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Drainage Improvement Under Railways with the Use of a Drainage Geocomposite

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ABSTRACT

Railway construction involves important earthworks (embankments and cuttings). Cuttings may reach the water table, embankments may need preloading when on soft soils. Even during operation of the railway line, 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 drainage geocomposite with mini-pipes Drain Tube at these different stages allows protection against high water table on the cutting, decreases the time for consolidation on soft soils and increases the overall drainage capacity of the system under ballast.

This publication presents a case study for each application along with the related laboratory study or on-site monitoring. Drainage geocomposites with mini-pipes Drain Tube has been successfully utilized for 30 years, the main advantages being the high drainage capacity of the product under high loads in addition to the non-sensitivity to creep when confined and its robustness.

INTRODUCTION

In Civil Engineering, the drainage systems were traditionally made with granular material layers and perforated collector pipes. The use of drainage geocomposites becomes more common with the development of products that meets the specific requirements of each application. Moreover, the geosynthetic solution is cheaper than the granular material (for the same performances) in the majority of applications. It is faster to install, requires less machinery and reduces the Greenhouse Gas (GHG) emissions of the project (Durkheim et al, 2010). Like any engineering solution, drainage geocomposites must be well selected and designed to function for specific site conditions. In railway engineering, Drain Tube drainage geocomposites are used as lateral drainage on vertical wick drains under preloading embankments, directly under the tracks to increase the drainage capacity of the ballast or in cuttings to intercept high water tables.

DRAIN TUBE DRAINAGE GEOCOMPOSITES

Geocomposite description

Drainage geocomposites with mini-pipes Drain Tube are used in civil engineering and more especially in earthworks project for the past 30 years. They are multi-linear drainage geocomposites (terminology as per ASTM D4439) 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 mini-pipes have two perforations per corrugation at 180˚ and alternating at 90˚ (see Figure 1)

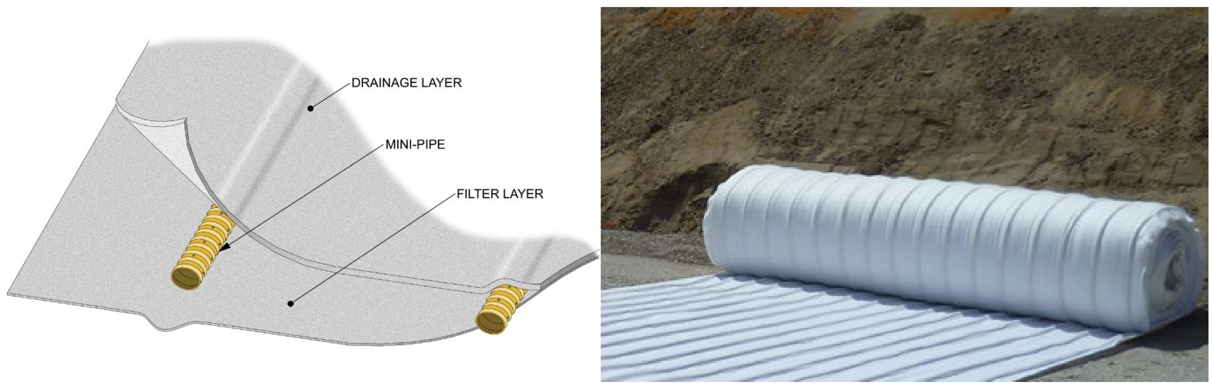

Figure 1. Geocomposite description

Hydraulic characteristics

The drainage capacity of the product (Transmissivity as per ASTM D4716) is driven by the number of mini-pipes within the product. There is a linear relationship between the distance between the mini-pipes and the transmissivity of the overall product (Blond et al., 2013 and GRI GC15). From Saunier et al. 2010, it has been shown that the flow capacity of the Drain Tube drainage geocomposite is not load or time sensitive when confined in soil. Figure 2 shows laboratory test results that have been carried out up to 2,400 kPa (50,000psf) on the product which represents a 120 m (390 ft.) high soil embankment (Figure 2).

