Expanding developments of high strength woven geotextiles

D. Janse, B.Sc.

TenCate Geosynthetics Europe, Netherlands (d.janse@tencate.com)

ABSTRACT:

Geosynthetics are used in a great variety of applications, and come in many different types and shapes where properties are adapted to enhance suitability for the specific structure. With respect to roadway and heavy-duty reinforcement applications such as embankments over extremely soft soils and tailing pond covers, a lot has been published on the use of geogrids. However, many engineers throughout the world are starting to see the benefits that the added functions of a high strength woven geotextile will provide in these applications.

This paper will go deeper into the multiple functions and benefits, which are possible with full surface, high strength woven geosynthetics in many difficult applications. When compared to geogrids and nonwovens, high strength woven geotextiles can be adapted on almost any possible material property, which comes to mind. Whether this is higher strength and modulus, better filtration properties, separation, confinement through a full coverage, high friction surface, enhanced drainage with specialty wicking fibers, long-term behavior, chemical resistance and seam strength for big panels, anything is possible to suit exactly what the application needs.

Going through several case studies of projects realized globally for road constructions, dock infills, road extensions in water, pond-covering systems etc. this paper covers in full detail where specific and complicated geotechnical problems are handled by specially developed properties of woven geotextiles, which are difficult and at times impossible to achieve with the other geosynthetic types.

Keywords: high strength woven geosynthetics; road construction; dock infills & soft sites & tailing ponds; embankment & foundation; stabilization

1 INTRODUCTION

Since the 1950's geosynthetics have been used in civil works all around the globe. The first use was in marine works such as dike repair, later other applications would follow. Initially, woven geosynthetics were most used in marine works, later followed by nonwovens for soil stabilization purposes. In the late 1970's / early 1980's the first two-directional geogrids were introduced, using the punctured and stretched plate production method, at first leading to geo grids with a maximum strength of 35 kN/m. Meanwhile, also late 1970's, higher strength woven geosynthetics were developed to reinforce the foundation of an embankment in the Netherlands. From tests it became clear that minimum strengths of 150 kN/m were needed, and that such a fabric should have an elongation which typically should not exceed 10%. It was actually the start of a whole new era for geosynthetics use, as it became clear that geosynthetics can solve geotechnical problems in a much more cost effective way than traditional building methods could. Later on the high strength woven geosynthetics were followed by the introduction of high strength geogrids, woven or knitted polymer construction, mostly coated with PVC or similar.

When the market grew over the years, the types of applications where higher strength geosynthetics are being used, increased from road building to reinforced embankments, sloped and vertical structures, void bridging, veneer reinforcement, breakwater foundations, land reclamations, piled embankments, and many more. It lead to a more and more common use of high strength geosynthetics as a trustworthy and vital part of geotechnical engineering.

Major players in the geosynthetics industry have grown along with that, and have developed high strength product ranges and provide design support to the geotechnical engineers. It depends on the type of raw material used, but for a common polyester based geosynthetic, tensile strengths up to 2000 or even 2500 kN/m are now even possible.

However, although the use of geosynthetics started with wovens, the use of grid and non wovens has become much more commonly used because of the great attention it has got from the major part of the worldwide producers. And with that, the basic engineers' knowledge or awareness about the technical functionality of the most (cost) effective geosynthetic material is fully underexposed.

By going through a couple of cases we make clear that (high) strength woven geosynthetics are really capable of making the difference.

2 WOVEN GEOSYNTHETICS

2.1 *Yarn types*

Woven geosynthetics consist of machine direction yarns cross connected with yarns in cross machine direction by weaving them into a specific pattern, called the binding. The yarns used come in various types, i.e. flat tape, fibrillated tape, split fibre, monofilament and multifilament.

The yarn type used, in combination with the binding gives a very high flexibility to steer the final properties of the material, which are defined in the international standards from the geosynthetic world. In this way it is possible to increase or decrease opening size, bring more or less elongation, vary with permeability, increase puncture strength or stiffness, and much more. Especially for reinforcement purposes no other geosynthetic material offers such kind of flexibility. Manufacturers tend to solve the absence of flexibility in properties of for instance a geogrid by combining 2 or more single basic types of geosynthetics and create a geo-composite. In general it can be concluded it will lead to a higher products cost, extra transport, CO_2 emission, and so on.

