Innovative mechanically stabilized earth walls with geotextile geocells

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ABSTRACT
Structures reinforced with geosynthetics consist in increasing the mechanical performance of a soil (mainly shear resistance) by associating it with flexible geosynthetics inclusions. One of the important issues in the construction of geosynthetic reinforced walls is the supply of natural backfill materials with the required properties needed for the stability of the wall. Indeed, unlike geosynthetics that exhibit stable properties due to extensive quality controls during the manufacturing process, soil matrix will vary from a site to another and even from the beginning to the end of the excavation work. It influences the soil stability itself and also the soil-geosynthetic interface.
As it minimizes the influence of soil characteristics on the stability of the reinforced structure, M3S geotextile geocells make possible, in addition to the construction of reinforced structures with complex shapes, to reuse the soil material excavated on-site to build the wall, including those with very poor geotechnical characteristics.
This publication presents the M3S cellular system and its mechanical and functional characteristics. It also gives a case study on the construction in 2019 of two MSE walls as part of the A71 motorway bypass on the APRR network, France.

RÉSUMÉ
Les structures renforcées par géosynthétiques consistent à augmenter les performances mécaniques d'un sol (principalement la résistance au cisaillement) en l'associant à des inclusions de géosynthétiques souples. L'une des problématiques importantes dans la construction de murs renforcés par géosynthétiques est l'approvisionnement en matériaux de remblai naturels ayant les propriétés requises pour la stabilité du mur. En effet, contrairement aux géosynthétiques qui présentent des propriétés stables grâce à des contrôles de qualité poussés au cours du processus de fabrication, la matrice du sol variera d'un site à l'autre et même du début à la fin des travaux d'excavation. Elle influence la stabilité du sol lui-même ainsi que l'interface sol-géosynthétique.
En minimisant l'influence des caractéristiques du sol sur la stabilité de la structure renforcée, les cellules alvéolaires en géotextiles M3S permettent, en plus de la construction de structures renforcées aux formes complexes, de réutiliser le matériau du sol excavé sur le site pour construire le mur, y compris ceux qui ont des caractéristiques géotechniques très médiocres.
Cette publication présente le système alvéolaire M3S et ses caractéristiques mécaniques et fonctionnelles. Elle donne également une étude de cas sur la réalisation en 2019 de deux murs renforcés dans le cadre de la déviation de l'autoroute A71 sur le réseau APRR, France.

1 INTRODUCTION

The study of a reinforced earth structure designed through the construction of a highway in Montmarault, France, highlights the constraints of an ambitious project and shows how a retaining structure made with geotextile geocells can adapt itself to this type of constraints. The first part describes the context of the project. Then, the geotextile geocells system is presented. Finally, the main design steps are described, and the limit of this solution is also considered.

2 CONTEXT OF THE PROJECT

2.1 Situation

The A71 highway between Paris and Clermont-Ferrand (France) needed to get a new interchange near Montmarault (figure 1). A bypass has then been constructed as part of this APRR (Autoroutes Paris-Rhin-Rhône) project. This bypass had to get stiffened embankments to free the platforms required for the construction of the two interchange structures.

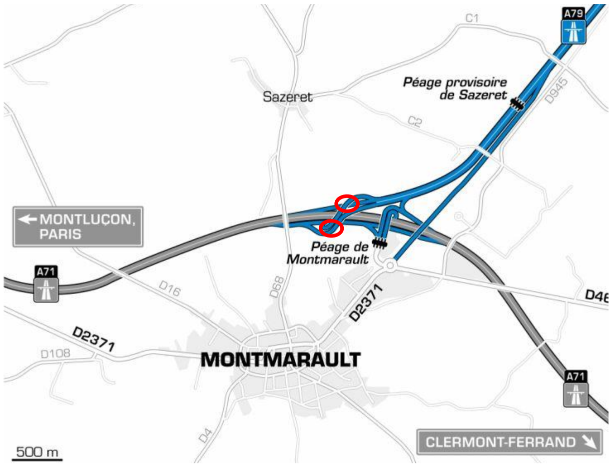

Figure 1. Localization of the platforms (Carto Diem – Thomas Grollier).

The North structure supports the 2x2 highway lanes and emergency lane over an M3S wall, 8 m (26 ft.) high (figure 2).


Figure 2. North structure (La Montagne source)

The south structure consists of a 4.5 m (15 ft.) high M3S wall over a 5 m (16.5 ft.) high soil-nailed wall (figure 3).