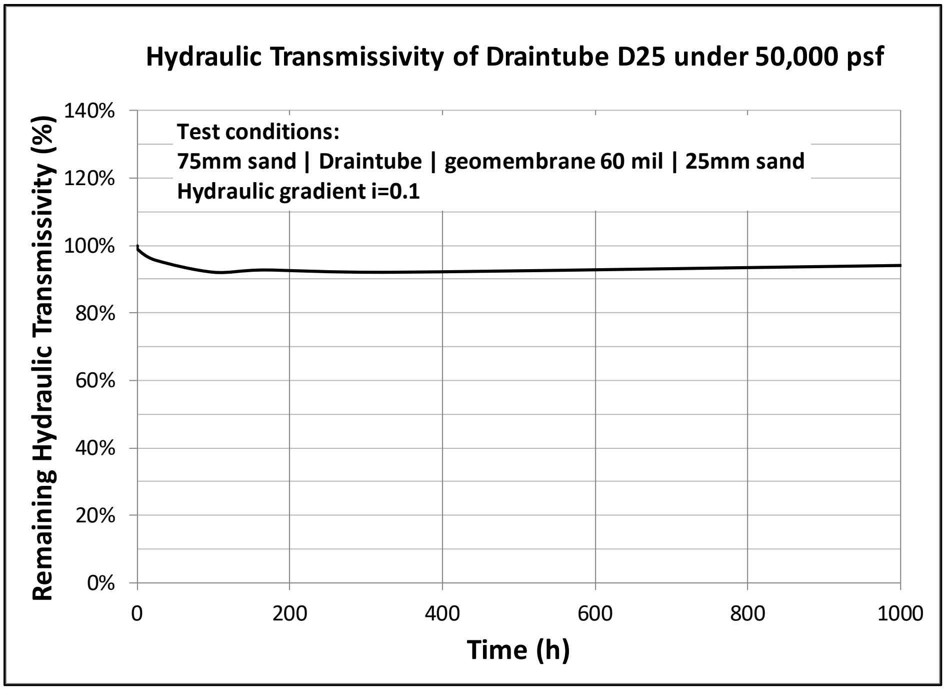

Figure 2. Remaining transmissivity under 2,400 kPa after 1,000 hours

Mechanical characteristics

Mechanical properties of the drainage geocomposite must be selected as a function of the drainage application, the installation conditions and the soil in which the product is in contact. The tubular drainage geocomposite is made with adapted short staple fibers geotextiles, from 200 g/m^2 (6 oz/sy) to 900 g/m^2 (26 oz/sy) or above. The elongation at break of the product is always greater than 50% (ASTM D4632) making the product flexible to provide a good connection with the subgrade soil when installed. The mini-pipes have a pipe stiffness at 5% deflection over 3,000 kPa (435 psi) (ASTM D2412).

DRAINAGE UNDER EMBANKMENT ON SOFT SOILS

Project description

One of the High-Speed Lines (HSL) constructed in France in 2008 (LGV – Rhin Rhône), crossed numerous compressible areas as well as bridges and made the preloading of the embankments necessary. These preloading embankments included vertical wick drains with a tubular drainage geocomposite on top as a horizontal drainage base layer. The major preloading embankments were 7.5 m (25 ft.) high and more than 40 m (130 ft.) wide. Subgrade was composed of loess on the first 4 m (13 ft.), sandy soil from 4 m (13 ft.) to 6.5 m (21 ft.) then clayey soil from 6.5 m (21 ft.) to 11 m (36 ft.).

Expected settlements were estimated to be from 4 to 9 cm (1-1/2 to 3-1/2 in.). The length of the vertical drains was set at 11 m (36 ft.) with a square grid of 1.2 m x 1.2 m (4 ft. x 4 ft.). The tubular drainage geocomposite was unrolled directly on the wick drains.

Completion of works

After the removing of the topsoil layer, the vertical wick drains were driven into the ground as required as depicted in Figure 3 and 4 below.

Figure 3 and 4. Installation of the vertical wick drains.

When topsoil removal was completed, the Drain Tube drainage geocomposite was unrolled perpendicularly to the railway line and overlapped the wick drains (Figures 5 and 6). The mini-pipes of the product have a diameter of 20 mm (3/4 in.) and a spacing of 0.50 m (20 in.) center-to-center. The geocomposite collects the water from the wick drains and drains it to ditches on each side of the embankment.

