SLOPE STABILIZATION BY MICOPILES ON EXISTING ROADS IN NORTHWESTERN TUNISIA

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ABSTRACT :

Tunisia faced current 2012 uncommon heavy rainy and snowy episodes, particularly in the northwestern of the country. These rainfalls combined with snow melt, lead mainly in mountainous areas to landslides spectacular in both numbers and sizes.

Those landslides damaged rural lanes and roads and broke up existing protections causing the isolation of many populated areas in the region.

Since the resulting risk on road users was real, and because many locations where completely inaccessible, the challenge in this case was therefore to undertake field expertise missions as well as, geotechnical investigations and studies, and to design and implement slope stabilization solutions in the shortest amount of time.

Geotechnical investigations by pressuremeters with continuous data recording, coring, piezocônes, dynamic penetrometers, have been realized, highlighting the nature of the soils involved in the landslides.

During investigation many soil natures were encountered depending on the location of the landslide: have been identified layers of filling on the first meters, claystone, sand and sandstone, sandy soils overlying sandstone, and also marls in some other places.

The recommended stabilization solutions that were implemented for fixing the damaged roads, consisted mainly in combining various stabilization actions, such as realizing lines of micropiles under the roads still accessible (nailing) as an immediate and provisional action to secure the roads, anchored retaining walls founded on micropiles (duets of vertical and inclined micropiles), and also sub-horizontal drains.

The first part of this paper includes a brief overview of the landslides mechanisms and soils involved, then a detailed presentation of the implemented stabilization solutions will be given, with a particular emphasis on the using of micropiles for dealing with such geotechnical issues.

RESUME :

La Tunisie a connu courant l'année 2012 des épisodes pluvieux et neigeux exceptionnels en particulier au Nord Ouest du pays. Ces importantes chutes de pluie, combinées aux épisodes de fonte des neiges, ont engendré en particulier dans les zones montagneuses des glissements spectaculaires tant en nombre qu'en envergure. Ces glissements ont sinistré des voies rurales et des routes, et endommagé les protections existantes, isolant ainsi de nombreuses localités.

Le challenge fut de réaliser des missions d'expertise, des campagnes et des études géotechniques, et d'élaborer des solutions de stabilisation en un temps record, étant donné que les dégâts occasionnés présentaient un risque certain sur les usagers, et que certaines zones étaient totalement inaccessibles.

Des sondages de types pressiomètres avec enregistrement des paramètres de forage, carottages, piézocônes, pénétromètres dynamiques, ont été réalisés, mettant en évidence la nature des terrains impliqués dans ces glissements.

Ces terrains varient selon les points de glissements considérés : ont été identifiés des remblais sur les premiers mètres, des alternances d'argilite, de sable et de grès, des terrains sableux surmontant des grès, ainsi que des terrains majoritairement marneux.

Les solutions de confortement préconisées et mise en œuvre pour la réparation des voies endommagées, consistent principalement à combiner plusieurs actions confortatives, à savoir réaliser des files de micropieux (clouage) sous les voies encore fonctionnelles comme action immédiate de sécurisation provisoire, des voiles de soutènement tirantés, supportés par des micropieux en chevalet, et mise en place de drains subhorizontaux.

Dans cet article seront abordés succinctement dans un premier temps la typologie des glissements et les terrains impliqués, puis seront détaillés les solutions de confortement retenues avec un accent particulier sur l'utilisation des micropieux dans l'appréhension de ce type de problème.

1. INTRODUCTION

Spectacular landslides triggered by rainy and snowy exceptional episodes, occurred in the North West of Tunisia during the year 2012 in the mountainous regions. These landslides have caused considerable damages: roads partially or totally destroyed, damaged homes, isolated communities, risk increased of human and material losses, ... etc.

The rapidity of these landslides, and the damage magnitude and extent as well, pushed the concerned authorities to take rapid and efficient actions to fix those landslides and related damages, mainly damaged roads.

Geotechnical investigations including pressuremeters surveys with drilling parameters recording, coring, piezometers, piezocônes, dynamic penetrometers, and also laboratory tests, were carried out, 2 to 8 geotechnical boreholes per landslide. The investigations were pushed to average depth of 15 m to 30 m, depending on slided volumes involved.

These surveys were carried out in record time given the project emergency.

Geotechnical boreholes were carried out in the landslides and on the edges of pavements involved.

