Recent geosynthetics road applications in Northern Africa: data base initialization

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ABSTRACT: The demand for geosynthetics earthworks is driven in most cases by the state of the nation's economy. This is particularly the case for Northern African countries where the state of economy is in the developing stage and therefore financial resources are available for infrastructures and resource development leading to increased demand for geosynthetics. This paper presents recent applications for transport infrastructures. It highlights the importance of considering geosynthetics solutions to address some of the technical difficulties inherent to the region.

1 INTRODUCTION

The diversity in functions that geosynthetics can offer combined with the possibility of speeding up project completions and the challenge to design and construct more economical structures with limited resources have resulted in an increasing uptake and acceptance of geosynthetics in Northern Africa. One needs to acknowledge that the increasing use of geosynthetics is also driven by major programs of infrastructure development funded either through international institutions or local governments. Lawson and Cowland (1999) indicated the demand for geosynthetics is in most cases driven by the state of the nation's economy. This is particularly true for Northern African countries.

This paper aims to give a snapshot of major projects or cases (not widely known or documented) which show a variety of applications in Northern Africa as described in Table 1. In some cases these are first time applications. Furthermore, the paper intends to contribute to the start of the establishment of a useful data base of projects related to geosynthetics earthworks in Africa. It will also highlight some of the issues typical to Northern Africa which probably are similar to the rest of the African continent.

Table 1:Case Histories

N°	APPLICATION	Earthwork Specificity	Geosynthetic Type	location	Country
B1	Bridge Abutment	Segmental wall	PE NonWoven+ PES yarns	Msila	Algeria
B2	Bridge Abutment	Independant Concrete Screen	PE NonWoven+ PES yarns	Dakar	Senegal
S1	Steep slopes	Vertical facing	PES Straps+ PE Coating	El Jebha	Morocco
E1	Embankment	Soil of poor bearing capacity	Geogrid +GeotextileFilter	Chott El-Hodna	Algeria
E2	Embankment	Soil prone to subsidence (Karst)	PE NonWoven+ PES yarns	Tunis Highway	Tunisia

2 GEOSYNTHETICS BACKGROUND

Nowadays, geosynthetics applications are very divers. Geosynthetics are widely used in geotechnical, environmental and hydraulic applications due to their versatility and their ability to perform a variety of functions. These functions include not only primary traditional functions such as reinforcement but also other functions (non-traditional or specialised) such as protection or micro-confinement of soil particles in erosion control applications, confinement of soils through the use of geocells or geocontainers. Geosynthetic products typically used as reinforcement elements are geotextiles and geogrids. Additional products include geocells and fiber reinforcement. Design and construction of stable steep slopes, bridge abutments, retaining walls and embankments within space constraints are major economical considerations in geotechnical engineering projects. As a result of this, the uptake of the geosynthetic solution has become very appealing to a number of North African countries.

3 BRIDGE ABUTMENTS

3.1. *Case B1, Bridge Access Embankment, M'sila, Algeria*

The revival of a railway link project between the cities of Bordj-BouArreridj and Ain Touta, via the city of M'sila (East of Algeria) has forced the national railway company to resume work on the flyover that crosses the railway line at the entrance of the city of M'sila. The structure was constructed in the 1980's but was never completed because the railway project was abandoned due to economical constraints (Figure 1). Given the urgency of the railway project, the local administration launched a consultation for the construction of the access ramps to the road bridge in order to avoid any disturbance to road traffic during the construction

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Figure 1:View of the unfinished bridge structure B1

of the railway track and complete the flyover structure for the benefit of the road users The classical embankment solution was excluded because of the proximity of farmland and a housing complex for which the expropriation process would have taken long time to complete. The contracting authority sought a solution that would stiffen the embankment fill, reduce the footprint and construction time. The solution adopted for the stiffening of the access ramps was to use segmental walls , inclined at 74^{o}, reinforced with high tensile strength geotextiles. Backfill material (alluvial material) was sourced locally and structure was completed in 2005 (Figure 2).

The calculation method used for the design of the structure was based on the software CARTAGE, and followed French guidelines for earthen structures (Delmas et al. 1986). This method determines the efforts mobilised in the reinforcement and takes into account the extensible nature of the geotextiles, the mechanical properties of the backfill material and the geometry of the structure.

Figure 2: Completed structure B1

3.2. *Case B2 , Bridge Access Embankments, Dakar, Senegal*

The highway which constitutes the main access to the peninsula of Dakar supports a very large flow of vehicles. Poorly designed intersections resulted in persistent bottlenecks leading to continuous and lengthy traffic jams. The improvement of urban fluidity included the construction of overpasses and access embankments. Lack of space, cost for crushed materials and the presence of soft clayey-sand subsoil were critical issues which had to be solved and made the construction of access reinforced embankments very attractive. The use of geosynthetic reinforced fills allowed the construction of vertical embankments and minimized the need to use concrete compared to traditional retaining walls. Dune sand, cheap and abundantly available locally, was used as backfill material. It was confined at the facing by geotextiles and laterite. The embankments were completed before the facing was installed, in order to allow consolidation of the clayey-sand subsoil.

