

COMPARISON BETWEEN HORIZONTAL DRAINAGE USING NATURAL GRANULAR MATERIAL AND USING INTERDRAIN GEOCOMPOSITES

CONTENTS:

1. INTRODUCTION
2. FINANCIAL COMPARISON
3. COMPARISON OF DRAINAGE CAPACITIES

1. INTRODUCTION

Horizontal drainage in earthworks (roads and railways) is included in the recent Circular Order 17/2003 "Recommendations for planning and constructing the underground drainage in road works" as a measure to:

- intercept flows or surges of underground water.
- layers for draining infiltrated rainwater (landfill, roads, surfaced and unsurfaced tracks, sports pitches, gardens, etc.).
- intercept capillary ascent (preventing freezing in the ground, damp, etc.).
- reduce water tables (jointly with trench drains).
- rapid consolidation of soft earth using strip drains or columns of gravel or sand.
- construction of embankments and other structures on soft earth saturated with water (marshes, high W.T., etc.).
- drainage of filtrations of underground water into buried structures.

As included in Order Circular 17/2003, horizontal drainage blankets can be created with granular materials and with drainage geocomposites. This Technical Study compares the two solutions – traditional and with INTERDRAIN drainage geocomposites highly resistant to crushing, from technical and financial points of view.

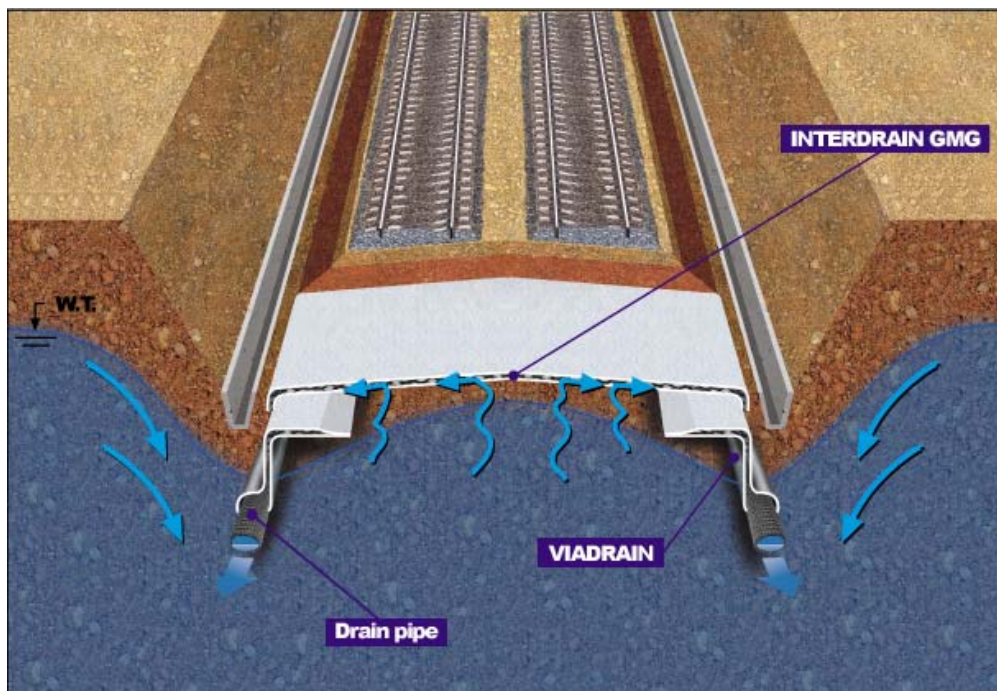


Figure 1. Example of water table reduction using the combination of INTERDRAIN GMG and VIADRAIN GMG geocomposites for longitudinal trench drainage. *Source: INTERMAS Nets SA*

This calculation is the result of our revised and corrected knowledge. INTERMAS refuses to accept any responsibility deriving from its use in works schemes and provides it purely for information purposes.

2. FINANCIAL ANALYSIS

This section will compare the financial cost of horizontal drainage using a 30 cm thick granular layer and an INTERDRAIN GMG 512 geocomposite.