2. GEOTECHNICAL CONTEXT

The geology of the areas where landslides took place, are mainly formed by hard marls, with intercalations of sandstone and limestone, and by compact claystones. Bedrock is topped by filling, elluvions, scree and by plastic clays, slightly to moderately compact.

The thickness of these soils varies depending on the geotechnical borehole, reaches in places 10 meters. The sites morphology is characterized by steep slopes profiles.

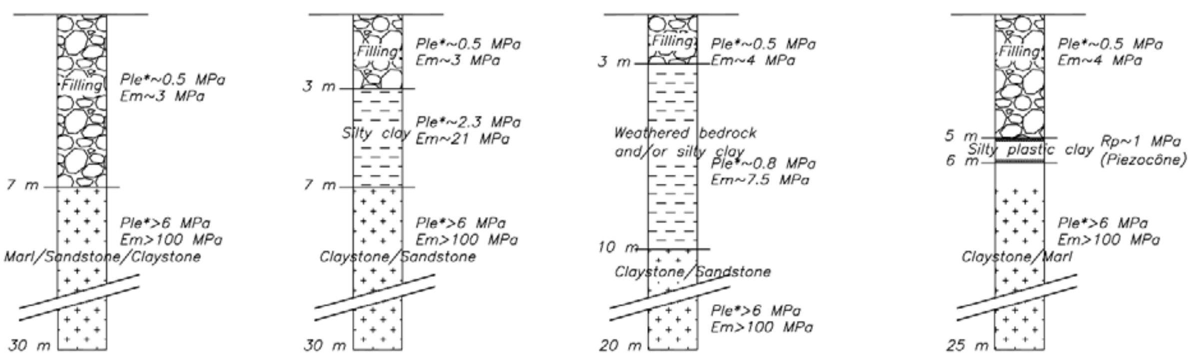

Fig.1. Soil log in some landslide sites

Occured landslides involved the upper layers, identified on the top of the bedrock, slightly to moderately compact, and with low permeability, they were triggered by water. They occurred (reactivated for some) by the significant water infiltrations resulting from heavy rains and snowmelt; the hydraulic system was thus modified and pore pressure in soil increased. The effects of those infiltrations were compounded by the malfunctioning of the existing drainage devices and collecting runoff.

The type of failure and soil movements of recorded landslides varies from one site to another, depending on the geological structure of the areas. The failure

surfaces were slightly close to circular shape, or had no specific form, or stuck the contact bedrock/upper layers for some cases. Three main landslide types were identified by the expertise study:
Pre-failure landslides (slow soil movements, deformations are observable but still acceptable), landslides where failure occurred, and reactivated landslides (reactivated old landslides).
Soil volumes involved in each landslide varies from few dozen to few thousand of m3.

Photo 1: Old lanslide reactivated, previously stabilized by a flexible gabions wall

Photo2: Landslide: pre-failure

Photo 3: Landslide: failure occured

Photo 4: Old landslide reactivated previously stabilized by gabions wall

Photos of some Landslides

3. STABILIZATION SOLUTIONS

3.1. Emergency solutions

For those landslides still in slow movement phases, with however observable deformations, emergency stabilization solutions were performed. The purpose was to slow down, or even to stop, immediately the roads deformations, and to perform finally a long term stabilization solution.
The retained solutions consist to:

- Reprofiling (soften) slope profiles mainly downstream the roads
- Soil nailing under the roads by rows of nails and micropiles, embedded in the bedrock and realization of devices for slope drainage. In figure 2, retaining wall, founded on executed micropiles for the emergency solution, is part of the long term solution.

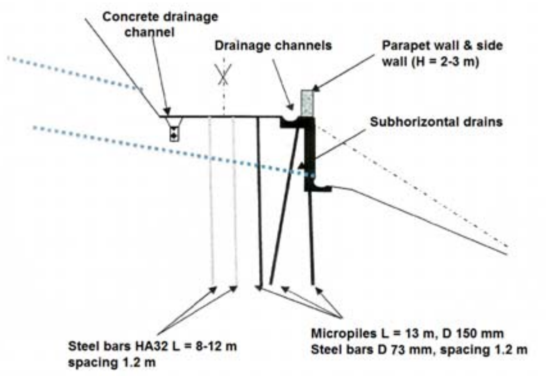

Fig.2. Example of an emergency solution for slope stabilization

Micropiles characaterictics are as follows :
- micropiles type III, IV (C, D), vertical and inclined (in duets), diameter 150 mm
- equipped with steel tubular bar diameter of 73 mm
- embedded at least 5 m in the bedrock
- variable spacing from 1.2 m to 1.5 m
- micropiles are set up on the total length of the road affected by the landslide, with an overhang on each limit of the area involved
- micropiles calculated to resist traction, compression and shear stresses

