A Case Study of the Use of Geosynthetics in the Oiltanking MOGS Crude Oil Blending and Storage Terminal, Saldanha, Western Cape

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Abstract

Construction of the Oiltanking MOGS Saldanha (OTMS) Crude Oil Blending and Storage Terminal entailed constructing bulk crude oil storage tanks with a total storage capacity of 9.9 million barrels of crude oil. The facility consists of nine completed reinforced concrete tanks, the sides of which consist of 9 m high retaining walls, constructed on the upper edge of 14 m long sloping embankments, with a gradient of 1V:1.5H.

A variety of geosynthetics were used in the design of this facility. The embankments were reinforced with a high strength uniaxial polyester geogrid. Each of the tanks were lined with 20 mm thick High-density polyethylene (HDPE) cuspated sheets along the slopes and bases to create a primary impermeable liner. Staple fibre nonwoven virgin polypropylene geotextile was used as a protection barrier to the HDPE geomembrane, on the outside vertical tank walls, against puncture from the embankment constructed from sharp backfilled slag material.

***Keywords**: Geogrid, Cuspated Sheet, Geotextile*

1. Introduction

The deep-water port of Saldanha (Figure 1) is geographically well located on global shipping routes and was therefore the ideal location to develop the world class oil storage facility, owned by MOGS Oil & Gas and Oiltanking GmbH. Once completed, the facility will consist of twelve 1.1 million barrel crude oil storage tanks, which will all be inter-linked, allowing for on-site blending of different crude oil American Petroleum Institute (API) API parameters. The aim of this paper is to showcase a wide variety of geosynthetics and their application in the construction of this state-of-the-art facility.

Figure 1: OTMS site location.

Each tank measures 110 m x 110 m in plan and is 18 m deep to the horizontal invert. The sides of the tanks consist of 9 m high vertical retaining walls that rest on sloping embankments constructed of slag fill. Each tank has a storage capacity of 174 886 m3 and the combined capacity of the tank farm will total 2 098 632 m3, once complete. Each tank contains 192 reinforced concrete columns to support the roof slab and a total quantity of 165 000 m3 of concrete was needed during their construction. The total quantity of fill material required was 1 300 000 m3. Nine of the twelve tanks have been completed, with the remaining three to be completed at a later stage. An aerial image of the tanks is shown in Figure 2.

Slag fill from the nearby Saldanha Works Iron Ore Smelter was used in lieu of the original calcrete specified at design stage, which not only resulted in a significant cost saving but was also more sustainable. One characteristic of the slag material is the sharp scissor-like edges on some of the slag fragments, which had to be considered when specifying the geogrid.

A select combination of geosynthetics would play an integral role in ensuring that the long-term design and serviceability state criteria were realised.

The following geosynthetic applications are discussed in this paper:

1. High strength uniaxial polyester geogrid used to reinforce the 1V:1.5H sloping embankments between the respective tanks, constructed of abrasive slag fill;
2. 20 mm HDPE cuspated sheets used to create a leak detection horizon below and along the sloping embankments of the tanks;
3. 1000 g/m^2 staple fibre non-woven virgin polypropylene geotextile used to protect the 2 mm HPDE liner from damage.

Figure 2: Aerial image of OTMS site during construction. (Image source: www.peri.co.za, November 2018)

A cross-section and plan of a typical tank is shown in Figure 3, detailing the concrete columns and reinforced slopes.

