Hydrological analysis and sizing of the landfill stormwater drainage system

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INTRODUCTION

This report supports the application by "Frisoli s.r.l." for an Environmental Permit to the alteration to the internal lateral landfill profile to extend the Ghallis landfill capacity in Malta.

The subject of this study regards the sizing and design of meteoric drainage pipes within the implementation of the expansion of the landfill. The analysis contains the description of the model and the results achieved in terms of estimation of the critical flow and subsequent verification of project artefacts.

The analysis considers the available Malta rainfall statistics and climatic data in order to properly size the lateral drainage pipeline concerning Frisoli's intervention.

The study contains also the equivalence between the GCD, utilized for this application into the capping system over the patented retaining structures and related to the meteoric waters, and the natural drainage layer.

MALTA'S CLIMATE WITHIN A GEOGRAPHICAL CONTEXT

Malta's climate can be described in the context of the topography of the Mediterranean basin where the flow of the lower atmosphere into the basin occurs mainly through mountain gaps, except over the southern shores east of Tunisia.

The seasonal features of the Mediterranean can be traced from the motion and development of the pressure systems over the Atlantic, Eurasia and Africa. While the Mediterranean spring is often a period of indecisive weather, summer is characterised by the intensification of the Azores High which tends to stably extend up to the Central Mediterranean, giving general weather conditions consisting of light surface winds ranging from the northwest to northeast. Autumn is relatively short and leads to wintry conditions in a fairly decisive and quick way. During this season Atlantic depressions move eastwards across northern Europe into the Mediterranean bringing with them waves of cold air. In its path, this cold air comes into contact with warm moist air causing vertical instability, the development of vigorous depressions, rainfall and frequent gales. From time to time the eastward march of travelling depressions is interrupted by cold air coming from the Arctic via the Norwegian Sea or Russia. This great thermal contrast leads to very active depressions.

In the Central Mediterranean region both Sicily and the Tunisian peninsula may play an important part on the local weather. Under certain prevailing conditions Sicily can act as a barrier against strong low-level northerly winds. This Italian island can also create local instabilities due to land heating effects or heat lows which may be advected towards the Maltese Islands depending on the prevailing winds.

Transient North African low pressure systems have the potential to produce strong winds over the Central Mediterranean. When for example North African lows occur south of the Atlas Mountains, strong easterly to southeasterly winds are likely over the Central Mediterranean resulting in high seas.

The presence of the surrounding water mass shapes significantly the climate of the Maltese Islands. The general weather is often cooler and more humid than what is experienced in inland areas of larger land masses. The high thermal capacity of the sea also reduces large fluctuations in the ambient temperature of the islands. But the presence of surrounding warm waters during the end of the summer season is a source of major weather instability when colder air migrates into the Central Mediterranean, thus creating areas with heavy thunderstorms and intense precipitation.

Advances of continental tropical air into the Central Mediterranean after a cold spell can give rise to active warm fronts, sometimes producing very active cumulonimbus clouds, copious rainfall and thunderstorm over the Maltese Islands. A period of sirocco in the Central Mediterranean, sometimes lasting for many days, often follows the first autumnal invasion of cold air.

AMBIENT AIR TEMPERATURE

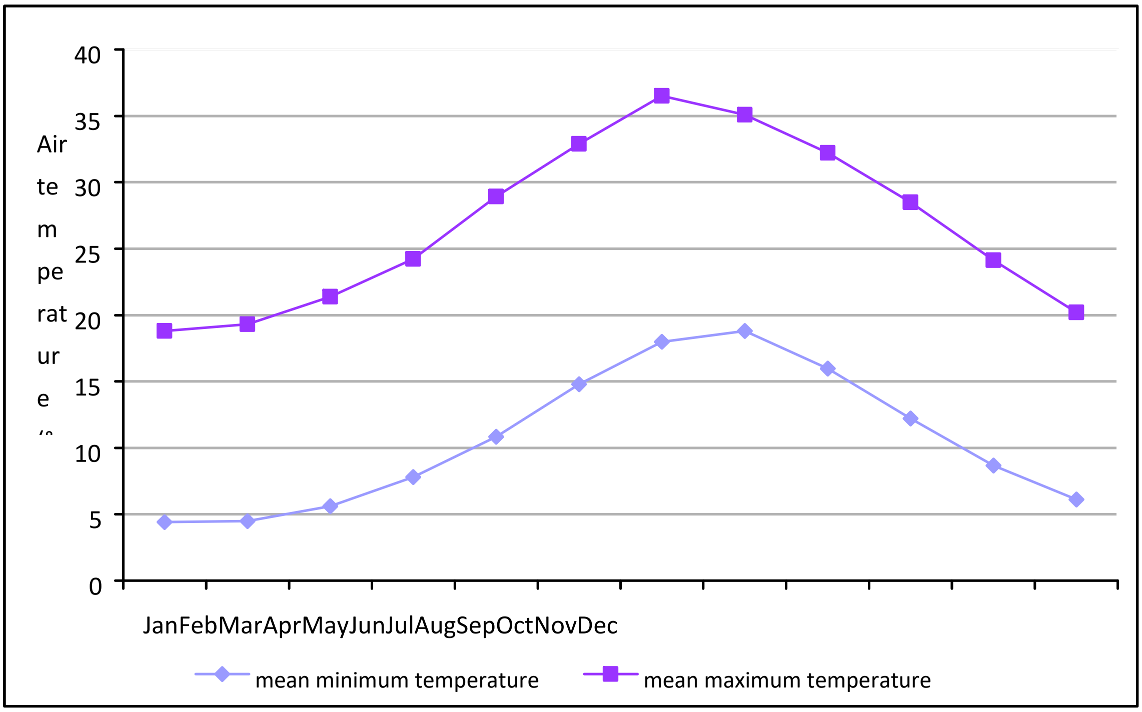
The climate normals related to temperature are based on the following weather variables: (1) the daily mean temperature, (2) the daily maximum temperature, (3) the night minimum temperature, and (4) the grass-height minimum temperature.

At Luqa Airport standardised instrumentation used to measure the air temperature has changed with time, ranging from dedicated thermometers for the measurement of the maximum and minimum air temperatures housed in appropriate screens, to calibrated shielded thermocouples mounted on masts at standard height.