3.2. Long term solutions

Long term solutions proposed initially by the expertise study, are mainly five, involving flexible and rigid structures. Those solutions were associated to earthworks (soil re-profiling).
The 5 options are:

- Option A: gabions walls
- Option B: stabilization by filling reinforced by metallic bars and mineral façade
- Option C: stabilization by a selected filling reinforced by reinforcement bars : reinforced bars, armatures in geosynthetic, mineral or vegetal façade
- Option D: stabilization by using rigid elements
- Option E: slope drainage devices

Structures of type A were dismissed because used previously and obviously ineffective in many old landslides in the concerned area. Option E should be used in association with the other stabilization options.
For most of recorded landslides, rigid solutions of type D, coupled with solutions such as E, were selected, calculated and implemented.
Such solutions plan includes reinforced concrete retaining wall, anchored if needed, and founded on rows of duets of micropiles. This solution is coupled with drainage operation, starting by fixing existing drainage devices, and drainage of the soil upstream the wall. This drainage is provided by sub-horizontal drains linked to a system for collecting and evacuating the water, and if necessary by setting up on landslides area, a draining material (figure 3).

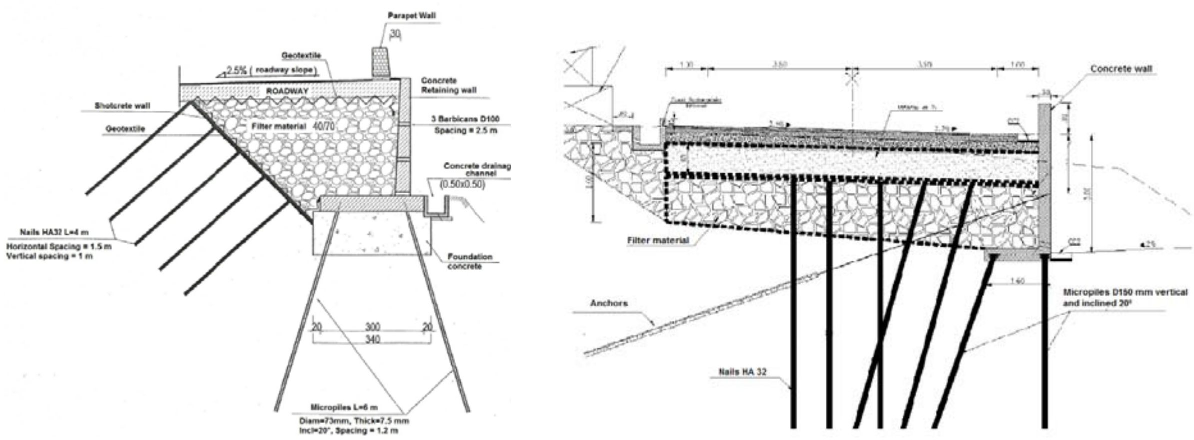

Fig. 3. Examples for selected rigid stabilization options

Characaterictics of walls foundation micropiles are:

- micropiles type III or IV (C or D), vertical or inclined (in duets), diameter 150 mm
- sealing using IGU or IRS procedure depending on the loads transmitted to the micropiles
- equipped with steel tubular bar diameter of 73 mm
- embedded at least 5 m in the bedrock
- variable spacing from 1.2 m to 1.5 m
- micropiles calculated to resist compression traction, and shear stresses

3.3. Calculation

Stability calculations have been performed using the following methods and tools:

-Software TALREN: slope stability calculation by common Bishop method, and design of the reinforcement elements.

-Software Plaxis 2D: calculation of the soil deformation and design of the reinforcement elements.

