The use of a geosynthetic-reinforced wall in the construction of bridge-access embankments in Dakar (Senegal)

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ABSTRACT
“Malick SY” and “Cyrnos” crossroads were recently converted to grade-separated interchanges. On these urban sites, lack of space and the presence of soft clayey-sand subsoil were critical issues which had to be solved. For these two interchanges, the bridge-access embankments were constructed using geosynthetic-reinforced wall technology. A vertical-sided embankment was designed with very thin prefabricated concrete panel facing which is totally independent of the fill. An opportunity existed to use dune sand which is the cheapest fill material locally available. The embankments were completely built before the facing was installed, in order to allow consolidation of the clayey-sand subsoil. On each embankment, a monitoring system using optic fibers has been installed in order to measure deformations within the fill during the working life of the embankment. Measurements to date show only very small deformations within the fill.

1. INTRODUCTION

As in many cities, increased traffic is one of the major problems in the centre of Dakar (Senegal). Here, a number of crossroads constituted black spots for traffic flow.

In order to alleviate this situation, “Malick SY” and “Cyrnos” crossroads were recently converted to grade-separated interchanges. On these urban sites, lack of space and the presence of soft clayey-sand subsoil were critical issues which had to be solved.

For these two interchanges, the bridge-access embankments were constructed using geosynthetic-reinforced wall technology.

2. GEOTECHNICAL CONTEXT

The characteristics of the local soils of the two distant a few hundred meters crossroads are given schematically in table 1 (synthesis for the embankments):

Table 1: Nature and characteristic of the local soils

Depth under original ground	Nature of soil	Average pressiometric values
0 – 8 to 13 m	Sands and clayey sands (sometimes covered with surface fill)	$0.25 \leq pl^* \leq 0.75$ MPa $2 \leq E_M \leq 6$ MPa
8 to 13 m – 30 to 45 m	Alternatively marls, marno-limestones, limestones, clays and silts	$0.95 \leq pl^* \leq 4.5$ MPa $6 \leq E_M \leq 200$ MPa

Water table levels crops out the surface of the original ground (depth varying from 0.3 m to 1.6 m at the time of the measurements).

3. PROJECT DESCRIPTION

The bridge-access embankments were made of:

- a geosynthetic reinforced fill : alternate layers of geosynthetics and fill material are placed, and the geosynthetics are wrapped round the fill at the facing to obtain a vertical, stable embankment maximum height 5.2 m.
- a prefabricated-concrete panel facing 20 to 25 cm distant from reinforced embankment. This facing is totally independent of the fill and does not support any earth pressure. It is founded on the ground in place or punctually on a risberme of geosynthetic reinforced fill (particular case of the northern side of “Cyrnos” crossroad).

These works are overlaid by road structure and the adapted railing systems. The abutments are founded on piles, figure 1 and figure 2.

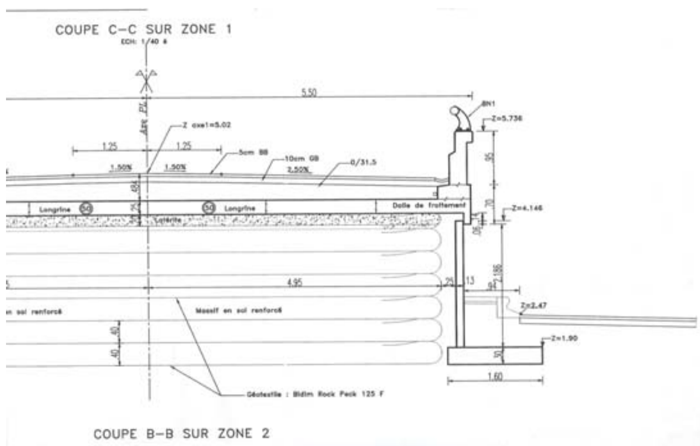

Figure 1: Transversal cross section – « Malick SY »