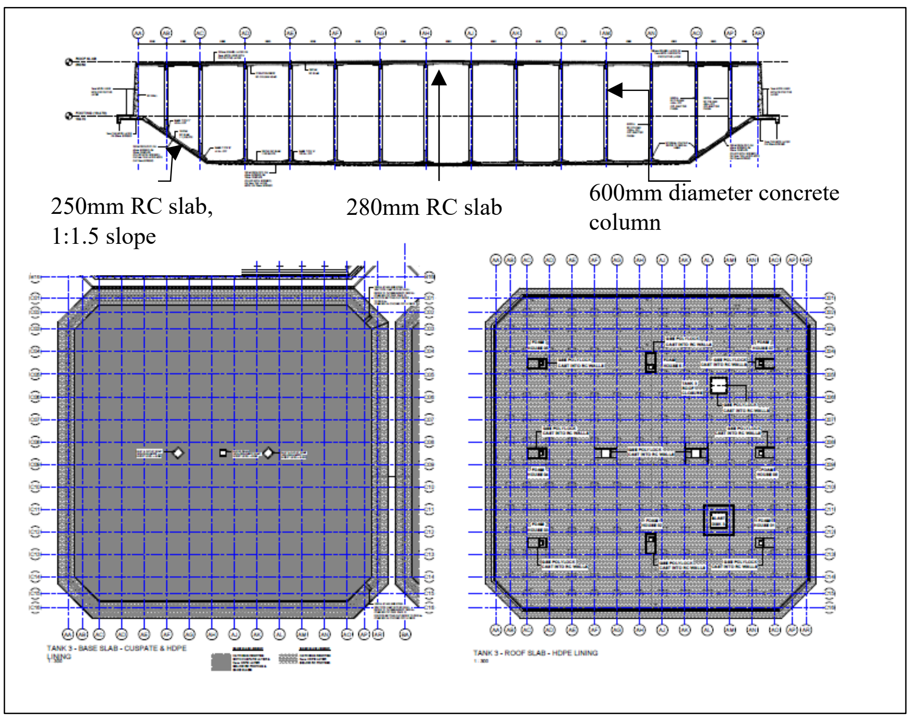

Figure 3: Cross-section and plan view of a typical oil tank.

2. Geogrid Reinforcement

The nearly 8 m high embankments have slopes of 1V:1.5H (Figure 4) that form the bottom part of the tank walls, on top of which 9 m high vertical concrete retaining walls are constructed to form the remainder of the tank wall (Figure 4).

In order to achieve and maintain acceptable long-term factors of safety against bearing failure and slope instability, the upper 2.5 m of the embankments were reinforced with geogrid. Four layers of geogrid were incorporated at vertical intervals of 600 mm, each with a tie-back length of 7 m. Uniaxial polyester geogrid with an ultimate tensile strength of 200 kN and 40 kN in the Machine Direction (MD) and Cross Machine Direction (CMD) respectively, was opted for. The polyester bar-type grid was used because of its superior creep strength over the long term (>100 years), when compared to other polymers such as polypropylene.

Because of the slag material's high abrasiveness due to the angular and often sharp edges of the individual pieces of aggregate, combined with the vibratory forces induced during compaction, an exceptionally stiff, robust, high strength, laid and welded geogrid was required. Images of the installation of the geogrid in the slag fill are shown in Figure 5. The properties of the selected geogrid are presented in Table 1.

Table 1: Geogrid properties.

Physical Property	**Test method**	**Values**
Geogrid manufacturing type	-	Laid & welded
Raw Material	-	PET
Tensile strength (MD/CMD)	EN ISO 10319 / ASTM D 6637	200/40 kN/m
Elongation (max.) (MD/CMD)	EN ISO 10319 / ASTM D 6637	<8 / <8%
Tensile strength at 1% elongation (MD)	EN ISO 10319 / ASTM D 6637	40 kN/m
Tensile strength at 2% elongation (MD)	EN ISO 10319 / ASTM D 6637	70 kN/m
Tensile strength at 5% elongation (MD)	EN ISO 10319 / ASTM D 6637	140 kN/m
Stiffness at 2% strain	EN ISO 10319 / ASTM D 6637	3500kN/m