The bridge-access embankments (Figure 3) were constituted of:

•a geosynthetic reinforced fill: alternate layers of high strength geotextiles and fill material were used. The geotextiles were wrapped round the fill at the facing to obtain a vertical, stable embankment with as maximum height of 5.2 m.

•prefabricated-concrete panel facing, 20 to 25 cm distant from the reinforced embankment. This facing was totally independent of the fill and did not support any earth pressure. It was founded on the ground in place or on a geosynthetic reinforced fill for the particular case of the northern side of this junction. The abutments were founded on piles. Short and long term internal and global stability of the reinforced fills were verified numerically using the conventional Bishop's method. For the particular case of the northern side of the junction where prefabricated concrete panels were directly founded on reinforced fills, the calculation was supplemented by an approach based on the use of the software CARTAGE (see case B1).A monitoring system using optic fibers (Geodetect®) has been installed on each embankment to monitor the deformations within the fills during the working life of the embankments. Monitoring measurements taken during installation and after construction completion showed very small deformations (average was around 0.5%).

It is worth noting that with this project (Figure 4) geosynthetic-reinforced wall technology was used for the first time in this part of Africa. Despite the absence of local experience on geosynthetic-reinforced wall construction, the project was easily completed. Furthermore, it illustrates how using local materials and a geosynthetic solution could provide sustainable growth.

4. STEEP SLOPES

4.1.*Case S2, Mediterranean bypass, El Jebha, Morocoo*

Northern Morocco is characterised by a poor road network. To open up the region, the Mediterranean

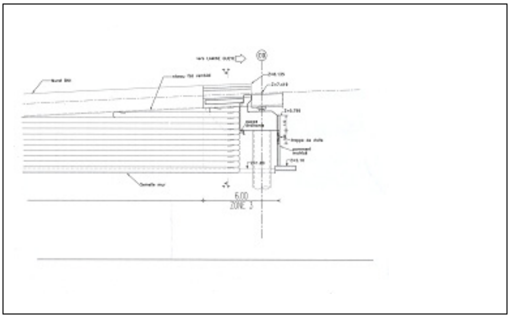

Figure 3 :Cross section near abutment,B2

Figure 4:View of the complete structure B2

bypass project was launched by the local authorities. It includes the rearrangement of 250 km of existing roads and the construction of 300kms of new roads. Reinforced earth structures played an important role in this major "open up" project. This case is in relation to the redevelopment of a mountainside road along the Moroccan Riff which is often on unstable slopes. The aim of the project was to stabilise the road as part of its widening on the section El Jebha/Beni Boufrah.

Figure 5:View of the geostrap reinforcement ,S1

The project involved the construction of 21 reinforced walls with height ranging from 8 to 16 m and length from 100 to 500 m, for a total area of 15 800 m². GeoStrap reinforcements, made from high tenacity fiber polyester encased in a polyethylene casing, were used in all the walls following Terre Armee concept (Figure 5).

5 EMBANKMENTS

5.1. *Case E1, Road Embankment, Chott El Hodna, Algeria*

The Chott El-Hodna project involves the construction of a 11 km long road through a salt lake (Chott El-Hodna, East of Algeria) linking the cities of M'Cif and Ain El-Khadra. The new road has opened up the salt lake for the inhabitants, who formerly had to make a 75 km detour, reducing the distance between the two cities to 16 km.

The salt lake is located at the extreme east of the highlands and is 220 Km long and 90 km wide. It is hydrologically a closed lake of more than 26.000 km^2. It was created by waters descending from the Atlas Tellien to the North and the Saharian Atlas to the South. The road will divide the lake in two parts, eastern lake and western lake with the eastern lake ending up with the largest area.

Figure 6: Site conditiond,E1

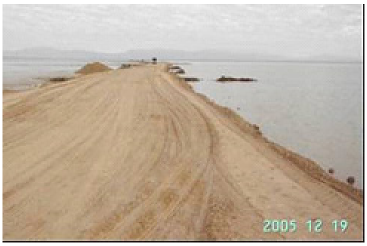

Figure 7: Partially inundated pilot road,E1

The salt lake is characterised by a very poor sub-grade (soft soil, undrained strength, C_u=9 kPa), Figure 6. During the winter it has a depth of 1 m, and remains filled with water 8 months of the year, Figure 7. In the summer it dries up due to evaporation and the bottom is completely covered with a layer of salt. The initial solution that was advocated was to dig two metres deep (carrier layer) over the entire length of the road and then fill the excavated area with a good quality fill material before building the road. However, this solution proved to be inadequate after a pilot test was conducted which indicated that it was difficult to conduct earthworks in very low bearing capacity soils and to find a suitable material in sufficient quantity and acceptable quality. The new solution with geosynthetics consisted of a shallow embankment which comprised from bottom to top of a separation/filtration geotextile, a compacted layer of fill material 0.40 thick, a bidirectional geogrid and a compacted 1.3 m of fill material (Figure 8). Furthermore, HDPE pipes with a diameter of 1000 mm were installed at regular intervals to ensure the continuity of natural flow between the two parts of the lake. Protection of the embankment slope consisted of a separation / filtration geotextile and rockfill shell.