2.1. COST OF HORIZONTAL GRANULAR DRAINAGE BLANKET

The financial cost of making a 30 cm thick granular drainage blanket surrounded by 2 filtering and protective geotextiles of 300 g/m² is given here:

m ²		Fitting polypropylene geotextiles in earthworks as filtering and protective elements		
Supply and fitting in earthworks of unwoven geotextiles made up of mechanically joined polypropylene filaments, with a grammage of 300 g/m ² and CBR of 2.8 kN				
Rate	U	Description	Price	Total price
0.03	h	Ordinary workers	13.53	0.41
1.10	m ²	Unwoven thermowelded polypropylene geotextile of 300 g/m ² and CBR=2.8 KN	1.30	1.43
3.00	%	Indirect costs	1.84	0.06
Total fitting for top geotextile				1.89
m ²		Supply and fitting of 30 cm thick horizontal layer of gravel		
Supply and fitting in earthworks of drainage layer of granular material with minimum permeability of k=10 ⁻³ m/s				
Rate	U	Description	Price	Total price
0.10	h	Foreman	15.64	1.56
0.10	h	Ordinary workers	13.53	1.35
0.33	m ³	Layer of drainage material (K>10 ⁻³ m/s) 0.3 m thick	14.00	4.62
3.00	%	Indirect costs	6.18	0.19
Total for fitting gravel				7.72
m ²		Fitting polypropylene geotextiles in earthworks as filtering and protective elements		
Supply and fitting in earthworks of unwoven geotextiles made up of mechanically joined polypropylene filaments, with a grammage of 300 g/m ² and CBR of 2.8 kN				
Rate	U	Description	Price	Total price
0.03	h	Ordinary workers	13.53	0.41
1.10	m ²	Unwoven thermowelded polypropylene geotextile of 300 g/m ² and CBR=2.8 KN	1.30	1.43
3.00	%	Indirect costs	1.84	0.06
Total for fitting top geotextile				1.89
Total for gravel (€/m²)				11.50

This part does not include:

- surface preparation (site clearance, compacting, formation of slopes, etc.)
- additional digging of 0.3 m
- grooved drainage pipe
- longitudinal trench drain (French drain type)

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2.2. COST OF THE INTERDRAIN GMG 512 HORIZONTAL DRAINAGE BLANKET

The cost of a geosynthetic drainage blanket made up of INTERDRAIN GMG 512 is attached here:

m ² Horizontal drainage of bases of cuttings or embankments using INTERDRAIN GMG 512 geocomposite with high resistance to crushing				
Horizontal drainage by fitting INTERDRAIN GMG 512-type drainage geocomposite with resistance to crushing of 1250 kPa (ASTM D 1621) and drainage capacity (ISO 12958) of 1.16 l/m-s at 20 kPa (i=1) and 0.74 l/m-s at 200 kPa (i=1) made up of a geonet 5 (mm) thick of HDPE with two unwoven PP geotextiles, thermowelded on both faces on a horizontal or almost horizontal surface previously levelled and regularised. It includes the overlaps between rolls, fixings and other elements necessary for proper installation. The grooved drain pipe is not included.				
Rate	U	Description	Price	Total price
0.03	h	Foreman	15.64	0.47
0.03	h	Ordinary workers	13.53	0.41
1.10	m ²	INTERDRAIN GMG 512 drainage geocomposite with resistance to crushing greater than 1250 kPa and drainage capacity of 1.16 l/m-s at 20 kPa (i=1) and 0.74 l/m-s at 200 kPa (i=1)	5.25	5.78
1.00	m ²	Additional elements for fitting drainage geocomposite over waterproofing or natural earth	0.10	0.10
3.00	%	Indirect costs	6.75	0.20
Total GMG 512 section (€/m²)			6.95	

This part does not include:

- surface preparation (site clearance, compacting, formation of slopes, etc.)
- grooved drainage pipe
- longitudinal trench drain VIADRAIN GMG 512 type

2.3. FINANCIAL COMPARISON BETWEEN THE TWO SOLUTIONS

- Fitting a horizontal drain using a 30 cm layer of gravel surrounded by two 300 g/m² geotextiles costs € 11.50/m².
- Fitting a horizontal drain using INTERDRAIN GMG 512 costs € 6.95/m²

Comparing the two solutions, the result obtained shows drainage with gravel is 60% more expensive than the solution with INTERDRAIN.