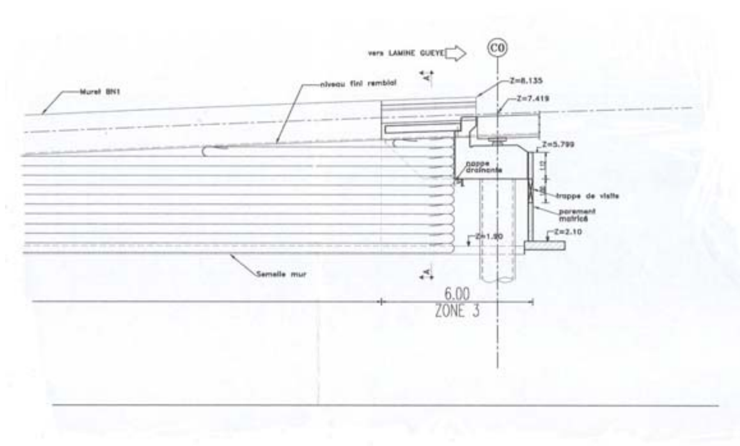

Figure 2: Partial longitudinal cross section near abutment C0 – « Malick SY »

4. PROJECT DESIGN AND JUSTIFICATION

4.1 Material used in fill construction

4.1.1 Fill material

The chosen materials for embankment fills were dune sands coming from “Keur Ndiaye Lo” quarry. These materials, which are available in abundance locally, show the following geotechnical characteristics:

Optimum density d_{opn} = 1.76 to 1.78
Water content at optimum density W_{opn} = 10.1 to 11.7 %
Fines content (size < 80 µm) 0.2 to 0.4%
Uniformity coefficient Cu = 1.6
CBR = 29 to 30

These sandy and pulverulent materials, with uniform granulometry, were confined in periphery and top of the embankments by compacted laterite, Figure 3.

Figure 3: Dune sand peripheral confinement with laterite

4.1.2 Reinforced geosynthetics

The reinforced geosynthetics used were composites which combine a polypropylene continuous filament needle-punched non-woven geotextile and high modulus polyester yarns.

The designed product for these works was TenCate bidim ROCK PEC 125 ASQUAL certified (Figure 4) which presented the following characteristics:

Tensile strength (ISO 10319):	T_{max}= 132 kN/ml Machine Direction (MD)
	T_{max} = 12 kN/ml Cross Direction (CD)
Elongation at maximal strength (ISO 10319):	ε_{max} = 11.5 % MD
	ε_{max} = 90 % CD
Dynamic perforation (EN 918):	18 mm
Thickness (ISO 9863-1):	2.5 mm
Mass per unit area (ISO 9864):	420 g/m^2

Figure 4: Reinforced geosynthetic sample

4.2 Stability analysis

4.2.1 Design methods and assumptions used

Internal and global stability of reinforced fills (short and long term) were carried out with Bishop's method with two-dimensional circular slip failure surfaces. A total factor of safety of 1.5 was required. Calculations were made with TALREN software from TERRASOL.

For the particular case of the northern side of "Cyrnos" crossroad where prefabricated concrete panels were directly founded on reinforced fills, this calculation was supplemented by an approach "called in deformation" carried out using software CARTAGE of the French laboratory LCPC. It allows one to add a horizontal criterion of deformation at the head (here D < 5 cm).

Soil shear parameters have been established with correlations using geotechnical data available.

Vertical spacing between geosynthetics layers = 40 cm
Friction efficiency factor : $\tan \phi_{sol\text{-}gtx} / \tan \phi_{sol} = 0{,}7$
Long term tensile strength is determined as follows :
$T_{Service} = T_{max} / F_{gtx}$ with :
T_{max} : Tensile strength
$T_{Service}$: Long term tensile strength
F_{gtx} : Safety factor on geosynthetic, equal to 3.3 here
Geosynthetic stiffness J = 1150 kN/ml

4.2.2 Calculation results

The realization of calculations made it possible to define the minimal length of the geosynthetics layers which are necessary to ensure sufficient stability for each configuration considered, Figure 5 and Figure 6.