Figure 8:Installation of geogrid and fill material,E1

5.2.*Case E2,Motorway Embankment, Tunisia*

Recently, karstic cavities have been observed on a section of about two kilometres during the construction of a motorway in Tunisia (Jamei et al., 2006). The geotechnical and geological data showed that the detected cavities were randomly distributed, and have varied shapes and depths. Two types of anomalies were indexed:

(1) Collapses related to the presence of karstic cavities, in general from 2 to 3 m in diameter (Figure 9), but being able to reach in certain cases 4 m to 5 m length by 2 m width. The collapse phenomenon is complex and very randomly (slowly collapse or collapse of blocks).

(2) Old chimneys (slow collapse), filled by argillaceous and marly materials . In these areas the soil is composed by gypsum of Triassic and marled clay with 30 m thickness, where heavy water activities were developed, which have a high acid concentration that induce the dissolutions of the gypsum and generate the formation of sub soil cavities.

The solution adopted for this project was to treat the cavities by injection of filling materials to slow down their evolution. This was combined with the use of a high tensile geotextile positioned at the base of the embankment to detect the presence of cavities, through the vertical movements obtained at the surface, and to limit the surface settlement to permissible values allowing traffic until repair works can be carried out. The geotextile was a non woven fitted with high tenacity polyester fibres (reinforcement was needed to support the required tensile force) in the traffic direction. The embankment was constituted of a 0.8 m thick layer of granular material. The thickness of the pavement road layer was about 0.35 m. For this project, the purpose of the designing method was to obtain in serviceability limit state a maximal surface settlement of 0.10 m for diameters of cavities of 2 m (maximal strain acting on the geosynthetic less than 5 %). The British Standard for reinforced fills and the French method (Villard et al. 2002) were used in this project. The major difference between the two methods is on the assumption of the collapse area over the cavity. Design methods allowed the selection of a geotextile with a the maximum average tensile strength of 260 kN/m corresponding to an elongation of 8%.

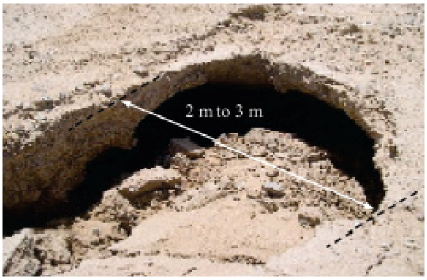

Figure 9: Karstic cavities (from Jamei & al,2006),E2

5.3 *Case E3, Kabale-Kutana road, Uganda*

The Kabale-Kutana road is the final link into Rwanda from Uganda. For much of its length the road runs along or close, to the interface between a swamp and sidelong ground. It is built either on embankment, or in half cutting and half embankment. Following extensive rainfall, two sections of embankment collapsed into the swamp with deep openings and cracks extending into the carriageway (Figure 10). This necessitated that the road be restricted to one lane for the use of light vehicles and closed completely to heavy vehicles.

Figure 10:Deep tension cracks in pavement,E3

Figure 11:Construction of geocell foundation mattress,E3

The repair work involved the use of a geocell mattress and geogrid reinforced soil. A 60° wraparound 5 meter high embankment was used to provide a stable structure on which the highway could be rebuilt. This minimised the embankment foot print, which would otherwise have meant extending the side slopes further onto the swamp areas with the continual risk of further failures. Soil filled bags were used to form the face angle of 60° with uniaxial geogrids wrapped around the bag work face and connected to the layer above using bodkins (Figure11). Locally fill was used in the embankment construction. The embankment fill was placed and compacted in accordance with local standards. The use of the geocell mattress was to provide a free draining, stable platform over very soft ground and to minimise differential settlement. It also allows water, percolating under the road, to escape without undermining the foundation between the existing cut half of the road, formed on a stable foundation, and the part of the road founded on swamp. It was rapidly assembled on site to form a deep, open cellular structure which is then filled with granular material. The design method was based on British Standards for earth reinforced fills. Ten years after its reconstruction, the road remains intact to the extent that the Ministry of Works removed it from its maintenance list.

6 CONCLUSION

Given the increased use of geosynthetics in various applications observed in the Northern African region over the past few years, it is interesting to speculate how the practice will develop in future. Geosynthetics will have a major role to play in this process. However, one should not lose sight of the need to adapt any transfer of technologies to local conditions and more importantly to tailor the selected solutions to the local specific needs of a country. Failure to acknowledge this aspect will result in the construction of too sophisticated structures or facilities that do not meet the local realities. Based on the cases reported in this paper, it is quite obvious that the use of geosynthetics is controlled by the rate of national economical development.

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