Figure 1 shows the monthly variation of the average minimum and maximum air temperature, while tables 1 and 2 provide information on the monthly mean maximum and minimum temperatures, together with the value and year of occurrence of temperature extremes for the period 1947-2017. Table 1 shows that while July has the highest mean maximum temperature, the highest extreme temperature was reached on 9 August 1999 when the mercury soared to 43.8°C, making this the hottest day recorded in Malta since 1947. Table 2 indicates that on average the lowest winter temperatures occur in February. However, the lowest ever recorded temperature occurred on 29 January 1981 when the minimum temperature fell to 1.4 °C.

Figure 1. Mean minimum and maximum air temperature

(Based on the 30-year climate period 1961-1990)



Data collected by the Malta Airport MetOffice

Table 1. Mean maximum, extreme maximum temperature, and occurrence during the period 1947-2017

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean maximum temperature (ºC)	18.72	19.40	21.97	24.67	29.31	33.59	36.38	35.77	32.39	28.64	24.39	20.42
Highest maximum temperature (ºC)	22.2	26.7	33.5	30.7	35.3	40.1	42.7	43.8	37.4	34.5	28.2	24.3
Year of highest maximum temperature	1982	1960	2001	1985	2006	1997	1988	1999	1990	1999	1998	1963

Data collected by the Malta Airport MetOffice

Table 2. Mean lowest, extreme minimum temperature, and occurrence during the period 1947-2017

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean minimum temperature (°C)	4.96	4.80	5.89	7.91	11.26	15.19	18.45	19.22	16.53	12.89	9.02	6.48
Lowest minimum temperature (°C)	1.4	1.7	2.2	4.4	8.0	12.6	15.5	15.9	13.2	8.0	5.0	3.6
Year of lowest minimum temperature	1981	1956	1949	1956	1970	1975	1980	1972	1969	1978	1995	1967

Data collected by the Malta Airport MetOffice

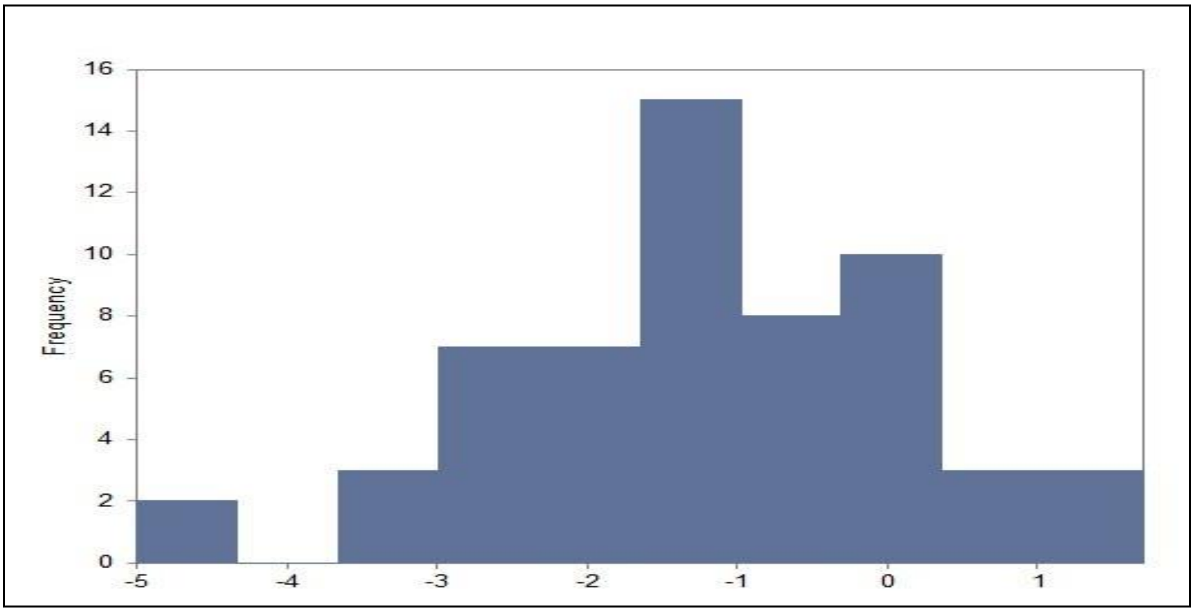
The grass-height minimum temperature is another variable that has been recorded by the Malta Airport MetOffice since 1953. The mean monthly temperature at grass-height follows the same pattern as the minimum air temperature. Table 4 shows that since 1953 the lowest mean grass-height temperature has been recorded during the months of January and February. During the period 1953-2017 the lowest minimum grass-height temperature was recorded on 4 February 1983 when the temperature dropped to -5.1 °C. Data collected since 1953 show that the average lowest grass temperature is -1.3 °C with a standard deviation of 1.4 °C. Freezing temperatures of around -1.3 °C constitute the highest frequency during the period 1955-2017 (figure 3).

Table 3. Mean lowest grass-height minimum temperature, extreme minimum, and occurrence during the period 1953-2017

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean minimum grass temperature (°C)	-0.1	-0.1	0.9	3.1	6.3	10.3	13.8	15.0	12.8	8.9	4.5	1.7
Lowest minimum grass temperature (°C)	-5.0	-5.1	-3.6	-0.5	2.0	6.1	10.0	10.9	7.3	3.0	-0.6	-3.0
Year of lowest minimum grass temperature	1966	1983	1982	1965	1970	1978	1970 and 1982	1968	1979	1978	1955	1967

Data collected by the Malta Airport MetOffice

Figure 2. Histogram for the most frequent lowest minimum grass temperature ranges
(Based on the period 1953-2017)