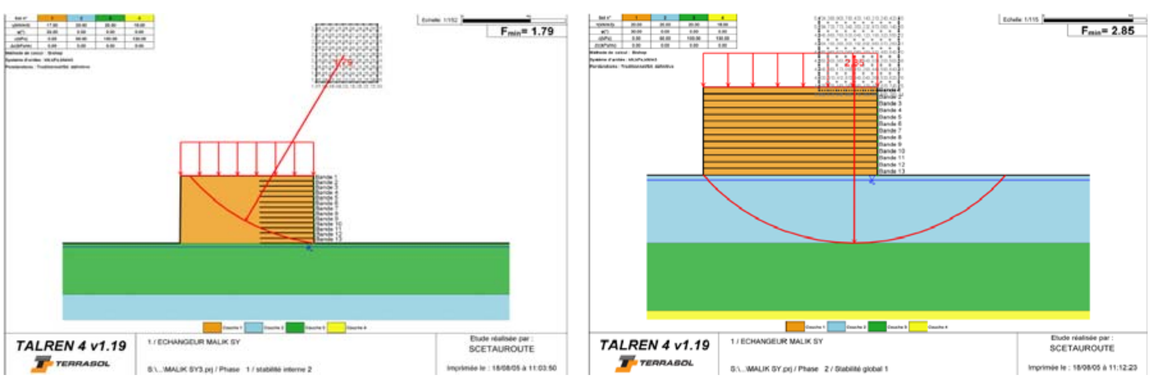

Figure 5: Internal and global calculation results – Abutment C0 « Malick SY »

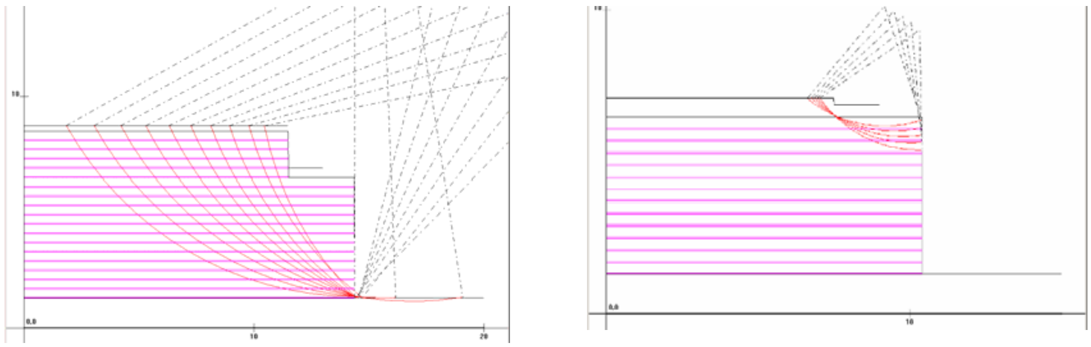

Figure 6: Internal calculation results with CARTAGE software – Abutment C3 “Cyrnos”

Ground total settlements estimation was carried out with correlations using pressiometric data. The estimation led to values between 10 and 30 cm depending on the embankments considered.

5. EMBANKMENT CONSTRUCTION

The principal stages of the construction of the geosynthetic-reinforced walls are described and illustrated hereafter.

Geosynthetics were laid in plane without folds. Reinforcement polyester yarns were oriented in perpendicular direction from facing.

The small geosynthetic length necessary for the anchoring of the wrapped round facing was turned up on the temporary formwork (concrete formwork for the first three levels, removable squares steel formwork then).

The fill was carried out taking care not to damage geosynthetic. Dune sand and laterite in periphery were compacted. When the layer thickness were reached, the small geosynthetic length is folded back on the embankment, slightly tensioned and anchored, figure 8.

In that case final concrete facing construction was delayed till ground soils consolidation effectively happened. During this period, U.V rays and accidents could have damaged geosynthetics. To avoid this, a light non woven has been unrolled on facing to temporarily protect the reinforced fill.

After ground consolidation, prefabricated concrete panels have been installed on concrete foundation. Figure 7 and figure 8.

Figure 7: Temporary formwork, fill installation and compaction – « Malick SY »

Figure 8: Fill elevation and prefabricated concrete panels installation – « Malick SY »

Figure 9: "Malick Sy" cross road completed.

6. GEOSYNTHETIC-REINFORCED WALL MONITORING

6.1 Description of the system

GEODETECT system allows monitoring the deformation of the geosynthetics through the strain measured directly in an attached optic fiber. This is possible using Fiber Bragg Gratings (FBGs) technology. FBGs are diffracting elements located in the photosensitive core of a single mode optical fiber. The FBG reflects a spectral peak based on the grating spacing. Thus, changes in the length of the fiber due to tension or compression will change the grating spacing and the wavelength of the reflected light (Fig. 1). Measuring the center wavelength of the reflected spectral peak allows quantitative strain measurements.