Figure 5 and 6. Installation of the Drain Tube

The embankment was placed directly on the drainage geocomposite to the final level.

Monitoring and results

The sub-base was monitored using profilometers to measure settlements over time and choose the correct moment to remove the overload. Examples of settlement measurement values are indicated in Figure 7.

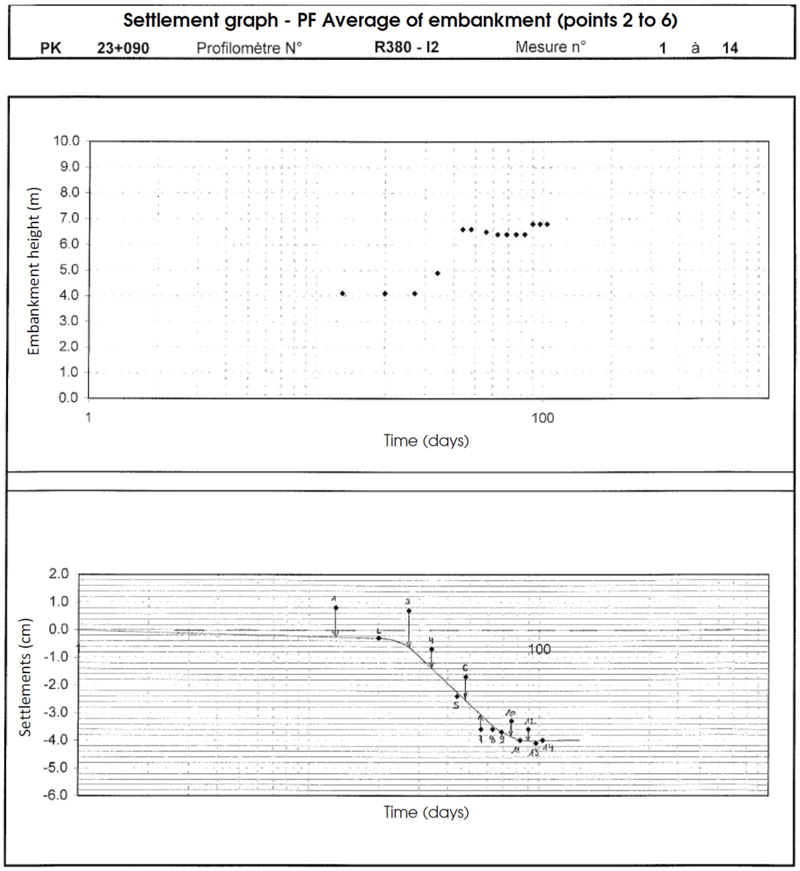

Figure 7. Example of settlement over time of the subgrade

The measured settlements did not exceed 4 cm (1-1/2 in.) which was lower than the estimated limit, in addition the effective consolidation time was about 3 months. The use of a drainage geocomposite for horizontal drainage instead of a granular layer offered consistent performances and reduced the cost of the preloading embankment construction as granular material should have been extracted and transported from the carrier to the site resulting in a heavy truck traffic in and around the work site. In comparison, one full truck can carry enough Drain Tube geocomposite to cover an area of 100,000 sf.

CUT SECTIONS

In earthmoving, cut sections involved large and high slopes to obtain stability and avoid landslides. In case of groundwater, drainage masks using granular material imply to carry and install a large amount of materials. The use of a drainage geocomposite for subsurface drainage reduces that need of granular material.

Installation

The drainage geocomposite is unrolled directly on the subgrade with the mini-pipes in the direction of the slope. It is anchored on top of the slope and connected to a French drain at the toe. The backfill is then placed on top of the product from the bottom to the top (Figures 8 and 9). The drainage geocomposite does not provide additional strength resistance for the stability of the slope.

But due to the non-woven needle-punched geotextile layers of the product, the geocomposite/soil interface angle is generally the same as the internal friction angle of the soil in contact.