Data collected by the Malta Airport MetOffice

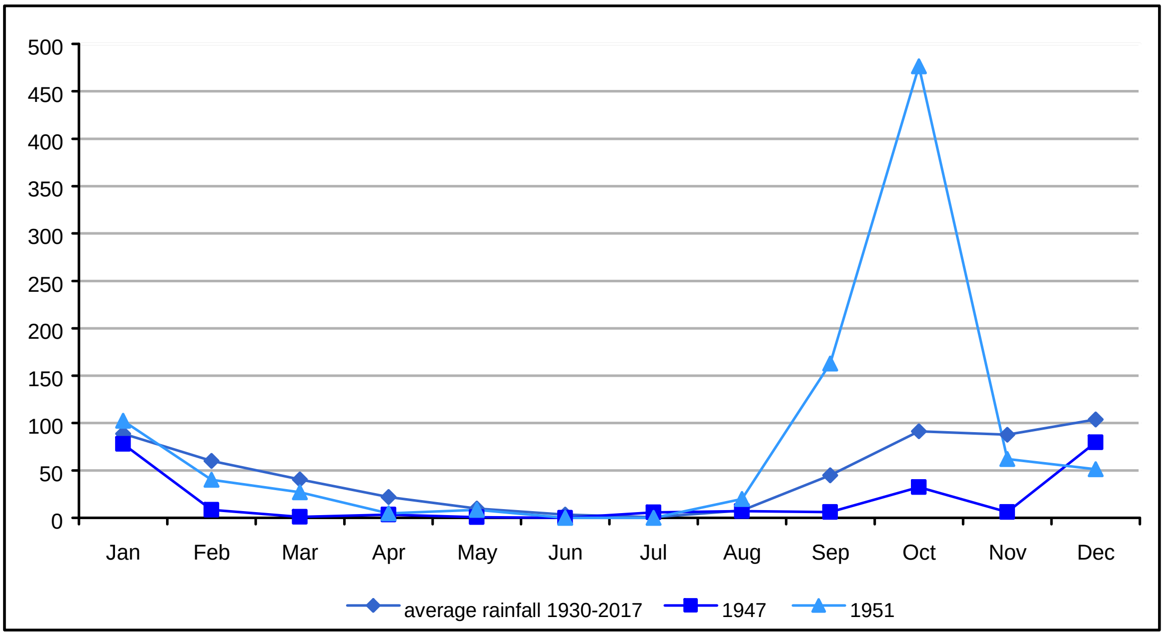
The most common forms of local precipitation include rain, hail, dew and soft rime. Meteorological observations for rain and dew are made by means of calibrated standard rain gauges that measure precipitation at regular intervals. This technique assumes that the amount of precipitation collected per unit area of the gauge's aperture is the same as the amount falling on the surrounding surface per unit area. Since 1947 these rain gauges have been and are still situated at Luqa Airport. Currently, rain gauges with tipping-buckets connected to electronic sensors are used by the MetOffice.

Because of the lack of updated statistical data, following are presented only the available updated data related to precipitation in Malta.

Data gathered by the Malta Airport MetOffice show that the driest year was 1947 when 228.41 mm of precipitation fell over Luqa Airport. Four years later, in 1951, a record maximum of 955.62 mm was registered at the same site.

For comparative purposes, figure 3 shows the monthly precipitation totals of 1947 and 1951 alongside the average monthly total precipitation registered during the period 1930-2010.

Figure 3. Total monthly precipitation of the driest and wettest years compared with the 1930-2017 average



Data collected by the Malta Airport MetOffice

Table 4 shows the highest precipitation ever recorded on a monthly basis over the Maltese Islands during the period 1922-2010 in comparison with the mean monthly precipitation of the same period. The highest amount of monthly precipitation ever recorded was of 476.50 mm, which fell during October 1951.

Table 4. Mean monthly precipitation, maximum and occurrence during the period 1922-2017

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly precipitation (mm)	87.75	60.53	42.73	22.10	9.92	3.12	0.49	7.31	42.94	86.28	87.73	102.48
Highest monthly precipitation (mm)	248.20	187.90	178.00	118.40	49.10	76.20	18.00	155.50	266.90	476.50	420.30	302.60
Year of highest monthly precipitation (mm)	2009	1965	1925	1994	1976	2007	1959	1964	1997	1951	1999	1970

Data collected by the Malta Airport MetOffice

The total amount of precipitation recorded in 24 hours is a good indicator of the vigour and duration of storms. The climatological trend of the total amount of precipitation recorded in 24 hours shows that, undoubtedly, November has the greatest variability which is attributed to convective storms triggered by the movement of the continental air mass from the North African region over cooler areas in the Central Mediterranean.

Data gathered by the Malta Airport MetOffice show that the maximum rainfall in a day was registered on October 24 (2010) with 102.2 mm.

RATIONAL MODEL

For the hydraulic dimensioning of the rainwater drainage pipes related to the Frisoli's intervention area, it is fundamental to identify the peak flow capacity that these pipes must be able to sustain.

This calculation is difficult because there are multiple factors, not easy to identify. Among these factors, due to the particular role, it should be considered the extension of the catchment basin, the nature of the lands that constitute it and the rainfall intensity. For the determination of the rainfall intensity and the peak flow rates, it can be used rational and/or synthetic models, both largely utilized in hydraulic.

In this case, it has utilized a rational model, more appropriate, based on the probability theory and referring to the return period T. The return period, also known as a recurrence interval is an estimate of the likelihood of an event, such as an earthquake, flood, landslide, or a river discharge flow to occur.

It is a statistical measurement typically based on historic data denoting the average recurrence interval over an extended period of time, and is usually used for risk analysis.

For the rainfall analysis, the maximum annual height of rain Ht, in a given time interval t and in a predetermined area of interest, is considered as the characteristic X variable. Based on the observation of an appropriate data series (ht1, ht2, ht3, ht4, ..., Htn), relative to the rain heights measured in an adequate number of years n, and related to the durations t = 1, 3, 6, 12, 24 hours, it is possible to perform a statistical analysis of the phenomenon.

The choice of the most appropriate return time for this case is related to technical-economic considerations that are made through an appropriate cost-benefit analysis; in fact, choosing a certain T value, it is clear that, after this time interval, a more severe meteoric event than the one considered would occur, with the consequence that the sizing of the rainwater drainage pipes is non-sufficient to guarantee, for that critical event, an adequate outflow of the water.

Therefore, it is evident that the return time must be strictly related to the importance of the considered infrastructure. Usually for minor works, whose hypodimensioning with respect to the critical event does not entail any significant economic damage in any case, the return time is less than 25 years, while for large works whose improper functioning could, instead, generate considerable damage (economic, harmful to people, etc.) T time must be assumed even hundreds of years.

The maximum value $h_{t,T}$ of Ht related to the return time T can be estimated using the following pluviometric probability law:

$$h_{t,T} = m_t K_T$$

With:

mt average Ht, function of t time

Kt law of variation (or law of growth) related to time T.