2.2 *Raw materials*

Although there are many “exotic” types of raw material possible to use, such as aramide and polyvinylacohol, for sure 99% of wovens manufactured in the world are made of polypropylene or polyester, and a for a smaller part from polyethylene. Each type of raw material has its properties which is suitable, less suitable or even not suitable for the application it will be used for. Polyethylene is very smooth, suitable for making monofilament yarns, which are commonly used for filtration or drainage purposes. On the one hand it is possible to make very stable highly permeable fabrics; it’s high elongation and low resistance to creep under load on the other hand, makes them unsuitable for reinforcement purposes.

When concentrating on applications where tensile strength of the woven is the most important property, we can purely concentrate on polypropylene (PP) and polyester (PET), each having its unique properties influencing the nature of the final product. In general with PP yarn, products can be made which are stable, strong, stiff, permeable, will float in water, robust, resistant against abrasion, UV stable, etc. When using PET multifilament yarns, materials can be woven with very high tensile strengths above 2000 kN/m and great resistance against creep during service life.

The best choice of the raw material to work with depends on a couple of factors:

- Intended service life, settling constructions or 100 years force applied
- Installation circumstances, prefab solutions, robustness
- Fill material/aggregate
- Filtration properties

By going through a handful a of case studies we will demonstrate the flexibility in product properties, fully adjusted to the application it is used for, leading to the optimum single geosynthetic solution.

3 EXAMPLES FOR THE OPTIMUM SELECTION OF WOVEN PRODUCT PROPERTIES

3.1 *Unpaved haul roads for windfarm road*

The most common use for geosynthetics is for road construction purposes. All typical types of materials are used for the application, nonwoven, wovens, grids, composites. The majority of geosynthetic materials are being used for separation purposes to prevent intermixing of soil layers. Stronger materials are used for reinforcement of subsoil, with the target to reduce aggregate layers in order to save cost.

When focusing on unpaved roads we are facing a lot of information with respect to the “ultimate” geosynthetic for this applications. Many books have been written about this subject, a lot of research projects in and outside laboratories have been carried out to try to prove that a specific type of geosynthetic is the ideal product to optimise the road design. However, as easy as the application seems to be compared to other structures in which geosynthetics are used such as retaining walls, in practice it turns out to be quite different. Without going to deep into the design methods and research, in many cases the outcome is that a geogrid is by far the best product to use. However the functionality of a geogrid is for a major part researched and written towards the appearance of the interlocking effects because of the rib structure of the geogrids. Interlocking can be described as a self-explanatory effect of aggregate which will partly penetrate the grid structure touching the aggregate below. Surrounded by the ribs of the grid, meaning it cannot move sideways anymore. This should have the effect that all the forces coming from the wheel loads from above will be directed into the grid and absorbed by its stiffness. Automatically this implies that grid opening and aggregate size used must be fully in line with each other. And exactly this is where research done and how things work out in practice in the field can be rather different. In theory the road design is worked out based upon aggregate use of a specific type, in practice we often see materials supplied being either much to fine or even vice versa, stone sizes which are far too big. It is clear that in such circumstances no interlocking effect can take place.

Besides that a geogrid misses the separation function which is absolutely needed. Often this is either solved by installing a separator first, or installing a composite, mostly a geogrid with a now woven laminated to it. Both solutions further decrease the possible effects of interlocking as the apertures in the grid are pretty much closed.

Figure 1 – difficulties to achieve interlocking effects

Woven materials however function by friction and work with almost any kind of aggregate including pure sand. Typically robust and rigid polypropylene based wovens are used for this application. The material shapes itself around possible large size stone being pressed down because of the soft soil which is below (if this was not case, no problem would be needed to solve!). The best possible name to describe this effect would be “embedment”.

