GHALLIS MSW LANDFILL ENLARGEMENT

Ghallis Complex - Malta

Technical report: verification of the anchoring and stability of the waterproofing system

CLIENT:

FRISOLI SRL
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THE TECHNICIAN IN CHARGE:

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TITLE:

FOUNDATION WORKS **"REFUSE DUMP CONTAINMENT STRUCTURE"**

ON BEHALF OF:

WASTESERV MALTA LIMITED
EkoCentre, Triq il-Latmija, Marsascala, MSK 4613

WASTESERV
CREATING RESOURCES FROM WASTE

DOTT. ING. RAFFAELE CALABRESE

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A	*First Issue*

REV.	DESCRIPTION	ISSUED BY	DATE
D			
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INTRODUCTION

WasteServ Malta Limited (WasteServ) operates the Ghallis landfill for non-hazardous waste, designed as a disposal facility implementing the requirements of Directive 1999/31/EC about waste landfill, as transposed by Legal Notice 168 of 2002 on waste management (landfill).
The landfill site was originally approved by PA 04834/04 after an environmental impact assessment process.

The activities of this plant were allowed on April the 6th 2007, by issuing of the integrated pollution prevention and control permit IP00 1/06/A; the permit's renewal was decided on January the 31st 2013, by issuing the IP001/06/B. The latest renewal, issued on April 14th 2020 is the n. IP0001/06/C.

In this context, WasteServ Malta Limited (WasteServ) is in the process of expanding the volume of its non-hazardous waste landfill facility at the same site, Ghallis Ta Gewwa.

The activities in the matters were permitted by PA 1586/18, amending PA 964/11, according to the ERA consultation on May the 27th 2019, which reviewed the draft documents PA01586/187/74a-74h and PA01586/18/75a-75d, and has no further comments.
The works were contracted to the company "Frisoli Srl", with the contract n. WSM 348/2017.

In any case, the activities covered by this report were the subject of the renewal of the IPPC permit in 2020 (IP0001/06/C).

DESCRIPTION OF THE EXTENSION STRUCTURE

Enlargement consists of changing the perimeter profile of the landfill in order to increase the volumetric capacity of the landfill for non-hazardous waste, while keeping constant the area of the site used for the disposal activities.
The model used to increase the landfill's volume capacity consists of:

- A perimeter coating system (along the authorized edge of the landfill), consisting, from below, of a geological barrier, geosynthetic clay liner layer (GCL), a geomembrane, consisting of an HDPE cloth, a non-woven geotextile (TNT) and, in the end, a fine protection layer made by sand;
- A "foundation", consisting of a layer of stabilized mixed material, wrapped with a woven geosynthetic, overlying a layer of gravel;
- A containment structure (Side-Cap), with a 70° angle, built according to the forecasts referred to the European patent EP 1661635 owned by the company "FRISOLI S.r.l.", based in Foggia (Italy) at Corso Garibaldi n. 92.

Preparation of the foundation

The re-engineering of the cell did not include any changes to the bottom of the existing landfill.
In particular, the slope of the embankment has remained unchanged.

Preparation of the foundations and extension of the base waterproofing (liner) by welding to the existing liner to ensure containment

In order to ensure the continuity of the liner of the existing cell with the founding area of the containment structures, an excavation has been carried out for searching for the existing HDPE.
The foundation works of the containment structures were carried out above the base of the existing line system of the Ghallis landfill, allowing the continuity of the HDPE inside the old cell, restored and extended to the foundation areas.
The system of waterproofing was laid on surfaces previously regularized by the client company, WasteServ Malta Limited, and prepared in such a way as to avoid any possibility of damage to the system.
The GCL was laid in place in overlapping strips. The waterproofing of the overlaps between the edges of the strips was achieved by incorporating the edges of the two overlapping geotextiles in loose dry bentonite powder, which turns into gel when hydrated. All the overlaps, both longitudinal and transverse, were made by identifying the two preferential directions, avoiding reversals in the overlap of adjacent sheets. The minimum overlap, in the longitudinal direction of the roll is 15-20 cm; the minimum overlap in the transverse direction of the roll is 30-40 cm.
The HDPE geomembrane was laid in contiguous strips, overlapped on the edges. Its installation is quick: the strips are laid with a side overlap and then welded.
The types of welded joints used are those mentioned by UNI 10567:

a) double track (with test duct), made by thermal element process and mechanized equipment;
b) overlapping cord, made by extrusion process and manual equipment: This welding is used only in the case of repairs at crossing points of several welds and at specific points where double track welding cannot be made. The surfaces to be joined by extrusion welding were first made rough by grinding, in order to improve bonding.

