Some case studies of geosynthetic solutions dealing with landslides and unstable slopes in north Algeria

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ABSTRACT

The efficiency and the sustainability of geosynthetics in the reinforcement applications are now well demonstrated. Standards, according to the Eurocode 7, give a framework for designs and facilitate the work of the engineer. In this article, we present case studies where geosynthetics solution are designed, compared to other methods and finally implemented on site for mitigation and/or rehabilitation of road affected by landslides.

1. INTRODUCTION

Landslides affect both natural slopes and anthropic structures like embankments. Most of them are due to natural events. In the north of Algeria, these instabilities are one of the most frequent and important natural risks.

The topography, very hilly and mountainous, make than most of the road are built on slopes. Geology is often complex and vegetal cover poor due to dry climate and forest fires. The subgrade material usually observed are flyshs, pelites, clay and claystones, marls, schists etc… Heavy rain events affecting these areas combined with damaged and unmaintained drainage systems leads to instability on slopes and embankments.

Empirical solutions, without geotechnical studies and designs, are still implemented. These systems are installed to maintain the roads serviceability. We can quote gabion toes, retaining structures (by weight, concrete slabs, piles…), drainage trenches and spurs.
The figures 1 to 4 show examples of the instabilities treatments build as empirical solutions, which often doesn't solve the problem long-term.

In this article, we present three slope slidings treated and solved by Geosynthetic-Reinforced Soil systems, a standardized and documentated solution (Alexiew 2005, 2012 ; Arab et al. 2007 ; Blivet et al. 1992 ; Gourc et al. 1995).

2. CW25 ROAD SLIDING

120 m of the CW25 road, in the Ouarsenis mountains in the south of the Ain Defla willaya (department), slided after a heavy rain event (figure 5). Short-term decision was to reduce the width of the road. But a long-term solution was mandatory to prevent the extension of the instability in the slope and a cut, out of service, of the whole road. This road is vital for the villages of the valley, for example, for the children to go to school with the bus.


Figures 1et 2. Examples of gabion toe


Figures 3 et 4. Examples of treatments with drainage trenchs and spurs.

For this project, in a first step, a generalist engineer office asked for some geotechnical investigations with dynamic penetrometer. With the results, he purposes a first solution:

- Removal of all the slided material in the downhill part
- Building of Geosynthetic-Reinforced Soil system to re-create the slope.
- Building of a classic masonry wall in the upper part of the slope

Figure 5. View of the road and the sliding before rehabilitation

An important point imposed by the contractor is to maintain the circulation in the road during the works. In the preparation of the project, the earthworks company asked a specialized design office further investigations and design. This showed:

- A deeper substratum than previously assessed in the preliminary study
- A real sliding risk during the road widening.

The GRS (Geosynthetic-Reinforced Soil) system has been designed according to standard XP G 38064. The different justifications used the following assumptions:

- 64° facing inclinaison (close to 2V/1H)
- Maximal height 6 m
- 100 years design life
- High stiffness modulus polyester (PET) geotextile woven with a design tensile strength of 18,9 kN/m
- Reinforcement length of 6,5 m long, to fulfill all stability requirements (external, general and mixed stability)
- Vertical spacing of 0,5 m between 2 reinforcement layers
- ≥ 1,5 m long wrap-around

Figure 6 shows the isochrones curves of the geotextile reinforcement to show the long-term creep behavior.

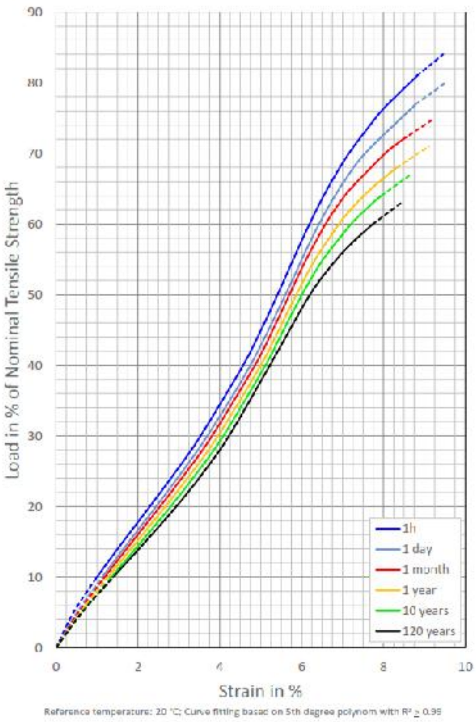

Figure 6. Isochrones curves of the geotextile reinforcement (Reference temperature 20°C)

Combined with the geotechnical design, the engineer office also defined a methodology for the rehabilitation earthworks.

- Methodic levelling of the slope, starting from the top
- Securing the half road remaining on service during the construction site
- Protection of the construction site against bad weather and runoff water
- Removal of all materials which slided
- Setting up of the drainage trench, according to the rules of the art, at the bottom of the newly excavated slope
- Installation of a drainage géocomposite at the interface between the slope and the new embankment
- Rebuilding of the half-road with the Geosynthetic-Reinforced Soil system
- Protection of the slope against UVs.