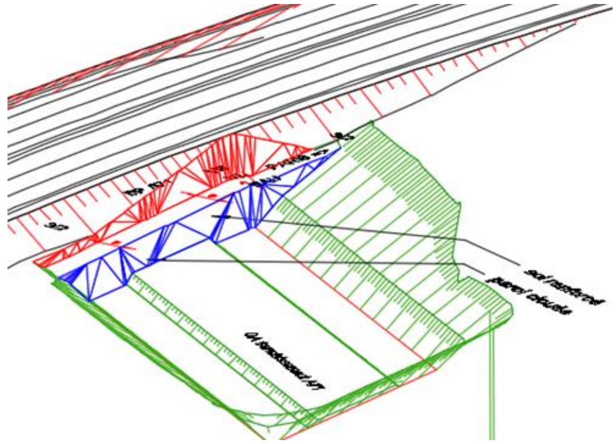
Figure 3. South structure - 3D view

2.2 Constrains of the project

The impossibility to stop the traffic on the highway required to complete the construction work in phases. The bypass has been constructed in the immediate proximity of the road (figure 4).

The materials used are materials resulting from the excavation work nearby (weathered granite).


Figure 4. Aerial view of the bypass (© Philippe Busser | XXI communication | APRR)

3 INNOVATIVE GEOSYNTHETIC GEOCELL

3.1 Three-dimensional reinforcement

There are three main types of Mechanically Stabilized Earth (MSE) retaining structures, all made of pre-fabricated wall facing elements and a soil mass reinforced with geosynthetic materials. Uni-directional and bi-directional reinforcement geosynthetic systems that operate using the friction between the geosynthetics and the granular soil and require anchoring. Three-dimensional systems as geosynthetic geocells that work with containment and do not require anchoring or specific fill material.

The M3S geotextile geocell system is a non-woven needle-punched alveolar reinforcement made in polyester (figure 5). The cells are 630 mm (25 in.) diagonal and 250 or 350 mm (10 or 13-4/5 in.) high. The bonds between the cells are made by seams on two bands, and geotextile outgrowths are using as a hook for the facing surface.

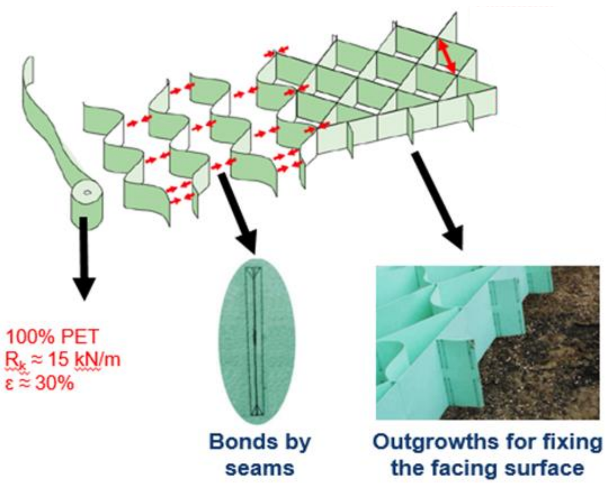

Figure 5. Geosynthetic geocells M3S

The geotextile geocells system offers numerous advantages on the project like the low storage space needed for supplies (figure 6), the implementation without trucks in and out, the valorization of the natural resources with the complete reuse of the excavated material and the overall cost savings. Even the gravely-clay material is suitable for the retaining structure by geotextile geocells M3S. The reduction of truck traffic also permits to reduce Greenhouse Gas (GHG) emissions. Last but not least, this innovative system allows to set up a vast choice of facing in front of the structure.


Figure 6. Storage for a 200 m (656 ft.) long and 4 m (13 ft.) high retaining structure

4 DESIGN STEPS AND PHASING OF WORK

4.1 Preliminary recognition and Modeling

Two preliminary studies helped to design the structure. The first required a geotechnical investigation with an excavator and the installation of a pressure meter at about 50 m (164 ft.) of the future reinforced structure. The second required laboratory analysis and enabled to control the input data. Then Panda® analysis was carried out at the bottom of the excavation to control the compaction of the material that will be used to build the wall. Table 1 presents the technical model selected for the project.

Table 1. Technical model selected

Material / Inputs	Characteristics
Weathered granite GTR B5	All the elevations including work Material exercising the pushes Low carrying capacity
0/80 mm soil	Backfilling material
Bedrock	Granite
Groundwater	No water
Seismic conditions	No seismic consideration (temporary construction)

The preliminary study shall meet the current Standards: Eurocode 7 and NF P 94-270. Limit state design requires the structure to satisfy two principal criteria: the Ultimate Limit State (ULS) and the Serviceability Limit State (SLS) (figure 7).