The most used in practice among the other laws of variation is that of Gumbel, for which we have:

$$K_T = (1 - K' \log\ln T/T\text{-}1)/(1+0{,}251K')$$

where K 'depends on the parameter Cv (coefficient of variation) to which it is linked by the following relation:

$$1{,}795/K' = (1/Cv) - 0{,}45$$

Having available an adequate series of n values of rain heights relative to duration t, it is possible to calculate the value of the coefficient of variation associated with it, which results:

$$Cv_t = S_t / \bar{h}_t$$

and, the standard deviation:

$$\sigma_t = \sqrt{\frac{\sum_{i=1}^{N} \left(h_{ti} - \bar{h}_t\right)^2}{N}}$$

and the average ht:

$$\bar{h}_t = \frac{\sum_{i=1}^{N} h_{ti}}{N}$$

being Cv related to t time, results:

$$Cv = \sum_{i=1}^{5} \frac{C_{Vt}}{5}$$

Where Cvt is related to t=1,3,6,12,24 hours.

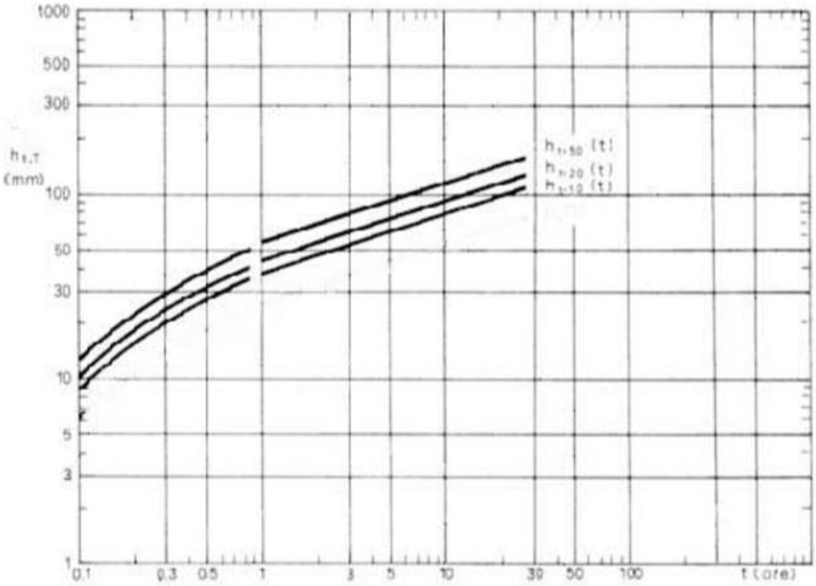
To calculate mt relative to a pre-established duration t, a regression analysis of th on t it is used by the following law:

$$m_t = at^{n}$$

Where a and n can be estimated following the linear model:

$$\log \bar{h}_t = \log a + n \log t$$

In the following figure is shown the diagrams, in logarithmic scale, of the lines relative to the rain heights (varying a and n) for T equal to 10, 20, 50 years.



Knowing the height of rain h and, consequently, the intensity I, it can be immediately determined the flow rate that flows through the end section of the basin with the following:

$$Q = j\ i\,A/3{,}6\ [mc^3/s]$$

Where:

Q = runoff rate (cubic meter per second),

j = Rational Method runoff coefficient,

I = rainfall intensity (mm per hour),

A = drainage area (Km2).

Therefore, after the estimation of the peak runoff flow rate Q, it can be calculated the flow Q ' that the rainfall drainage pipes can support. This flow can be easily obtained using the well-known Chezy formula:

$$v = \chi\sqrt{Rj}$$

where:

v is average velocity [m/s],

R is the hydraulic radius (~ water depth) [m], and

j is the bottom slope [m/m].

where

$$C = \frac{1}{n}R^{1/6}$$

C is the Chézy coefficient [m½/s],

R is the hydraulic radius (~ water depth) [m], and

n is Manning's roughness coefficient.

and:

$$Q = \chi S \sqrt{Rj}$$

If finally, comparing the flow rates Q and Q 'results:

