Drainage improvement under CN railways with the use of a multi-linear drainage geocomposite

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ABSTRACT
Under the action of cyclic loads due to the passage of trains, the ballast put into place under the railways undergoes densification and degradation over time which reduces the void index and thus the hydraulic conductivity of the material. This phenomenon may be critical for the durability of the structure if the ballast is not able to quickly evacuate the water, especially during heavy rainfall, flooding and/or snowmelt.

The installation of a geocomposite with mini-pipes Draintube under the ballast layer allows to increase the draining capacity of the overall system and compensates for the loss of hydraulic conductivity of the ballast. The high density of the mini-pipe network in the geocomposite offers a high flow capacity and a lower response time than a homogeneous layer of draining material even for zero slopes.

Sous l'action des charges cycliques dues au passage des trains, le ballast mis en œuvre sous les voies ferrées subie une densification et une dégradation dans le temps qui réduit l'indice des vides et ainsi la conductivité hydraulique du matériau. Cette problématique peut être critique pour la pérennité de l'ouvrage si le ballast n'est pas capable d'évacuer rapidement l'eau, notamment lors de phénomènes pluvieux important, d'inondations et/ou lors de la fonte des neiges.

La mise en œuvre du géocomposite à mini-drains Draintube sous la couche de ballast permet d'augmenter la capacité drainante du système et de compenser la perte de conductivité hydraulique du ballast. La densité du réseau de mini-drains dans le géocomposite offre une capacité de débit importante et un temps de réponse plus faible qu'une couche de matériau homogène et ce même pour des pentes nulles.

1 INTRODUCTION

Within the scope of work for some track reconfigurations, CN has sometimes used an alternative drainage system given the limited space available in certain track corridors.

CN usually requires open ditches on both sides of its tracks in order to ensure proper drainage of the track foundation. Given limited space, a series of mini-pipes can be used in order to efficiently evacuate the water from below the tracks. The mini-pipes are brought to a ballast drain or an open ditch. The present case looks at a scenario where two (2) tracks required to be drained into either an open ditch or a ballast drain installed approximately 1 metre below track level. Without a proper drainage system, potential drainage problems and a shortened life for the ballast would occur.

1.1 Geocomposite Draintube

In order to increase the hydraulic capacity of the track system, a geocomposite with a series of mini-pipes (Draintube) was required directly below the ballast on the sub-ballast which was sloped uniformly towards a ballast drain or an open ditch. The drain tubes were extended down to a galvanized outlet pipe running parallel to the track (ballast drain) to a catch basin or they were run to the top of the ditch, ensuring that the flow would never be obstructed.

2 GEOCOMPOSITE DESCRIPTION AND INSTALLATION

2.1 Geocomposite description

The Draintube geocomposite is composed of non-woven geotextiles that are needle-punched together with perforated, corrugated polypropylene mini-pipes regularly spaced inside and running the length of the roll. The pipes have two perforations per corrugation at 180˚ and alternating at 90˚ (Figure 1)

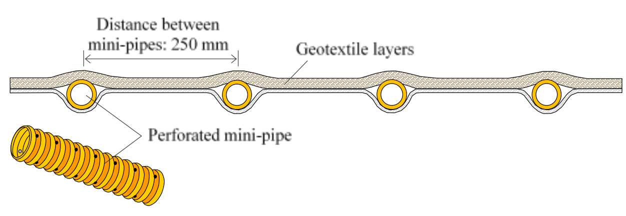

Figure 1. Draintube geocomposite description

For the drainage improvement under CN railways, mini-pipes are 20 mm diameter and they are spaced on 250 mm centers (figure 2).

The upper geotextile layer is comprised of short synthetic staple fibers of 100% polypropylene. It has a mass per unit area of 400 g/m^2 (12 Oz/sy) to mechanically protect the mini-pipes against puncture from the ballast. Its CBR puncture strength is 3200 N (ASTM D6241).

Figure 2. Roll of Draintube

The mini-pipes have a pipe stiffness at 5% deflection over 3000 kPa (ASTM D2412). From Saunier et al. 2010, it has been shown that in soil, the flow capacity of the Draintube geocomposite is not load or time sensitive (lab tests have been carried out up to 2400 kPa).

2.2 Geocomposite installation

Draintube geocomposite is unrolled directly on the sub ballast perpendicular to the directions of the tracks. The connections between two rolls are achieved by overlap and secured with hot air welds.