Figures 7 à 11 illustrate the different phases of the construction site

Figure 7. Widening of the road uphill and removal of the slided materials

Figure 8. Water management with drainage geocomposite and drainage trench

Figure 9. Building of the GRS

Figure 10. Protection of the slope against UV downhill and building of the masonry wall uphill

Figure 11. View of the finished project

3. RN66 ROAD SLIDING

The national road RN66 is a major road between the Ain Defla wilaya and the Tipaza wilaya in the valley of a wadi in a mountainous region (Figure 12).

Figure 12. 3D View and position of the different slidings along the RN66 Road

During a former rehabilitation of the asphalt layer, ponctual earthworks have been done to allow heavy machines to circulate. These works combined with a lack of management of the drainage systems lead to several localized sliding along the road. We present here the treatment of the sliding n°2 (figure 12)

The instability studied here is a regressive superficial sliding of a natural steep slope about 40 m long. The sliding is a treated not only for the RN66 but also for an electric line. By removing the natural toe of the slope and with the infiltration of rain water upstream (seepage observed), the previous works created a local instability.

A dynamic penetrometer drilling shows the substratum only 1 m under the surface.

The solution to stabilize the regressive sliding is to reestablish a slope toe by building a Geosynthetic-Reinforced Soil with green facing.

The execution studies had been led by a geotechnical engineer office mandated by the earthworks company. The design office optimizes the draft project and establishes the constructions and layout plans. The GRS (Geosynthetic-Reinforced Soil) system has been designed according to standard XP G 38064. The different justifications used the following assumptions:

- 65° facing inclination (close to 2V/1H)
- Maximal height 8 m
- 120 years design life
- Flexible with high stiffness modulus polyester (PET) Geogrid Fortrac T with a design tensile strength of 27,5 kN/m. The geogrids have a mesh size which allow a perfect interaction behavior with the embankment material.
- Reinforcement length is 6 m long, to fulfill all stability requirements (external, general and mixed stability)
- Vertical spacing of 0,5 m between 2 reinforcement layers
- Facing with ≥ 1,5 m long wrap-around for further greening.

The earthworks had been led in the dry season following the methodology:

- Removal of all materials which slided
- Installation of a drainage géocomposite for the management of the water coming from uphill
- Building of Geosynthetic-Reinforced Soil with control of material compaction at each layer.
- Installation a 1,5 m high gabion line at the bottom of the wall to protect them from erosion and possible traffic impact.
- Management of surface water.

Figure 13 to 15 show the different phases of the construction

Figure 13. Removal of slided material and levelling

Figure 14. Construction of the reinforced slope with Fortrac Geogrid, layer by layer

Figure 15. Construction of the reinforced slope with Fortrac Geogrid and compacted material

Figure 16. Earthworks completed – start of the greening of the facing

4. BENI MELLAL SLIDING IN SKIKDA

A 120 m long sliding occurred in Beni Mellal street in a hilly quarter of the city of Skikda. To prevent further evolution of the sliding which can damage the building uphill and reestablish the full width of the street, rehabilitation works has been done in 2014 following the methodology:

- Excavation of the slided material
- Drilling of horizontal anchorage in the in-place substratum
- Jet grouting of the excavated surface
- Creation of drainage trenches and spurs at the bottom of the embankment
- Installation of a drainage géocomposite
- Building of the Geosynthetic-Reinforced Soil, layer by layer, with compacted material
- Rehabilitation of the street uphill

The GRS (Geosynthetic-Reinforced Soil) system has been designed according to standard XP G 38064. The different justifications used the following assumptions:

- 64° facing inclinaison (close to 2V/1H)
- Maximal height 10 m
- 120 years design life
- High stiffness modulus polyester (PET) geotextile woven with nominal tensile strength of 200 kN/m.
- Reinforcement length is around 8 m long, to fulfill all stability requirements (external, general and mixed stability)
- Vertical spacing of 0,5 m between 2 reinforcement layers
- Facing with ≥ 1,5 m long wrap-around for further greening.

Figure 16 to 18 shows the different steps of the project until the actual state. No artificial vegetation has been applied but the facing is getting greener and greener with the colonization by natural vegetation.

Figure 16. Anchorage and jet grouting of the excavated sliding surface and then implementation of a drainage géocomposite

Figure 17. Building of the Geosynthetic-Reinforced Soil, layer by layer, filled by compacted material

Figure 18. View of the GRS 3 years of the construction. Natural greening of the facing and no cracks on the street uphill

5. CONCLUSION

Years after completion, all three jobs give entire satisfaction to the different contractors in term of water management, stability and facing. The system of Geosynthetic-Reinforced Soil to treat landslides and slope instabilities is, in the one hand, a cost-effective solution, especially because it allows to re-use site material, and is in the other hand a solution offering a good integration of the steep embankment in the environment.

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