Figure 8 and 9. Drainage mask construction with drainage geocomposite

Monitoring and results

On a new HSL constructed from 2013 in France (LGV Est), monitoring has been conducted to evaluate the two solutions: drainage layer made with granular material and made with Drain Tube drainage geocomposite. Two areas of 525 m^2 (5,650 sf.) each have been monitored with temperature sensors, water content gauges at the interface, and flowmeters (Heili et al., 2014). Details are shown on the Figure 10. The mini-pipes of the product have a diameter of 25 mm (1 in.) and a spacing of 0.50 m (20 in.) center to center.

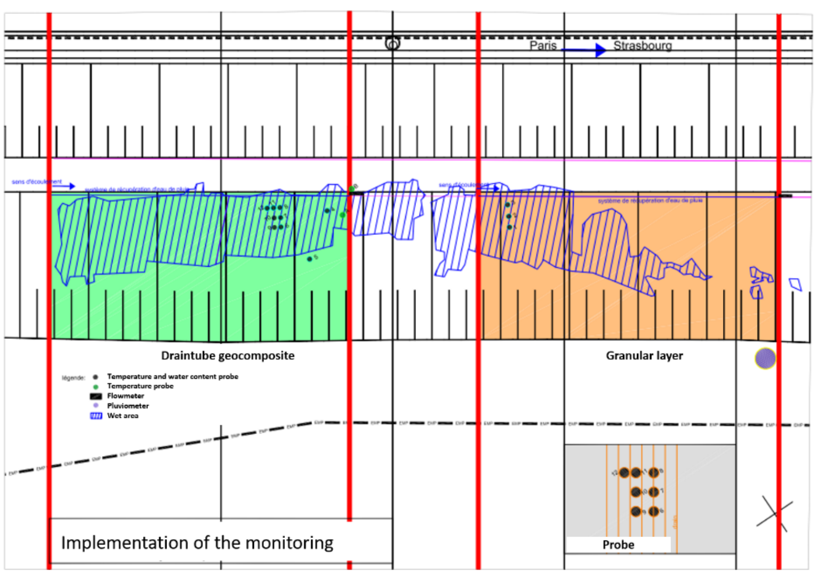

Figure 10. Monitoring

The water content monitoring for both solutions is shown on the Figures 11 and 12. It can be observed that the water content remains stable between 20% and 40 % at the gravel / soil interface and between 20% and 27% at the geocomposite / soil interface. These results show that both drainage systems perform well keeping the soil above unsaturated.