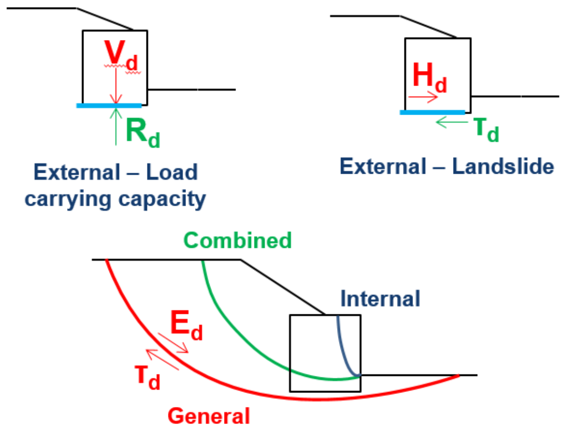

Figure 7. Verification of the ULS

The modeling is achieved using TALREN5® software. Several stability analyses are then conducted on the overall structure (figures 8 and 9).

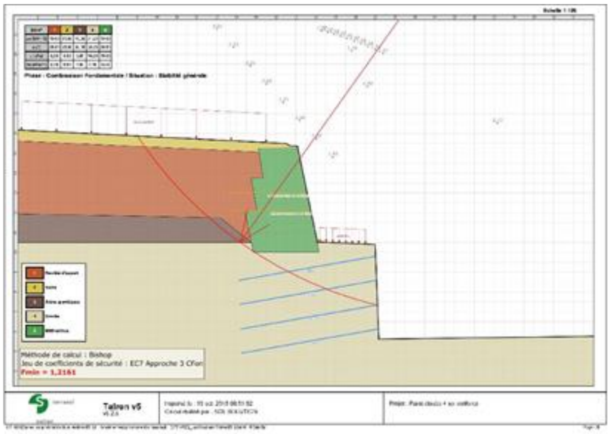

Figure 8. General stability assessment – South structure

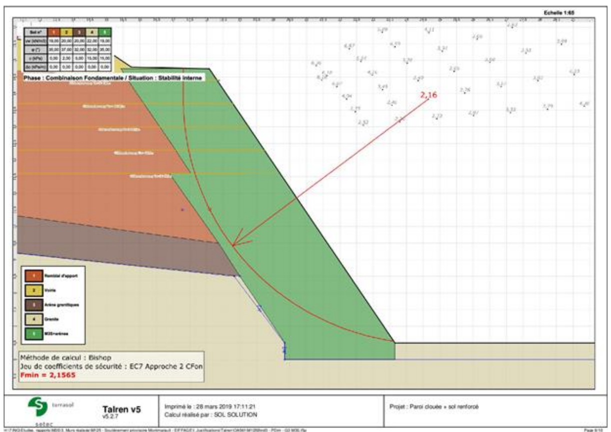

Figure 9. Combined stability assessment – North structure

4.2 General phasing of work

The main steps in the construction of the retaining structure are deployment and picketing of the first layer of the M3S geocells, backfilling, and compaction, then the next geocell layer is deployed, etc.

At the end is the installation of the facing structure. The facing system can be installed after expected deformations and stabilizations (if any) because the siding is dissociated from the retaining structure. Figure 10 describes the different steps of realization.

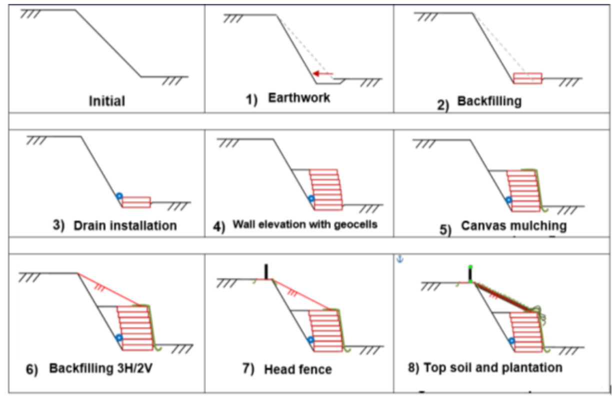

Figure 10. MSE wall construction steps with geocells

5 CONSTRUCTION PROCESS

The subgrade is first excavated at the required level (figure 11) then compacted. The compaction is controlled using PANDA® penetrometer.


Figure 11. Excavation of the subgrade

M3S geocells are deployed and temporarily maintained open with metal pins (figure 12). Afterward, these pins are removed

Figure 12. Geocells deployment

Backfilling is made with on-site material using a digger. The compaction is achieved with a manual compactor (figure 13).

Figure 13. Backfilling and compaction

These operations are repeated to raise the reinforcing structure (figure 14).

Figure 14. Elevation of the retaining structure

6 CONCLUSION

Despite numerous constraints like the work area, the site accessibility, and the bad characteristics of the on-site soil material, the retaining structure has been successfully achieved on time and within budget. The geosynthetic geocells system adapted itself to all these constraints because it permits to use the on-site excavated material.

There are no real technical limitations to retaining structures with geotextile geocells. Like every reinforced structure, it must be adequately designed regarding stability.

The installation of the system is fast and does not require heavy machinery. Moreover, the reinforced structures with geotextile geocells system resist to high differential settlements and are compatible with very low bearing capacities or water-saturated soils.

7 REFERENCES

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