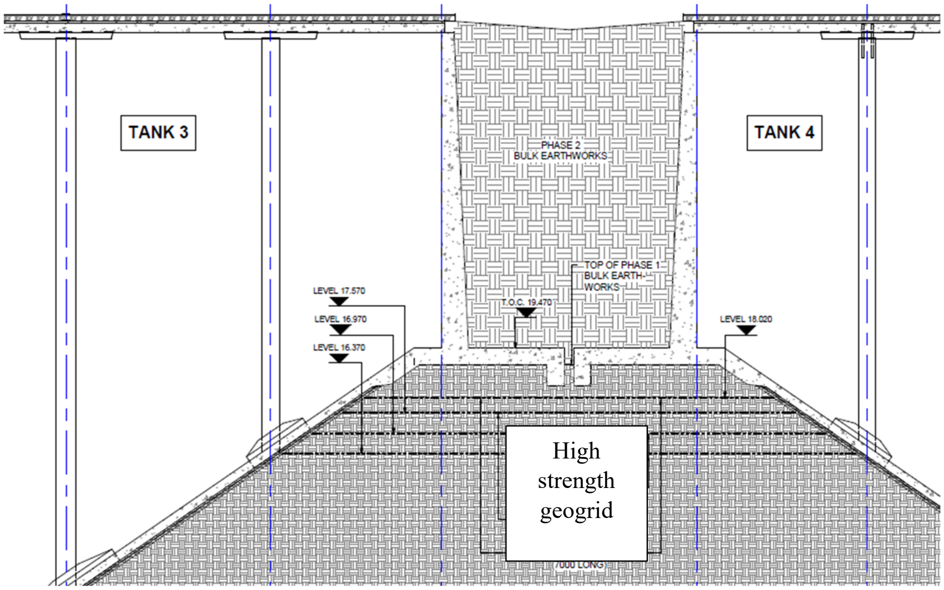

Figure 4: Cross-section of embankment and tank retaining wall.

Figure 5: High strength uniaxial geogrid placed onto the imported fill material.

3. Cuspated Sheet

The 250 mm thick reinforced concrete floors (horizontal and sloping sides) were placed on 250 micron damp proof membrane (DPM), on 40 mm screed, on 20 mm cuspated sheet (filled with screed), on a 2 mm thick HDPE liner, on 75 mm screed (Figures 6 & 7), to form a composite barrier system. A 20 mm cusp height was used for the leak detection application, as it would have the in-plane flow capacity required to conduct seepage and other particle laden viscous liquids without clogging.

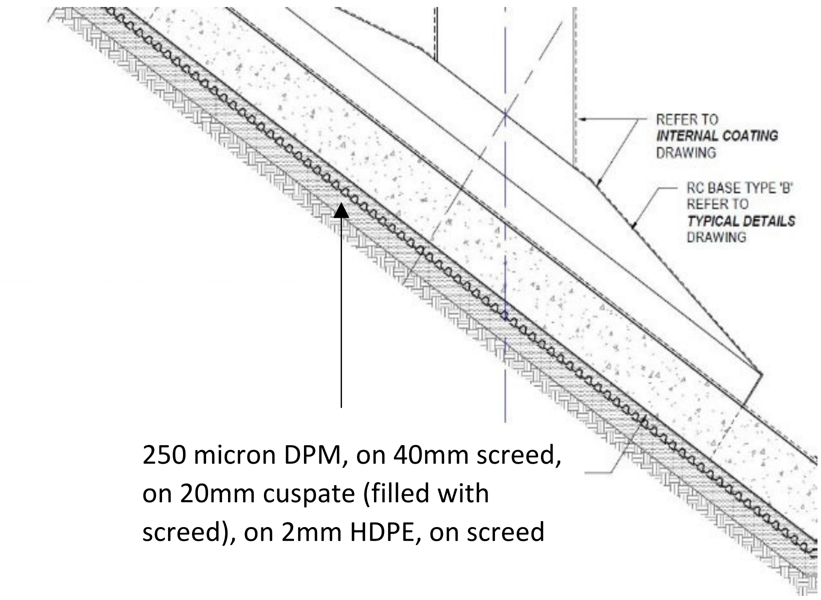

Figure 5: Typical design detail of the sloping composite barrier system.