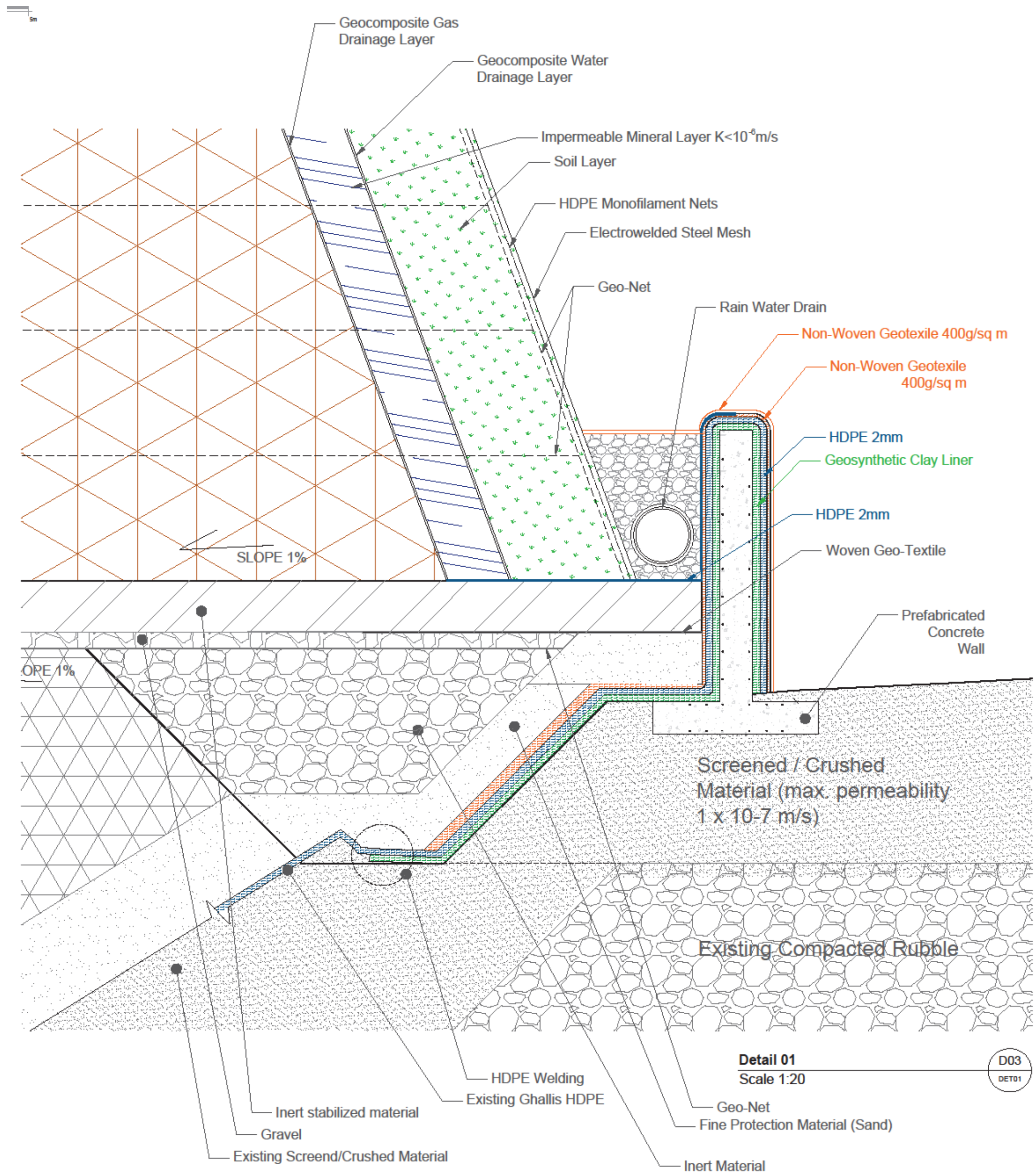
Q'> Q

the rainwater drainage pipes are suitable for guaranteeing, for a given return time T, the runoff of rainwater.

VERIFICATION AND SIZING OF THE RAINWATER DRAINAGE PIPE

It has considered that the rainfall over the external facing of the retaining walls, running on the same external face, it is intercepted by draining pipes placed at the foot of the walls, inside the waterproofed basin.

The flow rate relative to the aforementioned water can be estimated on the basis of the horizontal projection of the surface of the walls, estimated at 3.642 m2. For the sizing of the drainage pipe, reference will be made to a generic pipe with a length equal to that of the perimeter of the intervention area (667 m), along which a drainage pipe will be placed, located inside the external gutter, as shown in the following figure:



Based on the aforementioned precipitation data, it has estimated the peak runoff flow for a time t equal to the time of concentration Tc, calculated with Giandotti formula as follow:

$$t_c = (1.5\,L + 4\,A^{0.5})/[0.8\,(H)^{0.5}]$$

Where:

L = length of channel in meters from the head of the watershed to the crossing point (m),

H = elevation difference between highest point in the watershed and the crossing point (m),

A = drainage area (Km2)

The time of concentration (tc=0,896 h) permits to estimate the height of the rainfall associated to it, equal to:

H(tc) = 65,37 mm

Therefore, the rainfall intensity:

I = h(tc) / tc = 72,94 mm/h

The peak runoff flow is:

$$Q = j\ \ i\,A/3{,}6\ [mc^3/s]$$

j = 0,5 ,

I = 72,94 mm/h ,

A = 0,003642 Km2.

<u>Q = 0,0369 m3/s</u>

After the estimation of the peak runoff flow rate Q, it can be calculated the flow Q ' that the rainfall drainage pipes can support with the Chezy formula, which results:

<u>Q’ = 0,049 m3/s</u>

for a drainage pipe with following characteristics:

PEAD EN 13476 DN Ø [mm] = 200 (diameter)

Finally, comparing the flow rates Q and Q 'results:

Q'> Q

the rainwater drainage pipe is suitable for guaranteeing, for a return time T= 100 years, the runoff of rainwater.

SUPERIMPOSED LOADS

Considering the fact that the pipes are exclusively laid inside a draining layer consisting of gravel for a thickness of maximum 0.5 m without any further loads occurring to them, the draining pipes located at the foot of the retaining structures for waste are excluded from the static analysis.

SUPERFICIAL DRAINAGE SYSTEM

All the above estimates and relative sizing have been carried out in the configuration of the completion of Frisoli works. In this case, it has suggested to adopt for the upper capping system, not of responsibility of this project, a further drainage system considering the drainage area as the entire landfill area, excluding the horizontal projection area of the retaining structures calculated in the present study.

At this regards, it has suggested a superficial drainage capping system to be integrated with the one used by Frisoli s.r.l.. In Foggia landfill, it has studied a superficial drainage system constituted by properly dimensioned ditches covering the entire drainage area as a skeleton.

A brief description of the project is shown below.

COMUNE DI FOGGIA

Tipo Documento: **Progetto Definitivo**	Codice Documento: D.11

LAVORI DI COMPLETAMENTO, MESSA IN SICUREZZA E CAPPING, MEDIANTE LA TECNICA DEI MURI ED ARGINI IN RIFIUTI RINFORZATI, PRESSO LE DISCARICHE c.d. FRISOLI E c.d. ex-AGECOS

SEZIONE D

ELABORATI PROGETTUALI

TAVOLA		SCALA
D.11	PLANIMETRIA COPERTURA E PARTICOLARI COSTRUTTIVI	VARIA

STATO REVISIONI			
Revisione	Data	Descrizione	Liste di distribuzione
A	10/04/2015	Prima Emissione	N/A

PROGETTISTA:	IL D.L.L:	IL R.U.P.:	
RAFFAELE CALABRESE	RAFFAELE CALABRESE	PIO D'ORIA	
	dr. Ing. Raffaele Calabrese	geom. Pio D'Oria	
Data: aprile 2015	Data: aprile 2015	Data: aprile 2015	Data:

PLANIMETRIA COPERTURA
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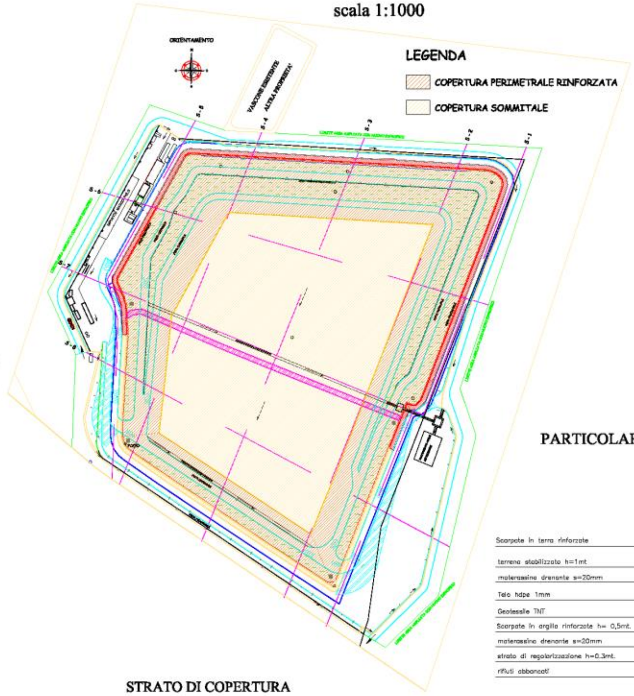