The product is connected to collector trenches or ditches on the sides of the tracks (Figure 3).

Figure 3. Connection to the collector trench

The first 150 mm layer of ballast is then put into place on the geocomposite (Figure 4).

Figure 4: Putting into place of the ballast

3 HYDRAULIC BEHAVIOR

3.1 Geocomposite drainage response time

From Del Greco et al. 2012, using a 2.5 m long and 2 m wide inclinable open box with rainfall simulator on top (figure 5), it has been shown that multi-linear drainage geocomposite Draintube enables rainfall to evacuate faster than a homogeneous drainage layer (Figure 6). This is due to the directional aspect of the product. The water is drained into the mini-pipes direction even if the slope is zero

Figure 5: inclinable open box with rainfall simulator

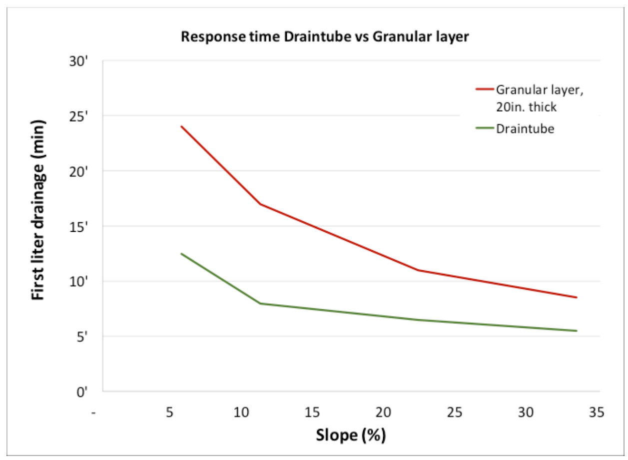

Figure 6: Drainage response time Draintube vs granular layer

3.2 Flow modeling

The hydraulic behavior of multi-linear drainage geocomposite Draintube has been characterized and a software named Lymphea has been developed in cooperation 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 permits to determine the drainage capacity of the product and the flow curves function of the geometry and the constraints of the project.

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 7.

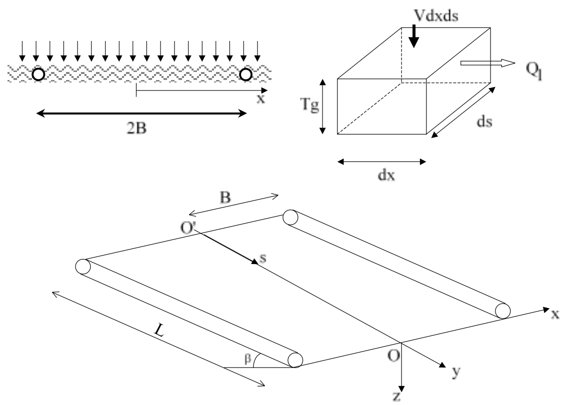

Figure 7: Flow modeling

In the following, we assume the mini-pipes staying unsaturated.

The flow dQ1 which enters perpendicularly via a surface element (dx.ds) of the non-woven layer is:

$$dQ_1 = Vdxds \quad [1]$$

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

$$Q_1(x,s)ds = V_1 T_g ds = -\theta \frac{dh_1}{dx} ds \quad [2]$$

with :
Q_1 : flow in the non-woven layer,
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,

$$\frac{d^2 h_1}{d^2 x} = -\frac{V}{\theta} \quad [3]$$

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

$$dQ_2(s) = 2VBds \quad [4]$$

Or the flow rate in the mini-pipes is characterized by the following form relationship:

$$Q_2 = q_d i = \alpha i^{(n+1)} \quad [5]$$

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

$$Q_2(s) = q_d i\, \lambda(s) = \alpha i^{(n+1)} \lambda(s) \quad [6]$$

With $0 < \lambda(s) < 1$ and $\lambda(0) = 0$; $\lambda(L_0) = 1$

Where L_0 is maximum length for the pipe staying unsaturated

By combining Eq. 4 and Eq. 5,

$$2VB = \alpha i^{(n+1)} \frac{d\lambda(s)}{ds} \quad [7]$$

$$\lambda(s) = \frac{2VB}{q_d i} s + c_1 \quad [8]$$

With the boundary conditions, we obtain:

$$L_0 = \frac{\alpha i^{(n+1)}}{2VB} \text{ and } (h_1)_{max} = \frac{VB^2}{2\theta}$$

4 CN RAILWAY PROJECT DESIGN

On the CN project in question, the most unfavorable section for drainage purposes was 10 meters long with a slope of 2% (Figure 8).