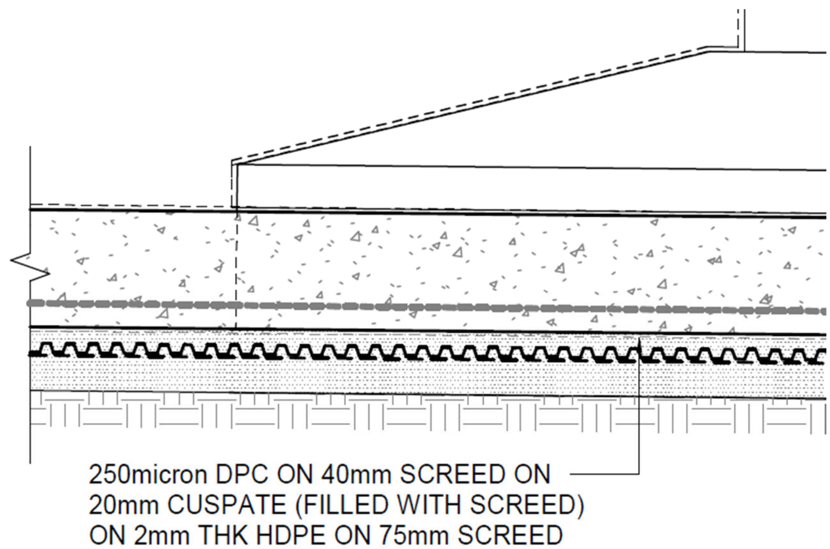

Figure 6: Typical design detail of the sloping composite barrier system.

The cuspated sheet was manufactured with a 100 mm selvedge for on-site extrusion welding and special rolls of 4.5 mm diameter weld rod was extruded from exactly the same HDPE polymer for this purpose. The physical properties of the cuspated sheet are listed in Table 2.

Table 2: Physical properties of cuspated sheet

Physical Property	Test method	Values
Type of material	Single cuspated (dimpled) HDPE	
Dimple centres	Approx.	52 mm
Drainage volume	Approx.	12.6 l/m^2
Mass per unit area	EN ISO 9864	1200 g/m^2
Overall Thickness at 2kPa	EN ISO 9863-1	20mm
Tensile strength MD / CMD	EN ISO 10319	11.5 / 10 kN/m
Elongation at break MD /CMD	EN ISO 10319	40 / 40 %
CBR puncture resistance	EN ISO 12236	1 800 N
Dynamic perforation cone drop	EN ISO 13433	4 mm
Compressive strength	ASTM D1621 (mod)	150 kPa (without screed)
Resistance to weathering	EN 12224	Excellent
Resistance to chemicals	EN 14030	Excellent
High pressure OIT (minutes)	ASTM D5885	>400

The cuspated sheet was installed on top of the 2 mm thick HDPE geomembrane with the dimpled side facing down, creating the air void and leak detection layer between the cusps and geomembrane. Extrusion welding of the cuspated sheet is shown in Figure 8 (a). Screed was then placed into the hollow side of the cusps, as shown in Figure 8 (b).

Figure 8: a) Extrusion welding of cuspated sheet; b) screed placement onto cuspated sheet.

4. Geotextiles

It was imperative to protect the HDPE liner along the sides of the retaining walls of the oil tanks from puncture caused by backfill during and after construction. A 1000 g/m^2 needle-punched staple fibre polypropylene geotextile was used for this purpose. The geotextile needed to have very high static puncture strength, tensile strength and elongation in order to provide adequate protection. The physical properties of the selected geotextile are shown in Table 3. An image of the geotextile is shown in Figure 9.

Table 3: Physical properties of the protection geotextile.

Physical property	Test method	Unit	Value
Static puncture strength (CBR test)	SANS 12236:2013	N	12 500

Elongation at break	SANS 12236:2013	%	>55
Tensile strength (MD/CMD)	SANS 1252:2013	kN/m	70/70
Elongation at break	SANS 1252:2013	%	>50
Dynamic Cone Drop	SANS 13433:2013	mm	0

Figure 9: Heavyweight protection geotextile installed onto 2mm HDPE liner along the sides of the retaining walls of the tanks.

5. Conclusion

This paper shows the application and therefore relevance of a wide variety of geosynthetic materials in a multi-disciplinary construction project. High tenacity uniaxial laid and welded polyester geogrid was used to reinforce the sloping embankments that formed the lower part of the tanks. An HDPE cuspated sheet was used to create a leak detection layer at the bottom and along the sloping sides of the tanks. A 2 mm HDPE geomembrane was installed to act as a barrier layer and a heavyweight staple fibre non-woven polypropylene geotextile was used to protect the 2 mm HDPE membrane from damage during and after construction.