SCARPATA
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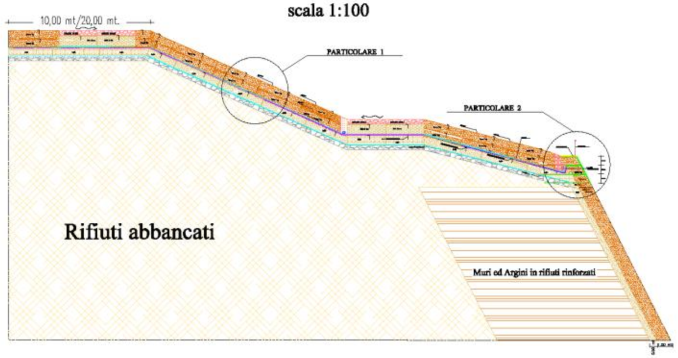

PARTICOLARE N.1 COPERTURA PERIMETRALE
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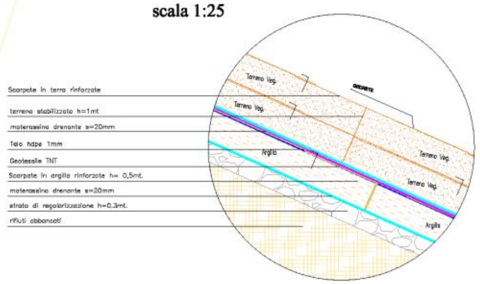

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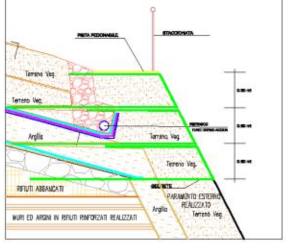

STRATO DI COPERTURA SOMMITALE
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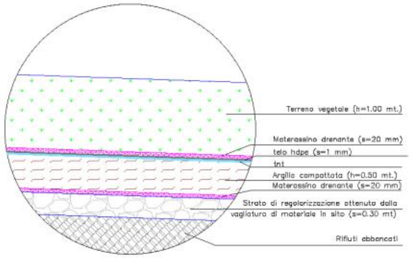

CANALETTA ACQUA PIOVANA ATTRAVERSAMENTO STRADA SOMMITALE
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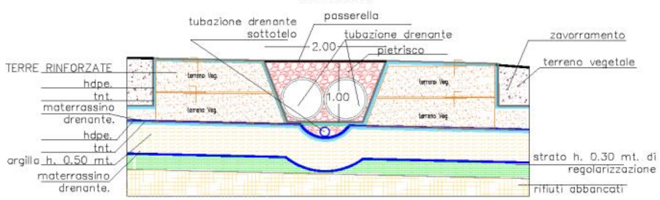


COMUNE DI FOGGIA

Tipo Documento: Progetto Definitivo	Codice Documento: D.12

LAVORI DI COMPLETAMENTO, MESSA IN SICUREZZA E CAPPING, MEDIANTE LA TECNICA DEI MURI ED ARGINI IN RIFIUTI RINFORZATI, PRESSO LE DISCARICHE c.d. FRISOLI e c.d. ex-AGECOS