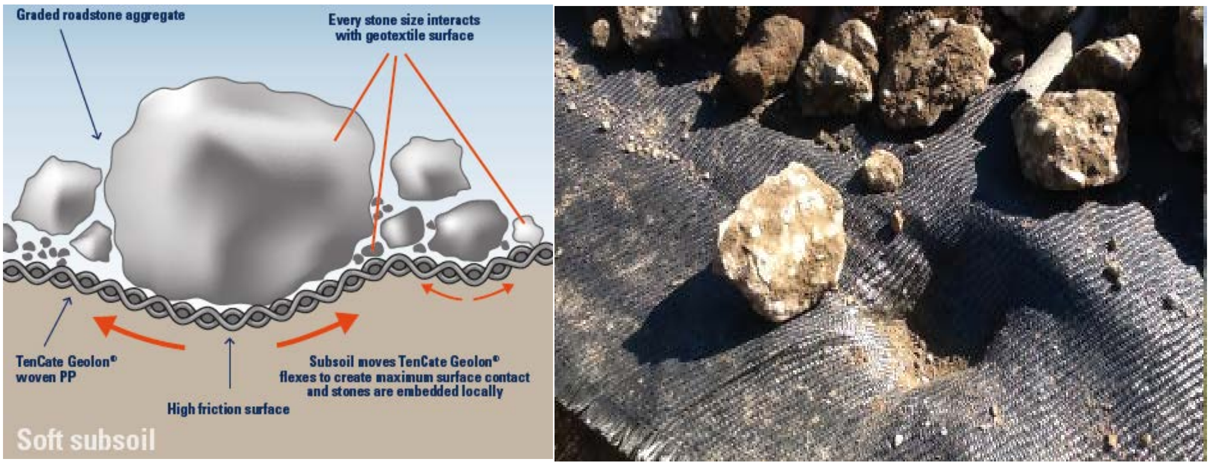

Figure 2 – Embedment of any mixed kind of sand/aggregate

The combinations of high tensile strength, puncture resistance, robustness and rough surface create a set of tools for excellent functionality in the most difficult soil circumstances. Many projects in desolated and swampy areas have been realised, making infrastructure for wind farms, forest roads, and the oil and gas industry. In fact these kinds of terrains would not be accessible at all without the use of high strength woven geosynthetics. Multifunctional use with reinforcement and separation in one product, flexible to install, no memeory effects requiring ballsasting during installation have proven their existence.

Figure 3 – fields inaccessible w/o the right geosynthetic

Other features of woven geosynthetics often forgotten is the possibility to be sewn together to panels of larger width then the usual maximum 5 – 5,20 m roll width. Using prefabricated panels saves overlap and makes extremely fast construction possible. Normally the seams are placed perpendicularly to the road axes, where overlaps normally are installed in the road direction. Depending on the soil state, such overlaps can mean a weak spot in the final road. For really soft soil circumstances middle overlaps should be avoided. This method was used on a large scale to construct more than 100 km of haul roads in Siberian muskeg circumstances for the exploration of an oil field. The fabrication method was chosen in order to be able to reach more than 300 m of finalized road per day which was required to start the exploration in time.

Figure 4 – prefabricated panels delivered and unfolded on site

3.3 *Building an embankment in the water*

Another good example of the use of high strength woven geosynthetics is the construction of an embankment in shallow water in a lagoon in Italy. The structure is intended to divide the lagoon into separate parts of which one part is owned privately and the other part is public domain. The owner of the private part wanted to close his part for fishing purposes with a controlled open sea connection. Besides isolating one part from the other, the second function of the embankment is to create a touristic cycle route on top of the structure.

The embankment has been designed under the lowest possible cost, and a geosynthetic solution was chosen, based upon high strength polyester woven geotextiles in 2 layers for reinforcement over the soft soil bottom of the lagoon. The geotextile has been prefabricated to large panels specially folded and rolled up on steel cores for ease of installation. Polyester raw material was chosen because of the needed long term design strength and secondly because it sinks to the bottom which enables easier installation. The embankment was built in 2 layers, wrapped as matresses between wooden poles. The fabrication makes sure the material stay well in place, which would have been rather impossible by using overlaps each 5 m.