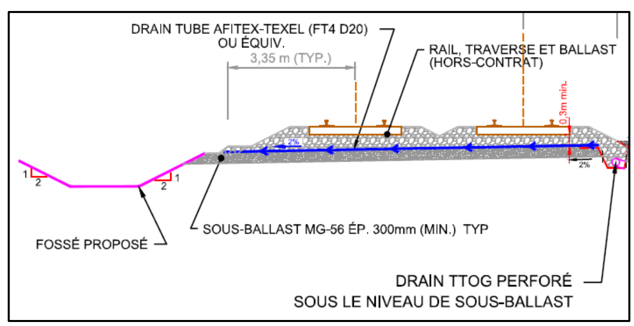

Figure 8: Considered cross section

Acording to the Lymphea software, the Draintube geocomposite (with a distance between mini-pipes of 0.25 m) is able to drain a flow per unit surface of 7.65×10^{-6} m/s. Assuming that all the rainfall is drained by the geocomposite, it is able to evacuate a rainfall of 661 mm/day with the mini-pipes staying unsaturated (figure 9).

The 100 years return period rainfall in Quebec is 156 mm/day. The drainage capacity of the Draintube is more than 4 times superior to the required drainage capacity to take into account the long term hydraulic behavior of the geocomposite under the critical conditions of the application.

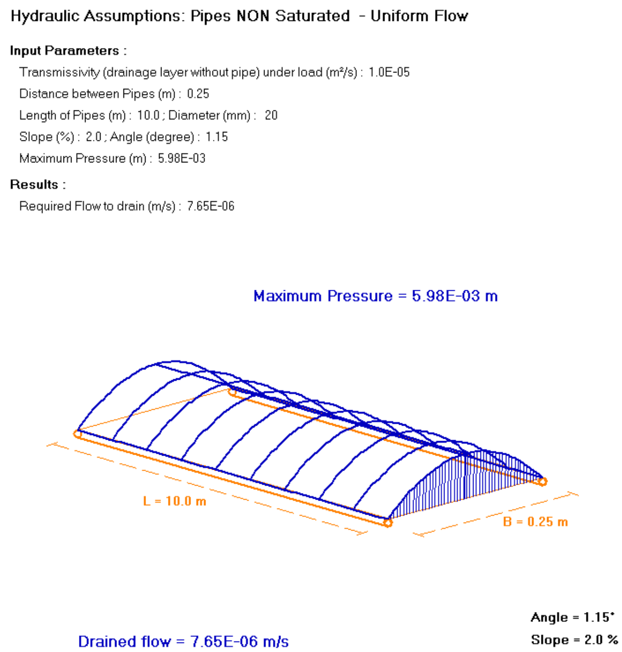

Figure 9: Draintube Flow capacity

5 ONSITE INSPECTION

As the multi-linear drainage geocomposite is under sever conditions, a series of onsite video inspection will take place in 2018 under the CN freight transport railways where the geocomposite has been installed since 2013 to assess the condition of the product and more precisely, its drainage capacity after several years in operation.

A video endoscope will be used to go inside the mini-pipes of the geocomposite (figure 10). It will give the opportunity to control the shape of the mini-pipes and see potential punctures and their localizations.

Figure 10: Video inspection using a video endoscope

In parallel a laboratory testing program is under development to quantify the impact of the deformations of the mini-pipes on the geocomposite drainage capacity.

6 CONCLUSIONS

Multi-linear drainage geocomposite Draintube has been used with success over the years under CN railways. Its composition with a dense network of small diameter perforated mini-pipes between two geotextiles gives to the product a high drainage capacity, a short drainage response time even for low slopes and a high mechanical resistance.

Given the particularly severe conditions to witch the product is subject, the network of mini-pipes within the Draintube is denser than ultimately needed.

As the product is in use under CN railways since 2013, an onsite inspection program is in progress in conjunction with laboratory testing to get a feedback on the product behavior after 5 years and evaluate more accurately its expected long-term drainage capacity. It will lead eventually to an optimization of the drainage geocomposite for future applications.

7 REFERENCES

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