SEZIONE D

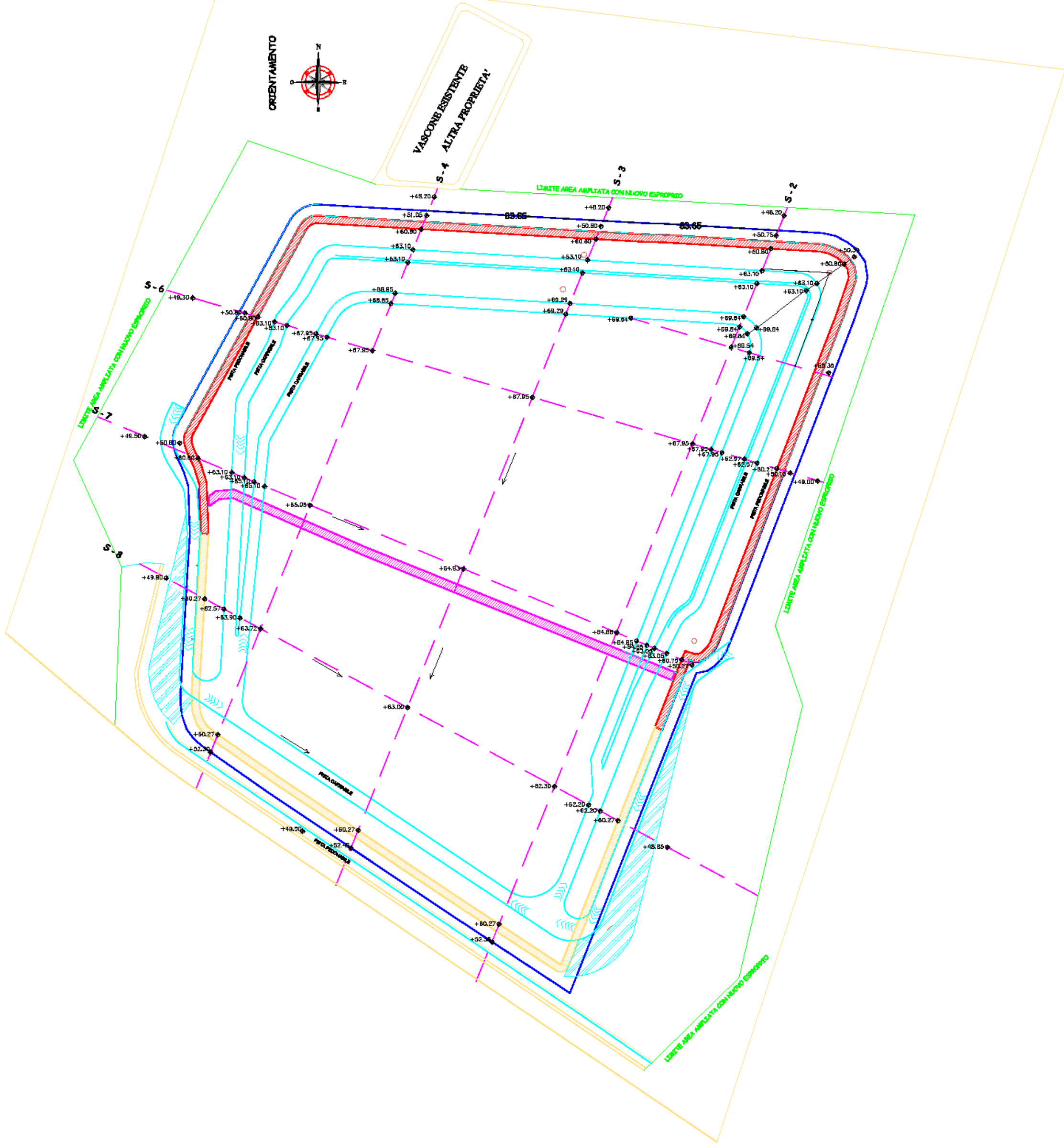
ELABORATI PROGETTUALI

TAVOLA		SCALA
D.12	PLANIMETRIA COPERTURA FINALE	1:1000

STATO REVISIONI			
Revisione	Data	Descrizione	Lista di distribuzione
A	10/04/2015	Prima Emissione	N/A

PROGETTISTA:	IL D.LL:	IL R.U.P.:	
RAFFAELE CALABRESE	RAFFAELE CALABRESE	PIO D'ORTA	
	dr. ing. Raffaele Calabrese	geom. Pio D'Orta	
Data: aprile 2015	Data: aprile 2015	Data: aprile 2015	Data:

PLANIMETRIA COPERTURA FINALE



GEOCOMPOSITE DRAINAGE LAYER INSTEAD OF NATURAL LAYER

The proposed package for the capping system related to the retaining structures is typical of a landfill for hazardous waste, in which the draining geocomposites correspond to hydraulic equivalence with respect to the inert layer. Substantially, it is utilized in substitution of the draining layers in granular matter with draining geocomposites.

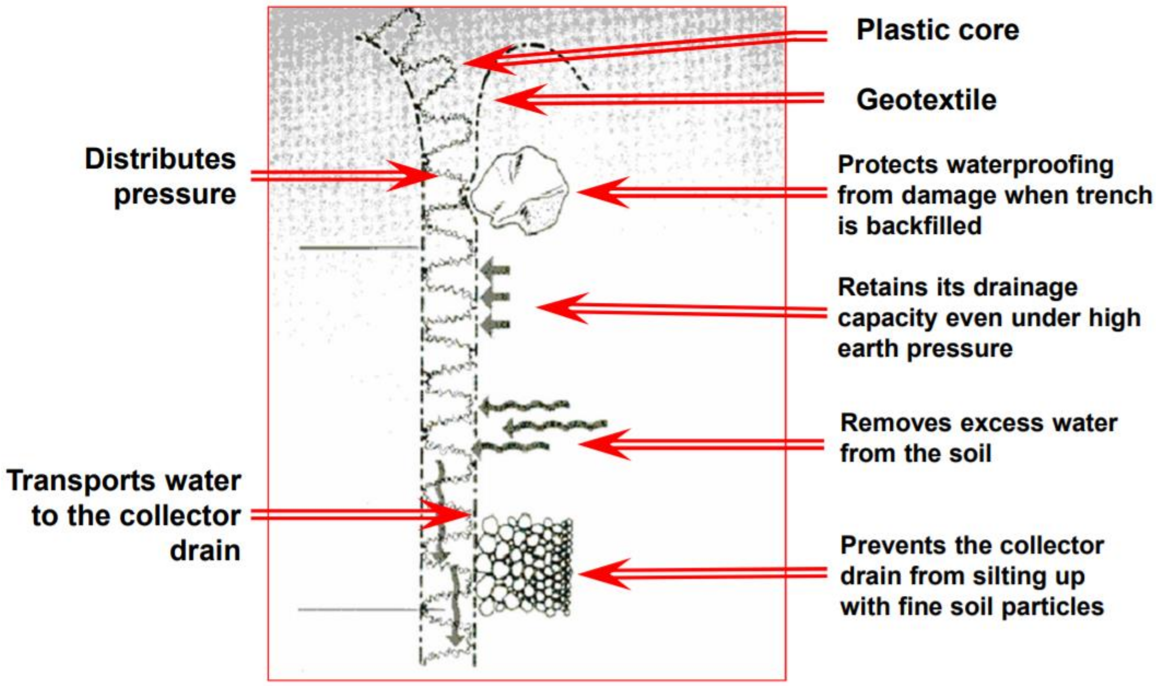
As per the Best Available Technology Not Entailing Excessive Costs (BATNEEC) Guidelines, this replacement is necessary and opportune for several reasons:

- limit the subsidence phenomena and the settling of the upper parts, reducing the weight of the cover. In fact, to replace the granular materials, which have a minimum thickness of 1.0 m and weight close to 2.0 t / m2 of coverage, with synthetic materials of minimum thickness and total weight of less than 2 kg / m2, means significantly reducing the load transmitted to the body of the landfill and, therefore, reduce possible settlements;

- limit the difficulties of verification in seismic conditions;

- reduce the costs related to the use of natural materials provided for by the decree (gravel). It is emphasized that it is not just a matter of costs of an economic nature, linked to the living costs of materials, but also and above all to the environmental cost due to the necessary cavities and to the traffic induced by the transport of material by means of vehicles. Suffice it to say that for example 60,000 m3 of gravel is needed for an extension of about 60,000 m2 of closure (over 3,000 trucks with a 20 m3 platform).

Advantages of the use of geosynthetics instead of natural drainage layer:



GCDs as opposed to granular layers have the following advantages:

- Need less material with required characteristics (cost effective);
- High environmental friendliness (low CO_2 emission);
- Can provide geotechnical stability on sloped surfaces (engineered);
- In case of landfills, increase waste capacity (benefit to the municipality).

Therefore, it is to provide information on the choice of synthetic materials that can be used as an alternative to natural materials (draining layers), and in particular related to geocomposites for the drainage of rainwater and biogas. Evidently, the replacement of natural materials with synthetic materials is carried out for objective and demonstrable impossibility of using natural materials, and is carried out by guaranteeing, with an adequate factor of safety, a performance equivalent to the materials that is to be replaced.