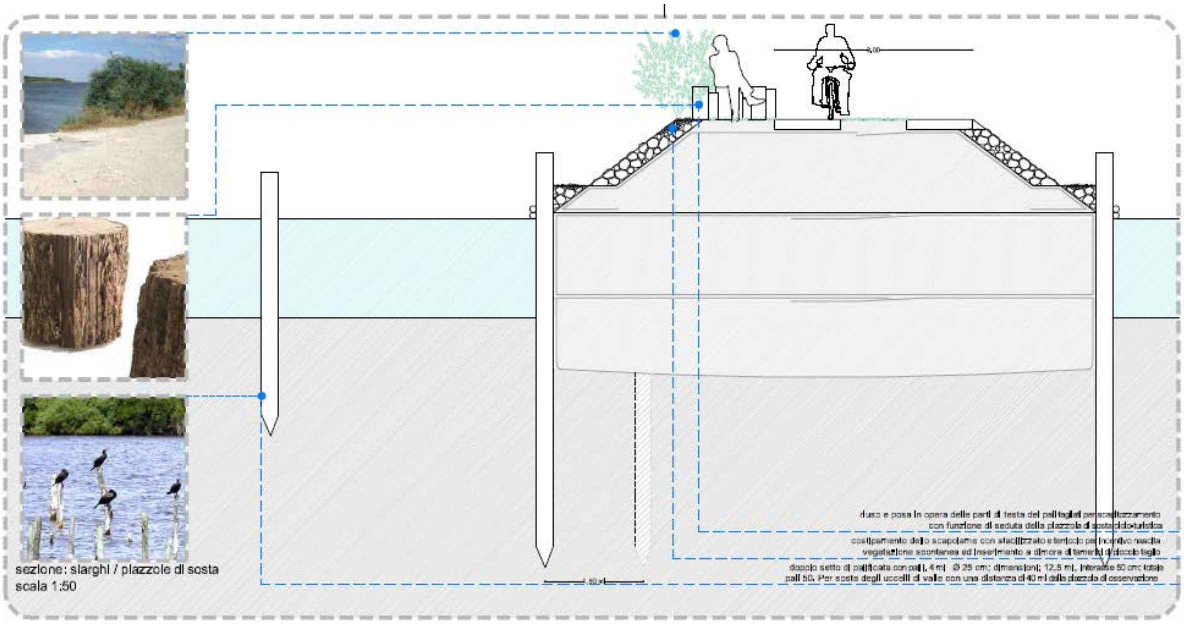

Figure 5 – reinforced embankment installed under water

The panels of 17 long x 50 m wide were made from a 150/50 kN PET woven for the bottom layer, and 100/50 kN for the second one. The riprap on top is installed on a light weigth PP filterweave to prevent washout of fines due to wave impact.

Installation was done by unrolling the panels from the extra long steel cores resting on the poles at both ends. Due to its own weight the textile slowly sank down to the bottom after which it could be filled easily with local soil from the bottom of the lagoon. After the right height level was reached, the soil package was “enveloped” as a mattress, on which the next layer was installed. A temporary nonwoven on the top of the piles prevented the textile from getting stuck and possibly ripped when sinking down.

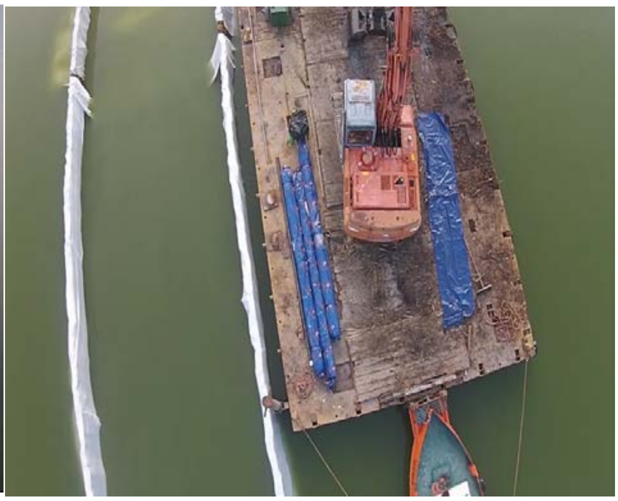

Figure 6 – unrolling and filling of the embankment

One of the lessons learned here is that, despite the main force in the textile are perpendicular to the embankment, still the installation and especially filling caused a lot of stress on the seams. Although no single seam failed, the installation could have been carried out faster being less cautious. A biaxial geotextile version would even have been more ideal for this application.

High strength woven polyester geotextiles up to strengths from 2000 kN have been applied for many years for deep water installation of breakwater structures for port construction. Also for this application prefabrication of larger panels systems which can be easily unrolled under water have meanwhile proven to be very advantageous, saving costs in the full construction in labour and material use.