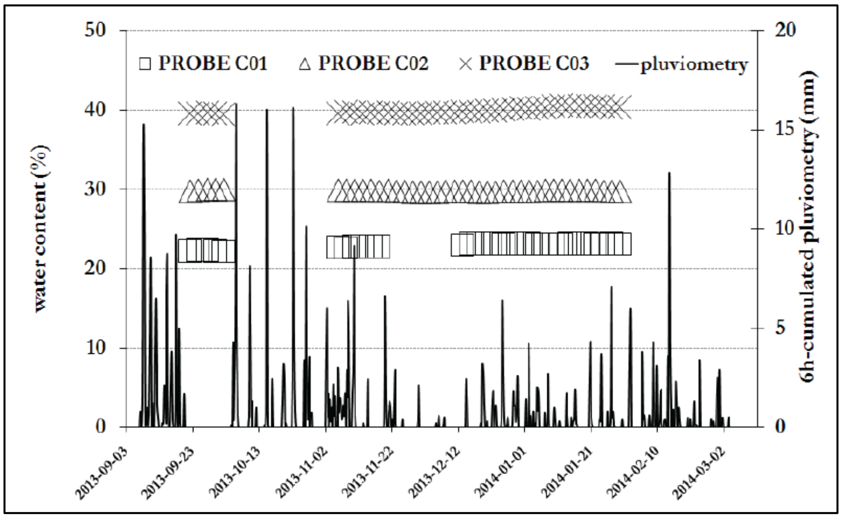

Figure 11. Water content at gravel / soil interface

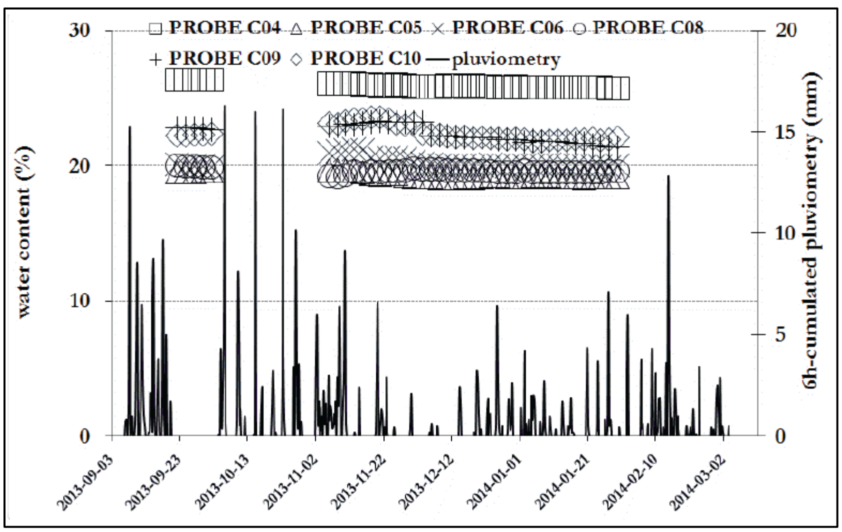

Figure 12. Water content at geocomposite / soil interface

DRAINAGE IMPROVEMENT UNDER RAILWAYS

Project description

Within the scope of work for some track reconfigurations, alternative drainage systems are used given the limited space available in certain track corridors. A drainage geocomposite with 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.

A Canadian National Railways project located in Quebec in 2016, required two tracks to be drained into either an open ditch or a ballast drain installed approximately 1 meter (3 ft.) below track level. Without a proper drainage system, potential drainage problems and a shortened life for the ballast would occur. The tubular drainage geocomposite was placed directly under the ballast (Figure 13). The mini-pipes in the product had a diameter of 20 mm (3/4 in.) and a spacing of 0.25 m (10 in.) center to center.

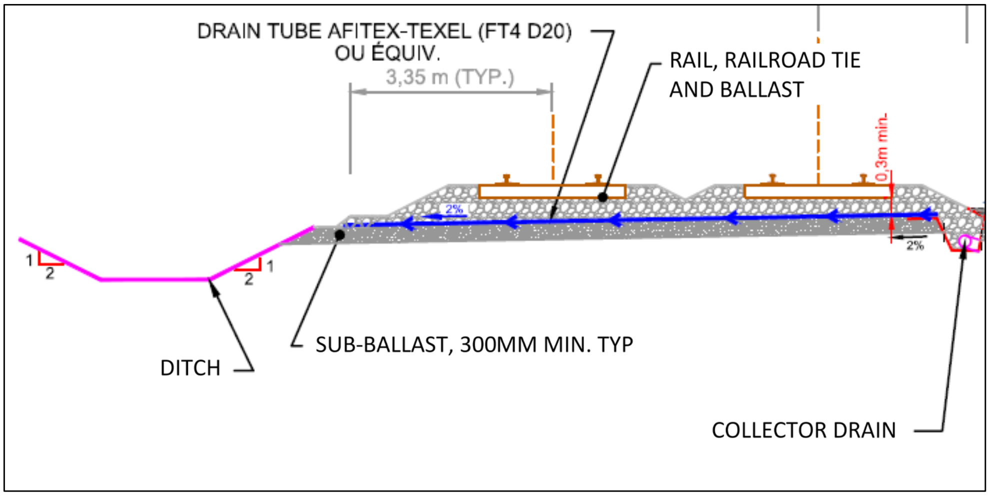

Figure 13. Typical cross section

Completion of works

The Drain Tube drainage geocomposite were unrolled perpendicular to the tracks directly on the MG-56 subgrade soil (Figure 14). After which the ballast was installed in two layers of 150 mm each (Figure 15).