LAYING THE WATERPROOFING COATING SYSTEM: Unconfined Condition

With reference to the clarifications requested by ERA - Environment and Resources Authority, during the installation phase, one of the problems could be the anchoring of the waterproofing system.
In this regard, it should be noted that during the laying phase, i.e. before the planting of the filling material, consisting of stabilised inert material and pre-existing waste, the waterproofing coating is placed on the horizontal plane, at the head of the slope, for a length of not less than 5 m and turned upside down.
The verification of the anchorage led to the conclusion that it is not necessary to build a trench, but it is sufficient to lay the fill soil on the sheet for a sheet width of 1.5 m and a thickness of fill soil of 15 cm.
Subsequently, when the waterproofing, after the filling, is in confined conditions, the waterproofing system is turned over on the "inverted T" wall, designed to delimit the Ghallis landfill from the one called, Maghtab, made by laying prefabricated reinforced concrete elements of the "New Jersey" type.
The following is the study related to the tensile strength and anchoring of the geomembrane.

VERIFICA DELLA RESISTENZA A ROTTURA E DELL'ANCORAGGIO DELLA GEOMEMBRANA

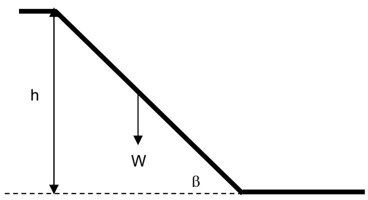
In condizioni non confinate

PREMESSA

Il calcolo stabilisce inizialmente il fattore di sicurezza nei confronti della possibile rottura di una geomembrana sottoposta al solo peso proprio, lungo un piano inclinato.

Successivamente, si va a verificare il possibile moto traslazionale del prodotto lungo il potenziale piano di scorrimento, valutando il dimensionamento del sistema di ancoraggio più opportuno.

FONTE: X. Qian, R.M. Koerner, D.H. Gray, "*Geotechnical aspects of landfill design and construction*", 2002;



DATI DI INPUT

	$\sigma_{\_nom}$ =	36	[N/mm^2]	carico di snervamento
	$t_{\_gmb}$ =	2.10	[mm]	
		2.10E-03	[m]	
*)	$\rho_{\_gmb}$ =	0.94	[g/cm^3]	
		940.00	[kg/m^3]	
	g =	9.80	[m/s^2]	
	δ =	10.00	[°]	

**): valori generalmente compresi tra 0,92 e 1,4 g/cm3*

H =	6.50	[m]
β =	45.00	[°]
sen(β) =	0.71	[ad]
cos(β) =	0.71	[ad]
L = h/sen(β) =	9.19	[m]

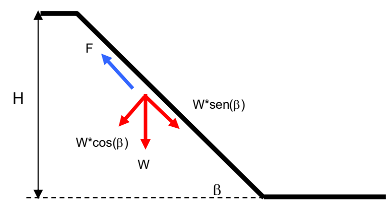
DATI DI OUTPUT

<u>1° STEP) calcolo delle componenti derivanti dal peso proprio della GMB</u>

$W = g*\rho_{\_gmb}*t_{\_gmb}*[h/sen(\beta)]$ — $W_{\_gmb}$ = **0.17783** [kN/m]

$W_{\_/} = W*cos(\beta)$ — $W_{\_/}$ = **0.13** [kN/m]
componente normale al piano inclinato

$W_{\_//} = W*sen(\beta)$ — $W_{\_//}$ = **0.13** [kN/m]
componente parallela al piano inclinato



<u>2° STEP) calcolo della componente di attrito F</u>

$F = W_{\_/}*tan(\delta)$ — F = **0.02** [kN/m]

<u>3° STEP) calcolo della forza di trazione a cui è sottoposta la GMB per effetto del peso proprio</u>

$T_{\_prog} = W_{\_//} - F = W*sen(\beta) - W*cos(\beta)*tan(\delta)$ — $T_{\_prog}$ = **0.1** [kN/m]

$T_{\_amm} = \sigma_{\_amm}*t_{\_gmb}$ — $T_{\_amm}$ = **25.2** [kN/m]

dove

$\sigma_{\_amm} = \sigma_{\_nom} * FS_{\_prod}$ — $\sigma_{\_amm}$ = **12**

$FS_{\_prod}$ — $FS_{\_prod}$ = **3** [ad]