- $\gamma = \text{Cost 30 cm gravel drain} / \text{Cost GMG 512 drain} = 11.50 / 6.95 = 1.65$

If a 50 cm layer of gravel is used, the total cost would increase to € 14.60/m², more than double the cost of the solution with INTERDRAIN.

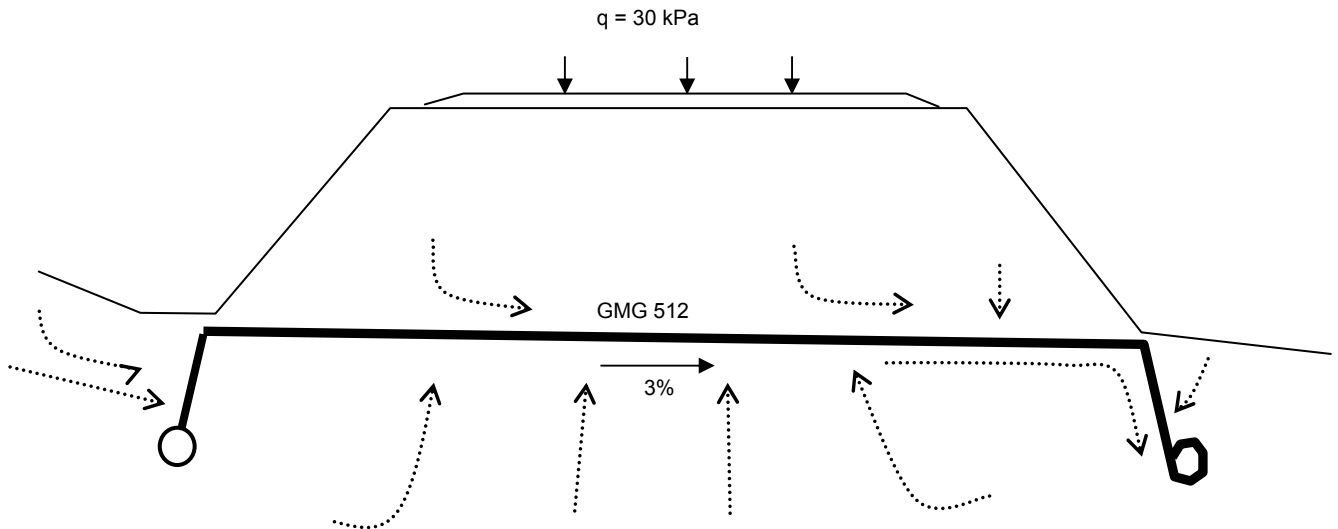
- $\gamma = \text{Cost 50 cm gravel drain} / \text{Cost GMG 512 drain} = 14.60 / 6.95 = 2.10$

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3. COMPARISON OF DRAINAGE CAPACITIES

This section will compare the drainage capacity of a 50 cm thick granular layer surrounded by two filtering and protective geotextiles, with the drainage capacity of INTERDRAIN GMG 512 drainage geocomposite, at the base of a railway embankment.

3.1. DIAGRAM



3.2. DESCRIPTION OF THE GRANULAR DRAIN FOR DRAINING THE BASE OF A RAILWAY EMBANKMENT

The granular drain will be 50 cm thick and will be made up of clean gravel surrounded by two geotextiles acting as filtering and protective elements. It will work under an embankment 13 m high. A high-speed train will run on top of the embankment (additional load = $q = 30 \text{ kN/m}^2$). The maximum permeability of this gravel, taking into account the minimizing action of the geotextile, is $k = 1 \cdot 10^{-3} \text{ m}$

The transversal slope of the drainage system will be 3% to facilitate the removal of the water.