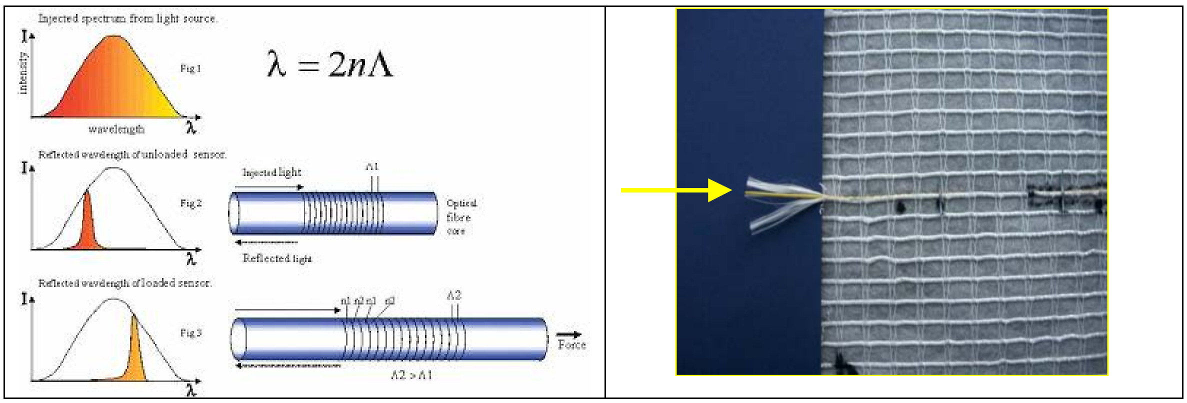

Figure 9: FBGs principle and detail of the optical fiber on geosynthetic strip

6.2 Project application

Each embankment from « Malick SY » and « Cyrnos » crossroads included two strips. Each strip includes five sensors, figure 10.

The strips were installed at approximately 10 m long of the abutments and 1.2 m higher than the reinforced fill base (lower third of the embankment). They were laid out perpendicular to each facing, figure 11.

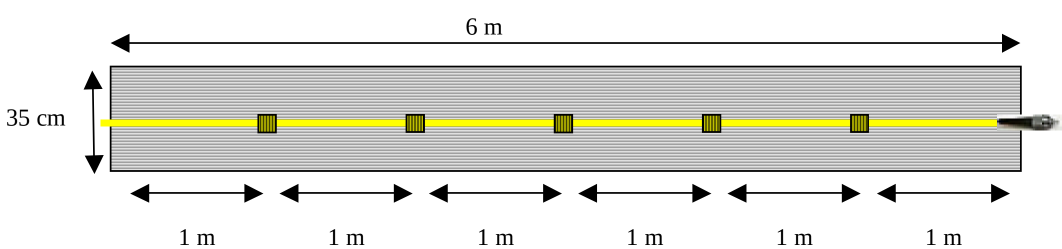

Figure 10: Dimensions and sensor position on strips

Figure 11: Strip control before installation and installation

Measurements made on the different embankments during installation and after construction completion gave the following values:

- Elongation after installation was lower than 0.12 %
- Elongation at the end of the fill construction ranged between 0.28 and 1.06%, the average value was 0.51%

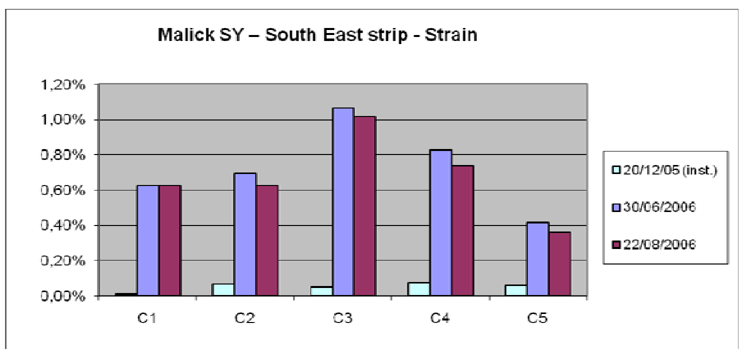

Figure 12 : Elongations measured on each sensor of one of the strips

7. CONCLUSION

“Malick SY” and “Cyrnos” crossroads conversion to grade-separated interchanges was a great opportunity to use geosynthetic-reinforced wall technology which had not been used until this project in this part of the world. The following particular points can be noticed:

- This site was an opportunity to use dune sand which is the easily locally available material. This material was confined at the facing by geosynthetic and laterite. As other parts of the world, Africa is facing to the lack of build material availability. This project is an illustration of what geosynthetics solutions could provide to local needs.

- The embankments were completely built before the facing was installed, in order to allow consolidation of the clayey-sand subsoil.

On each embankment, a monitoring system using optic fibers (geodetect®) has been installed in order to measure deformations within the fill during the working life of the embankment

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