$FS = T_{\_amm} / T_{\_prog}$ — FS = **252** [ad]

La sollecitazione imposta non eccede la capacità di resistere a trazione della GMB

4° STEP) calcolo della condizione di stabilità

Perché il prodotto non scivoli lungo il piano inclinato occorre che

F > W*sen(b)

dove ricordiamo

F = W*cos(β)*tan(δ)

da cui

W*cos(β)*tan(δ) > W*sen(β)
tan(δ) > tan(β)

FS = tan(δ) / tan(β) — FS = **0.18** [ad]

valori consigliati compresi tra 1,25 e 1,5

valore non adeguato

5° STEP) calcolo del sistema di ancoraggio

$T_{prog} = W_{//} - F = W*sen(\beta) - W*cos(\beta)*tan(\delta)$ — T_{prog} = **0.1** [kN/m]

$T_{anc} = T_{anc\_1} + T_{anc\_2} = \gamma_{tr}*h*b*tan(\delta) + 2*k_0*\gamma*h^2/2*tan(\delta) + \gamma*t*L_{anc}*tan(\delta)$ — T_{anc} = **1.32** [kN/m]

$T_{anc\_1} = \gamma*h*b*tan(\delta) + 2*k_0*\gamma*h^2/2*tan(\delta)$ — T_{anc_1} = **0** [kN/m]

dove

h :	profondità della trincea	h =	0	[m]
b :	base della trincea	b =	0	[m]
γ :	peso specifico del terreno costituente la trincea	γ =	0	[kN/m^3]
ϕ :	angolo di attrito del terreno	ϕ =	0	[°]
k_0=1-sen(ϕ) :	coeff. di spinta a riposo del terreno	k_0=1-sen(ϕ) =	1	[ad]

$T_{anc\_2} = \gamma*t*L_{anc}*tan(\delta)$ — T_{anc_2} = **1.32** [kN/m]

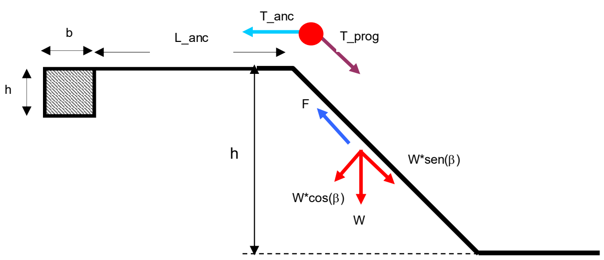
dove

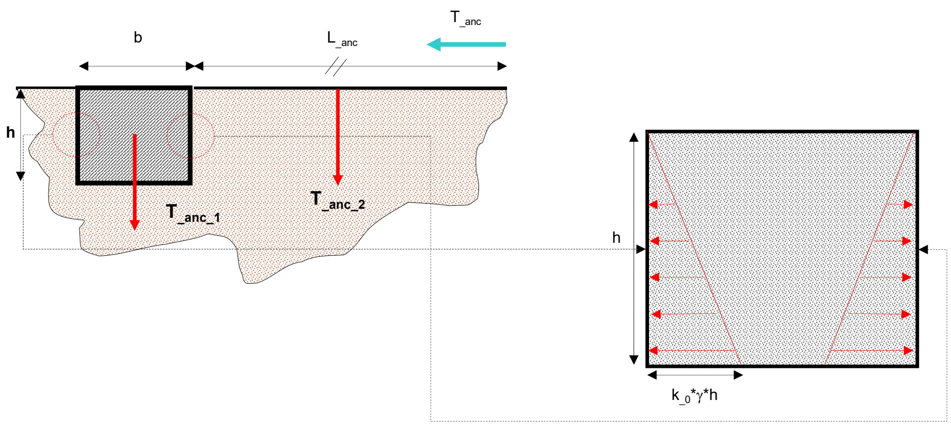
γ :	peso specifico del terreno costituente la trincea e/o di quello di riporto	γ =	18	[kN/m^3]
δ :	angolo di attrito all'interfaccia terreno/GSY	δ =	18	[°]
L_{anc} :	lunghezza di ancoraggio orizzontale	L_{anc} =	1.5	[m]
t :	spessore del terreno di riporto	t =	0.15	[m]