Furthermore, EPA (Environmental Protection Agency)-Landfill Site Design Guide said: "*The drainage layer can consist of granular material, of minimum thickness 0.5m or a geosynthetic drainage medium.*"

Following, a technical comparison between gravel layers and GCDs.
From Darcy:

$$Q = k\ A\ i$$

where
- K is permeability of the granular layer
- A is area per m width of the draining layer 0,5 m thk x 1 m width = 0.5 m2
- i is the gradient of the draining layer

The permeability of the granular layer is not defined.
It can be estimated it in the range of $5\times10^{-4} < k < 10^{-2}$ l/m.sec (typically $k = 10^{-3}$ l/m.sec).

Water flow capacity of the GCD needs to be greater than or equal to the one of the gravel (0,5m):

$$\mathbf{Q_{GCD} \geq Q_{gravel} = K \cdot e \cdot i \text{ (Darcy)}}$$

GRANULAR LAYER
In this analysis the selected granular layer is assumed as sandy gravel material, with a permeability of $k = 5\times10^{-3}$ [m/sec], and a hydraulic gradient of i=0.9. The hydraulic capacity of this granular layer, using the Darcy Law equation, may be obtained as
$Q = k\ A\ i = (5\times10^{-3}) \times (0.5\times1) \times 0.9 = 0.23\times10^{-2}$ [m^3/sec]

GCD
Assuming 1 m as the height for restoration soil, and 20 kPa as the fill unit weight, and assuming a safety factor of 2.5 to account for uncertainties and variability of life loads, the vertical stress considered to act on the geocomposite will be computed as follows:
$\sigma h = (20\times1) \times 2.5 = 20 \times 2.5 = 50$ kPa

For granular layers correction factors are required.

Reduction of the Flow Capacity of a drainage geocomposite (in blue suggested values in Bibliography for Surface Water drains in cappings)

1) Clogging or blinding of the core due to:
   - chemical precipitation (1.0 – 1.2, according Koerner)
   - biological intrusion (1.5 - 3,5, according Koerner)

2) Long term compressive creep deformation of the core of the geocomposite due to the constant load applied. (it depends of the configuration of the product, raw material, gradient & pressure ; for high quality products it ranges from 1.1 – 1.5)

3) Intrusion of the geotextiles into the core when loaded - reduction of the effective cross draining section – (it depends of the core, pressure, gradient and stiffness of the geotextile)
   - short -term intrusion (Transmissivity Test on Laboratory)
   1 when is run hard/soft or soft/soft conditions
   1.3 – 2.0 at least, when the tests are run in hard/hard conditions
   - long-term intrusion of the geotextile due his creep
   1.3 – 1.6 according

From the nominal Q_{STreq} short term value, the Q_{LTreq} long term design value may be calculated under serviceability conditions, by means of adequate reduction factors, in accordance with:

$$Q_{LTreq} = Q_{STreq} \times RFin \times RFcr \times RFbc \times RFcc$$

Partial Reduction Factors:
RFin=1.10 Reduction factor for elastic deformation or geotextile intrusion;
RFcr=1.00 Reduction factor for creep deformation over time. Already considered in the load applied by the restoration soil;
RFbc=1.20 Reduction factor for intrusion of biological material;
RFcc=1.10 Reduction factor by chemical clogging of the draining network.
The overall reduction factor will be RF_{tot}=1.10 x 1.00 x 1.20 x 1.10 = 1.45

Assuming that the required discharge was: Q_{STreq} = Q = 0.23 x10-2 [m³/s], we have

$$Q_{LTreq} = Q_{STreq} \times 1.45 = \mathbf{0.3 \times 10\text{-}2}\ [m^3/s]$$

In the hypothesis of using draining geocomposites, it is necessary to identify a material that, under a load of 50 kPa, guarantees a calculated hydraulic flow in the most unfavorable situation, as above calculated.
The selected GCD has water flow capacity greater than the calculated one (l/m.sec) for a 50 cm gravel layer, as shown below in the analysis carried out by the supplier.

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Data:

*WATER FLOW CAPACITY (L/m*s)*

Prodotto: **SINDRAIN B22-750 FCF130**

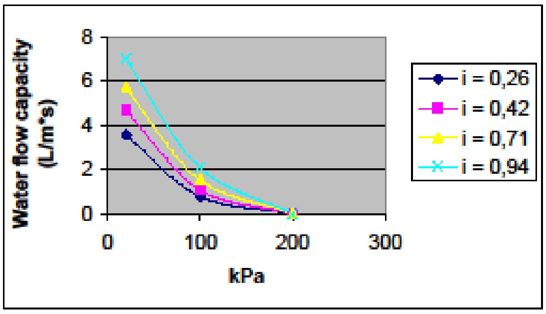
Norma: UNI EN ISO 12958

Dimensioni provino: 20 cm x 40 cm

Angolo	Radianti	Sen angolo	i	DH (cm)
15	0,261799388	0,258819045	0,26	10,40
25	0,436332313	0,422618262	0,42	16,80
45	0,785398163	0,707106781	0,71	28,40
70	1,221730476	0,939692621	0,94	37,60

kPa	daN	i	V(L)	t1 (s)	t2(s)	t3 (s)	q1(L/m*s)	q2(L/m*s)	q3(L/m*s)	q1(L/m*s)
20	160	0,26	5	7,26	6,84	6,97	3,44	3,65	3,59	3,56
20	160	0,42	5	5,42	5,34	5,32	4,61	4,68	4,70	4,66
20	160	0,71	7	6,22	6,16	6,14	5,63	5,68	5,70	5,67
20	160	0,94	9	6,51	6,27	6,55	6,91	7,18	6,87	6,99
100	800	0,26	1	6,28	6,5	6,51	0,80	0,77	0,77	0,78
100	800	0,42	2	9,1	9,38	9,22	1,10	1,07	1,08	1,08
100	800	0,71	3	9,82	9,82	9,8	1,53	1,53	1,53	1,53
100	800	0,94	5	12,09	12,27	11,64	2,07	2,04	2,15	2,08

	i = 0,26	i = 042	i = 0,71	0,94
kPa	q (L/m*s)	q (L/m*s)	q (L/m*s)	q (L/m*s)
20	**3,56**	**4,66**	**5,67**	**6,99**
100	**0,78**	**1,08**	**1,53**	**2,08**
200	0	0	0	0



REFERENCES

The Climate of Malta: statistics, trends and analysis, 1951-2010. – Valletta: National Statistics Office, 2011 viii,