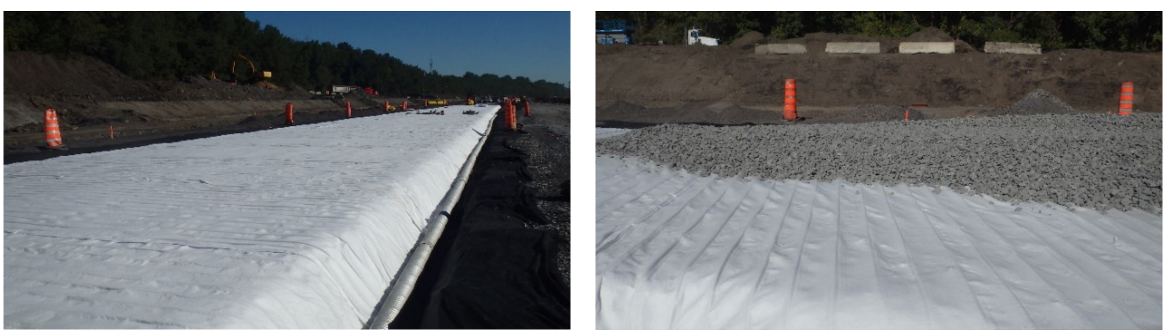

Figure 14 and 15. Installation of the geocomposite and backfilling with ballast

The product was designed to have the ability to evacuate rainfall of 661 mm/day with the mini-pipes staying unsaturated (Ruel et al., 2018). The 100 years return period rainfall in Quebec is 156 mm/day. Assuming that all the rainfall is drained only by the geocomposite, the drainage capacity is more than 4 times greater than what is required, taking into account the long term hydraulic behavior of the geocomposite under the critical conditions of the application.

Laboratory study

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 16), it was shown that multi-linear drainage geocomposite Draintube enables rainfall to evacuate faster than a homogeneous drainage layer (Figure 17). This is due to the directional aspect of the product. The water is drained into the mini-pipes even in the situations when the slope is zero.

Figure 16. Inclinable open box with rainfall simulator

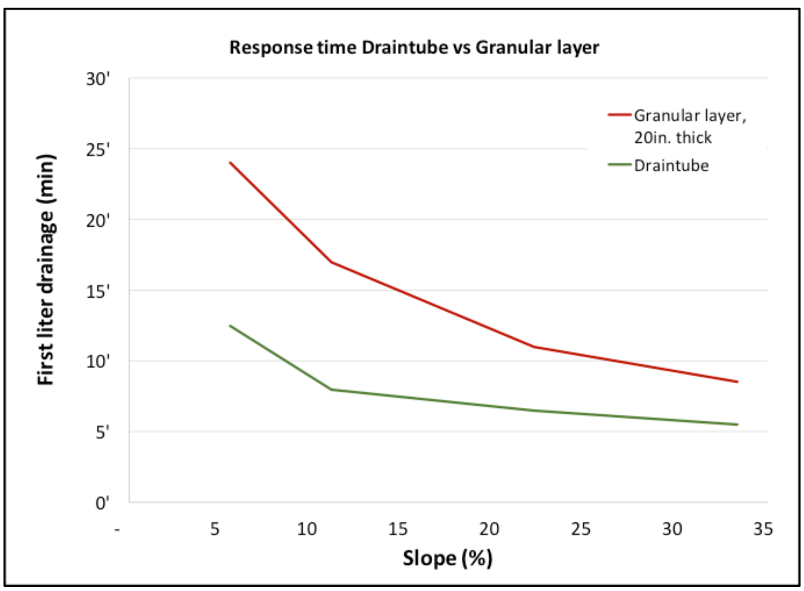

Figure 17. Drainage response time Drain Tube vs granular layer

That behavior is significant for low slopes, where the rainfall water must be evacuated rapidly before building up into the overlying layer or infiltrating into the subgrade.

CONCLUSION

Tubular drainage geocomposites have been used successfully on many earthworks projects and more specially on railways construction projects. Depending on the project and the design consideration, it is used either for drainage under embankments and subsurface drainage on cut slopes as a replacement of the granular layers or for drainage improvement under railway tracks.

Its main useful characteristics, on an installation point of view, are its flexibility and robustness. Other advantages include its long term remaining drainage capacity, even under high loads, and its faster response time compared to a homogenous drainage layer. All this makes the Drain Tube geocomposite efficient and safe given its designed performances.

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