6° STEP) calcolo del FATTORE di SICUREZZA associato al sistema di ancoraggio

$FS = T_{anc} / T_{prog}$ — FS_anc = **13.2**

il range di valori consigliati è compreso tra 1,2 e 1,5





LAYING THE WATERPROOFING COATING SYSTEM: Confined Condition

The typical geometry of the landfill is characterized by steep slopes and high gradients, designed to contain large quantities of waste in the smallest possible space. However, this geometry can lead to breaks in the impermeabilization system due to the steep slopes.
To ensure the stability of these systems, it is necessary to take into account the slope inclination, the weight of the overlying waste/soil layers, and the shear strength between the geosynthetic-soil, geosynthetic-geosynthetic, and geosynthetic-waste/sand interfaces.
The slope of the landfill's inner embankment has intermediate berms.
In this case, the destabilizing stresses are transferred to the horizontal plane of the individual berm.
Therefore, since the characteristics of the slope are not known, below we perform the stability calculation of the impermeabilization system considering the upstream slope of the first berm, which is affected by the expansion intervention.

The materials constituting the waterproofing system, their shear strength, and the interface friction determine the slope's sensitivity to movement along the interface

The purpose of the verification is to ascertain whether the tensile stresses transmitted from the waste mass to the waterproofing system, located on the inner embankment, are compatible with the breaking strength of the various elements constituting the package.

Therefore, it will be necessary to verify that the stress state generated at the interface between each synthetic layer is consistent with the mechanical characteristics of the materials specified in the design.

Since the profile changes along all the considered sectors, the calculation is performed by considering the two extreme situations, better highlighted in the graphic examples provided below.

The stress on the embankment is due both to the mass of the waste directly on the wall covering and to the mass of the elevated structures. These two parameters are calculated separately based on the two geometries that, as mentioned, will be considered. The general formula is as follows; the two components are calculated separately and then summed up:

$$W_w = 1/\tan\beta \times A_{sez.rif.} \times \gamma \quad [kN/m]$$

Where, for $A_{sez.rif.}$ it is meant the area of the section, measured transversely to the embankment, involving both the mass of waste and the mass of elevated structures. The frictional force that develops along a vertical sliding plane within the waste mass results from the sum of the two components (waste mass and wall mass) mentioned above, calculated separately as follows:

$$F = (1-\text{sen}\phi_{Rif.}) \times \gamma \times A_{sez.rif.} \times \tan\phi_{Rif.} \quad [kN/m]$$

The maximum vertical stress, equal to the difference between total weight and friction, is:

$$W = W_w - F \quad [kN/m]$$

Finally, it must be considered the passive earth pressure of the refuse, which constitutes the horizontal stress but essentially does not affect the result because it does not bear on the embankment:

$$S_{p.r.} = (1-\text{sen}\phi) \times A_{sez.rif.} \times \gamma \quad [kN/m]$$

To set up the verification, the following parameters must be further defined:

- *Geometry of the slope on which the system will be installed (length, slope).*

- *Characteristics of the deposited waste, including height, specific weight, cohesion, and friction angle.*
- *Mechanical properties of the geosynthetic materials specified in the waterproofing package (allowable tensile strength, friction angle at the upper and lower interfaces, upper and lower adhesion, thickness).*

Given β as the slope of the embankment, the stress W can be decomposed into two components: normal (W_N) and parallel (W_P) to the slope:

$W_N = W \cos\beta$
$W_P = W \sin\beta$

From the literature, parameters have been derived for each interface in terms of friction angle (ϕ) and cohesion (c), which will allow performing mechanical integrity checks on the products (Manassero et al., 2011).

Given the tangential stress states (T_i) for all interfaces, it is sufficient to perform the following check for each considered material:

$$\tau_{\max} > (\tau_{\sup} - \tau_{\inf})$$

Where:

$$\tau_{\max} = \frac{T_{\max}}{s}$$

with

Tmax = *allowable maximum tensile strength of the considered geosynthetic material [kN/m];*
s = *thickness of the considered geosynthetic material [m];*
tmax = *allowable maximum stress of the considered geosynthetic material [kPa];*

To set up the problem in favor of safety, the adhesion factor (a) is neglected, and the mechanical integrity check is developed as follows:

$T_{i\text{-}sup} = W \cos(\beta) \tan(\phi_{i\text{-}sup})$

$T_{i\text{-}inf} = W \cos(\beta) \tan(\phi_{i\text{-}inf})$

The stress induced on the individual geosynthetic layer will therefore be:

