes,
- the flow slope in the mini-pipes,
- the distance between mini-pipes,
- the flow conditions in the mini-pipes (saturated, partially saturated or not saturated).

For this project, design was carried out using the LYMPHEA software, taking into consideration the hydrogeological context and geometric characteristics of the embankment.

The following hypothesis were taken into account for calculation of the drainage under the earthwork in Lille:

- height of embankment : 8 m
- mini-pipes saturated
- uniform flow
- two mini-pipes per metre (spacing: 0.5 m)
- flow lengths : 17.5 m
- transmissivity of the drainage layer under stress due to 8 m of earthwork: 5 10^{-6} m²/s
- slope : 0%
- maximum pressure inbetween the mini-drains: 0.01m



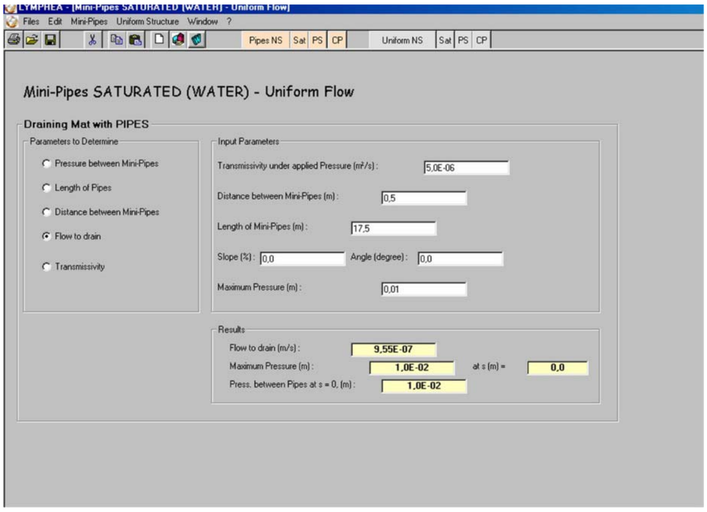
Drainage with SOMTUBE \ DRAINTUBE or Uniform Structure Drainage Geocomposite

PROJECT
Reference: ARMENTIERES
Area (m²) : 15000
Design on : may 2002
By : GEOROUTE

Design Option
● Draining Mat with PIPES
○ UNIFORM Structure (without pipe)
Pipe Diameter (mm): Gris

Flow Type
○ Non Saturated, Uniform Flow
● SATURATED, Uniform Flow
○ Partially Saturated
○ CONSTANT PRESSURE predetermined

Figure 5 Presentation of the project (Lymphea)



Mini-Pipes SATURATED (WATER) - Uniform Flow

Draining Mat with PIPES

Parameters to Determine
○ Pressure between Mini-Pipes
○ Length of Pipes
○ Distance between Mini-Pipes
● Flow to drain
○ Transmissivity

Input Parameters
Transmissivity under applied Pressure (m²/s) : 5,0E-06
Distance between Mini-Pipes (m) : 0,5
Length of Mini-Pipes (m) : 17,5
Slope (%) : 0,0 Angle (degree) : 0,0
Maximum Pressure (m) : 0,01

Results
Flow to drain (m/s) : 9,55E-07
Maximum Pressure (m) : 1,0E-02 at s (m) = 0,0
Press. between Pipes at s = 0, (m) : 1,0E-02

Figure 6 Entry of parameters and results obtained (Lymphea).

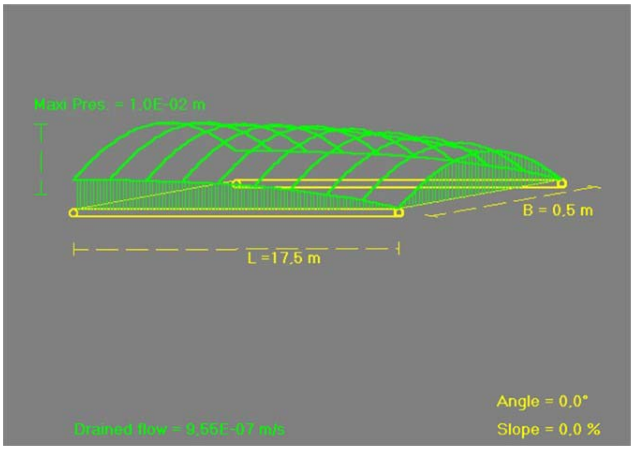


Figure 7 Piezometric surface in the layer and the mini-drains (LYMPHEA)

The calculation indicates a flow entry of around 10^{-6} m/s for a maximum imposed pressure of 0.01 m (1 cm).
This flow is quite acceptable considering the volumes attained.

5 VERTICAL SUPPORT WORK REINFORCED WITH A GEOTEXTILE

The embankment reinforcement is intended to consolidate the soil closest to the railway line. This support is composed of two skins one of which is temporary (the one located to the right of the future butt) the other is permanent.

The geometric characteristics of the walls are all follows:

- width at base: 5.5 m
- height of wall: 7.10 m in the temporary state and 8.10 m after completion
- road surface load: 20 kN/m².

The technique employed consists of raising an earthwork in layers separated by geotextile layers.

The materials compacted are therefore enveloped by the geotextile and the vertical skins are composed of removable shuttering and ″big-bags″. The stacking of ″big-bags″ enables creation of a solid shove which, although very resistant, will take up the differential settlement to be expected of the compressible soil.

The ″big-bags″ are held in the mobile shuttering in groups of three over the skins and they are filled with material 0/100 using a mechanical excavator (Figure 8). The three bags are filled simultaneously with a lift of approximately 30 cm in height.

Beforehand, external and internal stability calculations were carried out taking into consideration the compressible character of the materials on site.

The internal stability is calculated using Cartage software developed by LCPC and LIRIGM. It is conform to the "*Recommendations for the use of geotextiles for the reinforcement of earthwork*" compiled by the **C**omité **F**rançais des **G**éosynthétiques (French Geosynthetics Committee).

This method enables calculation of the forces used in the reinforcement taking into account the extendable character of the reinforcement geotextiles, the mechanical characteristics of the earthwork and the construction geometry. In this way the number, resistance, length and spacing of the geotextile layers may be calculated. The final aspect of the walls may be seen in Figure 9.

Figure 8 View of the big-bags and removable shuttering

Figure 9 Final aspect of the reinforced walls

6 CONCLUSION

The construction was completed in March 2003. Measurement monitoring is planned for a period of 18 months. The readings taken until now are conform to predictions.

7 REFERENCE

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