3.4 *Dock infills and soft site closures*

Another good example of the advantages that only high strength woven geosynthetics can bring are dock infills and soft site closures. Also here prefabrication plays the largest role as these projects are often limited in space around the site and the impossibility to access the area to be covered as it is too soft or even just water. These kinds of projects typically require a robust fabric, resistant to puncturing from debris. In most cases the fabric needs to avoid any risk of having fines coming up due the pressure from above. Special seam strength techniques have been developed to create seams with strengths up to 80 or even 100% of the fabric strength. Usually the choice is made for the use of high strength biaxial polypropylene wovens as these are able to fulfil all the above requirements in a single material.

As the area to cover cannot be accessed by equipment, sometimes not even by persons, solutions have been developed to create the largest possible panels which can be pulled from one side over the full area. If possible setting the area under water may ease the process as the polypropylene will float until ballasted. Even combinations of PP and PET in a woven have been used to install fabrics which are the same weight as the water. Minimal ballasting makes the fabric evenly sink down to the bottom with low risk of falting.

In most cases the weight of the panel is the limitation for handling and shipping and determines the maximum single panel size. Adjacent panels need to be connected to each other. This connection needs to resist force but moreover keep the silts below the geotextile for the full 100% in place.

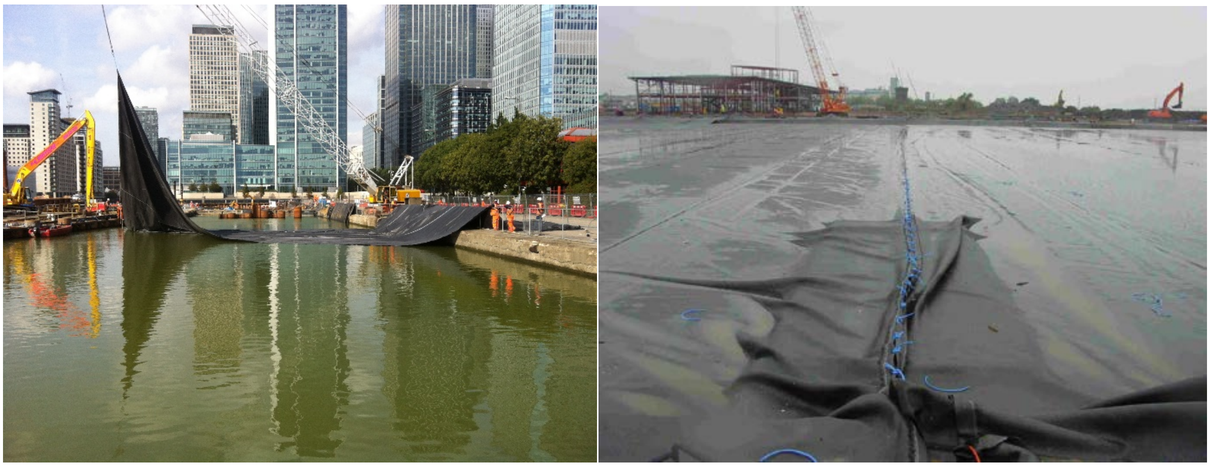

Figure 7 – typical dock infills

The purpose of dock infills can vary. Cases have been realised where old unused dock gets a new function as roll-on-roll-off terminal parking lot, but also docks are filled to create a working platform inside the dock for piling rigs, to create piled foundations for new buildings in old dock areas.

A similar application is the closure of tailing points or sludge lagoons, so-called soft site closures, where the geotextile operates as a kind of capping layer. Also here the purpose can be a new function like a recreational park over polluted lagoons, or simply to protect the environment from harzardous materials just be isolating it. Also coal ash basins are a good example where geotextiles can bring the optimum solution.

Also for this purpose the choice of material, the panel sizes and the way of installation are the key factors to success.

Figure 8 – soft site closures

4 CONCLUSIONS

High strength woven geotextiles have been around for many years providing specific optimum solutions in the geotechnical engineering for which other types of geosynthetics are less suitable or even fully unsuitable. But even in the daily use of geosynthetics for road constructions the benefits of these materials, especially in combination with wet and soft soil circumstance are rather underappreciated in the geosynthetics market. It is in the interest of the industry, and the whole market that the value these materials can bring are highlighted instead of degraded, in order to grow the full market and the use of all types of geosynthetics out here as a full worthy construction product.

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