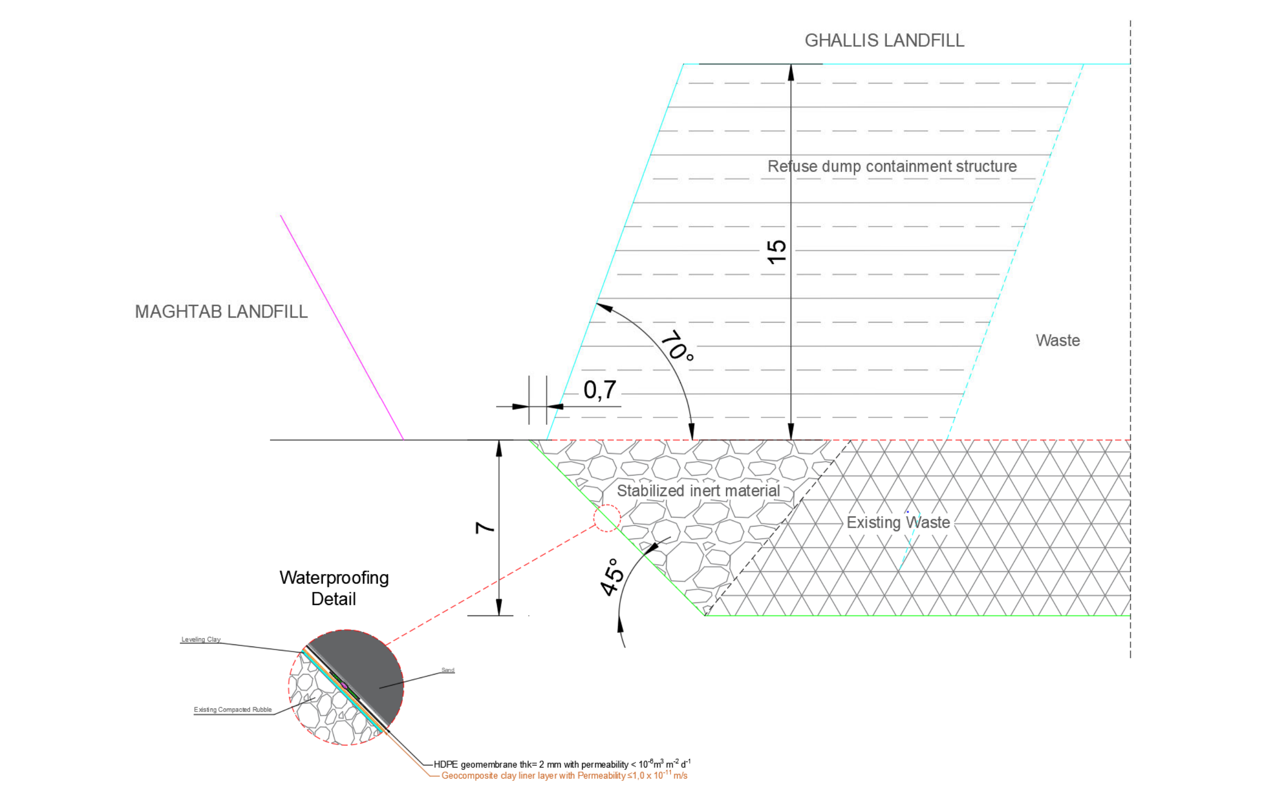
$$\sigma_i = \frac{T_{i\cdot\sup} - T_{i\cdot\inf}}{s_i}$$

Therefore, it is necessary to verify that the induced stress (σ_i) does not exceed the maximum strength capacity of the individual element of the considered waterproofing layer.

The final step involves calculating the associated safety factor:

$$FS = \frac{T_{\max}}{T_i}$$

Below, the calculation results for each component of the waterproofing package are presented for the two considered geometries, as shown in the graphical examples.