3.3. CALCULATION OF THE DRAINAGE CAPACITY OF THE 50 cm THICK GRANULAR DRAIN

The maximum drainage capacity of the granular drain is estimated using Darcy's equation:

$$Q = K \cdot A \cdot i \quad (\text{m}^3/\text{s})$$

$$q = K \cdot e \cdot i \quad (\text{m}^3/\text{s} \cdot \text{m})$$

Where:

- k = Maximum permeability of the granular material = $1 \cdot 10^{-3} \text{ m/s}$
- A = Section of the granular drain (m^2)
- e = Thickness of the granular drain = 0.5 m
- i = Hydraulic gradient = 0.03 (corresponds to the transversal slope)

$$q_{\text{GRAVEL}} = K \cdot e \cdot i = 1 \cdot 10^{-3} \cdot 0.5 \cdot 0.03 = 3 \cdot 10^{-5} \text{ m}^2/\text{s} = \mathbf{0.015 \text{ l/m/s}}$$

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3.4. CALCULATING THE INTERDRAIN GMG 512 DRAINAGE CAPACITY

The INTERDRAIN drainage capacity can be calculated by using the ISO 12958 Standard (Transmissivity Test) and it depends on the perpendicular pressure on the INTERDRAIN plane and on the hydraulic gradient.

3.4.1. Calculating the pressure on the drainage geocomposite

The maximum pressure on the drainage geocomposite (due to the embankment weight) is:

$$\sigma_v = [\gamma \cdot h + q] \quad (\text{vertical pressures})$$

Where:

- h = maximum depth = 13 m
- q = additional vertical overload = 30 kN/m² = 30 kPa
- γ = density of the ground = 20 kN/m³

$$\sigma_v = [\gamma \cdot h + q] = [(20 \cdot 13) + 30] = 290 \text{ kN/m}^2 = 290 \text{ kPa}$$

For calculation purposes, a conservative pressure value of **300 kPa** will be used.

3.4.2. Calculating the hydraulic gradient (i)

The hydraulic gradient corresponds to the transversal slope of the site: **i=0.03**.

3.4.3. Drainage capacity of the GMG 512 INTERDRAIN drainage geocomposite

The INTERDRAIN GMG 512 drainage geocomposite must drain more than 0.015l/m/s

$$q_{\text{GMG 512}} (\sigma = 200 \text{ kPa}, i = 0,1) = 0.17 \quad (\text{ISO 12958, hard/hard})$$

$$q_{\text{GMG 512}} (\sigma = 400 \text{ kPa}, i = 0,1) = 0.12 \quad (\text{ISO 12958, hard/hard})$$

$$q_{\text{GMG 512}} (\sigma = 300 \text{ kPa}, i = 0.1) = 0.14 \quad (\text{interpolation})$$

To estimate the drainage capacity of INTERDRAIN GMG 512 on various gradients, Rimoldi's experimental formula is used:

$$q_{i2} = q_{i1} \cdot \frac{\sqrt{i_2}}{\sqrt{i_1}} \quad (\text{Rimoldi, 1989})$$

Where:

- q_{i1} : drainage capacity corresponding to the gradient tested i_1 (m³/s·m)
- q_{i2} : unknown drainage capacity corresponding to the untested gradient i_2 (m³/s·m)
- i_1 : tested hydraulic gradient immediately above the untested gradient i_2
- i_2 : Hydraulic gradient corresponding to the desired drainage capacity.

We obtain:

$$q_{\text{GMG 512}} (300 \text{ kPa}, i=0,03) = 0.14 \cdot \sqrt{\frac{0,03}{0,1}} = 0.076 \text{ l/s·m}$$

3.5. CALCULATING THE SAFETY FACTOR

The safety factor of the GMG 512 drainage geocomposite compared with the granular drain is:

$$\text{S.F.} = q_{\text{GMG 512}} / q_{\text{GRAVEL}} = 0.076 / 0.015 = 5$$

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