GCL

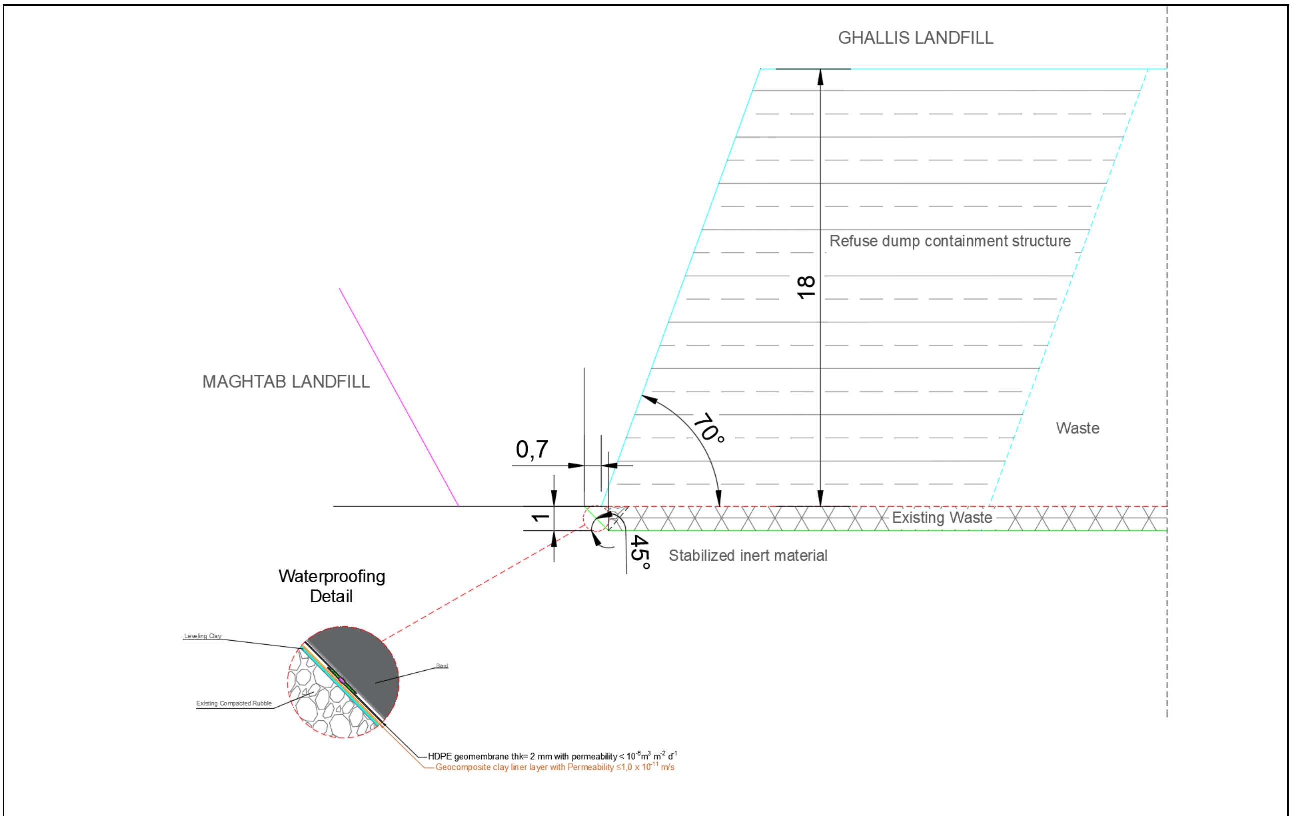
Peso specifico rifiuti =	11	kN/m³	γ	
Resistenza meccanica telo=	23.68	kN/m	Tmax	Real value
Spessore telo =	14	mm	s	
Altezza muri =	15	m	H	
Altezza bacino =	7	m	h	
Lunghezza scarpata =	9.9	m		
Profondità scarpata =	7.0	m		
Distanza base muro / bordo vasca =	0.7	m		
Angolo scarpata bacino =	45	°	β	
Angolo scarpata base muro =	70	°		
Angolo attrito interfaccia superiore=	16	°	φ sup.	
Angolo attrito interfaccia inferiore =	15	°	φ inf.	
Coesione interfaccia supuperiore =	0	kN/m²	c	
Coesione interfaccia inferiore =	0	kN/m²	c	
Angolo attrito interno rifiuto=	28	°	φ Rif.	

Peso muro =	589.1	kN/m
Peso rifiuti su scarpata =	269.5	kN/m
Ww =	858.6	kN/m
Spinta Rifiuto a riposo =	455.5	kN/m
Attrito interno Rifiuti =	121.1	kN/m
W_N =	521.5	kN/m
W_P =	521.5	kN/m
Ti sup. =	149.5	kN/m
Ti inf. =	139.7	kN/m
Ti =	9.8	kN/m
σi =	700.0	kN/m²
FS =	**2.42**	

HDPE

Peso specifico rifiuti =	11	kN/m³	γ	
Resistenza meccanica telo=	63	kN/m	Tmax	Real value
Spessore telo =	2.1	mm	s	Real value
Altezza muri =	15	m	H	
Altezza bacino =	7	m	h	
Lunghezza scarpata =	9.9	m		
Profondità scarpata =	7.0	m		
Distanza base muro / bordo vasca =	0.7	m		
Angolo scarpata bacino =	45	°	β	
Angolo scarpata base muro =	70	°		
Angolo attrito interfaccia superiore=	20	°	φ sup.	
Angolo attrito interfaccia inferiore =	16	°	φ inf.	
Coesione interfaccia supuperiore =	0	kN/m²	c	
Coesione interfaccia inferiore =	0	kN/m²	c	
Angolo attrito interno rifiuto=	28	°	φ Rif.	

Peso muro =	589.1	kN/m
Peso rifiuti su scarpata =	269.5	kN/m
Ww =	858.6	kN/m
Spinta Rifiuto a riposo =	227.8	kN/m
Attrito interno Rifiuti =	121.1	kN/m
W_N =	521.5	kN/m
W_P =	521.5	kN/m
Ti sup. =	189.8	kN/m
Ti inf. =	149.5	kN/m
Ti =	40.3	kN/m
σi =	19190.5	kN/m²
FS =	**1.56**	



GCL

Peso specifico rifiuti =	11	kN/m³	γ	
Resistenza meccanica telo=	23.68	kN/m	Tmax	Real value
Spessore telo =	14	mm	s	
Altezza muri =	18	m	H	
Altezza bacino =	1	m	h	
Lunghezza scarpata =	1.4	m		
Profondità scarpata =	1.0	m		
Distanza base muro / bordo vasca =	0.7	m		
Angolo scarpata bacino =	45	°	β	
Angolo scarpata base muro =	70	°		
Angolo attrito interfaccia superiore=	16	°	φ sup.	
Angolo attrito interfaccia inferiore =	15	°	φ inf.	
Coesione interfaccia supuperiore =	0	kN/m²	c	
Coesione interfaccia inferiore =	0	kN/m²	c	
Angolo attrito interno rifiuto=	28	°	φ Rif.	

Peso muro =	22.0	kN/m
Peso rifiuti su scarpata =	5.5	kN/m
Ww =	27.5	kN/m
Spinta Rifiuto a riposo =	7.3	kN/m
Attrito interno Rifiuti =	3.9	kN/m
W_N =	16.7	kN/m
W_P =	16.7	kN/m
Ti sup. =	4.8	kN/m
Ti inf. =	4.5	kN/m
Ti =	0.3	kN/m
σi =	21.4	kN/m²
FS =	**78.93**	

HDPE

Peso specifico rifiuti =	11	kN/m³	γ	
Resistenza meccanica telo=	63	kN/m	Tmax	Real value
Spessore telo =	2.1	mm	s	Real value
Altezza muri =	18	m	H	
Altezza bacino =	1	m	h	
Lunghezza scarpata =	1.4	m		
Profondità scarpata =	1.0	m		
Distanza base muro / bordo vasca =	0.7	m		
Angolo scarpata bacino =	45	°	β	
Angolo scarpata base muro =	70	°		
Angolo attrito interfaccia superiore=	20	°	φ sup.	
Angolo attrito interfaccia inferiore =	16	°	φ inf.	
Coesione interfaccia supuperiore =	0	kN/m²	c	
Coesione interfaccia inferiore =	0	kN/m²	c	
Angolo attrito interno rifiuto=	28	°	φ Rif.	

Peso muro =	22.0	kN/m
Peso rifiuti su scarpata =	5.5	kN/m
Ww =	27.5	kN/m
Spinta Rifiuto a riposo =	7.3	kN/m
Attrito interno Rifiuti =	3.9	kN/m
W_N =	16.7	kN/m
W_P =	16.7	kN/m
Ti sup. =	6.1	kN/m
Ti inf. =	4.8	kN/m
Ti =	1.3	kN/m
σi =	619.0	kN/m²
FS =	**48.46**	

CONCLUSION

From the above calculations, since in all cases the value of the Safety Factor is higher than the value of 1.2, the stability of the waterproofing system is guaranteed.

Lucera, February the 13th 2024

ORDINE INGEGNERI DELLA PROVINCIA DI FOGGIA
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