Examples of calculation results are given in the following figures (calculation is given for the landslide in photo n°2, § 2):

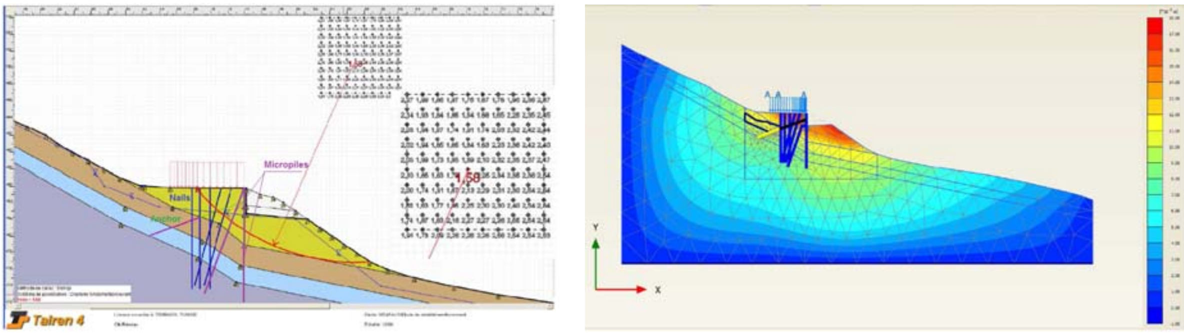

Fig. 4. Slope stability calculation: Example by TALREN 4, and by PLAXIS 2D

Micropiles bearing capacities have been calculated using the following standards and tools:

-Software FOXTA-V3, and the French standard "Fascicule 62".

3.4. Control tests on micropiles

In addition of the ongoing work control on site, tensile tests were performed on test micropiles to validate the design bearing capacities. Those tests were loaded to twice the service load. Examples of test results are given in figure 4, 5 and 6.

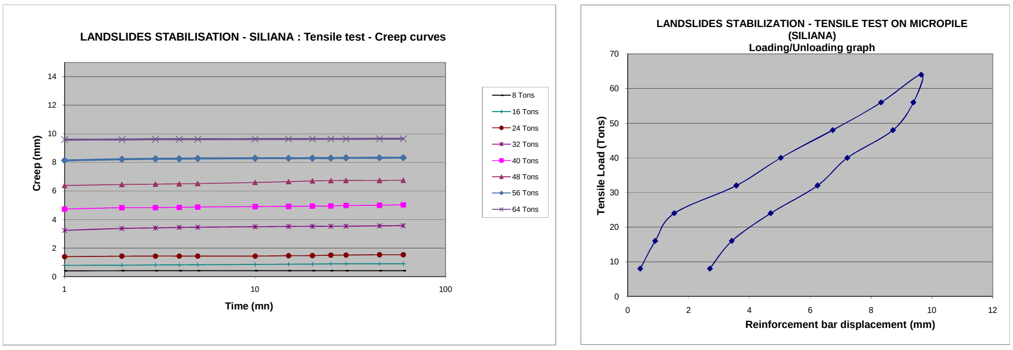

Fig. 4. Tensile test : creep resistance not reached

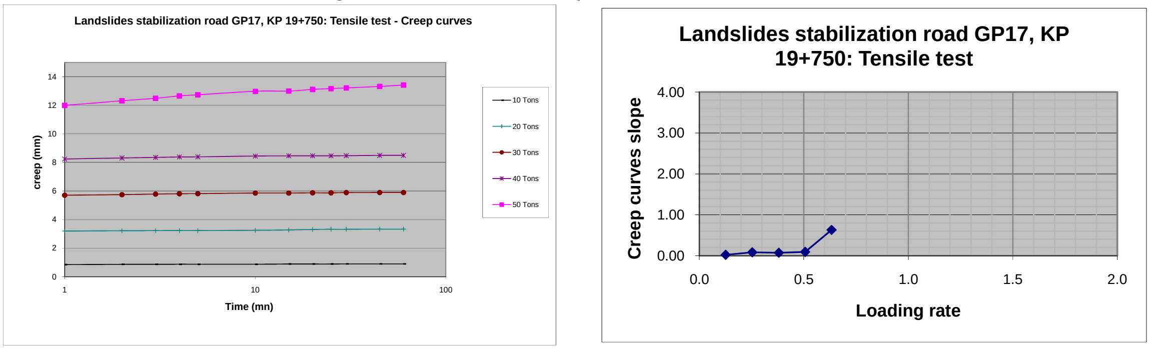

Fig.5. Tensile test : creep resistance reached for a load of 34 Tons

4. WORKS REALIZATION

The stabilization works for this major project are still in progress in many landslides site, and should be completed within 6 months. The micropiles works are almost totally completed.

Photos. 2. Anchors works in progress

5. OTHER USE OF MICROPILES IN TUNISIA

Slope stabilization is not the only field for using micropiles in Tunisia. These are widely used for at least twenty years, particularly in the following cases

- underpinning work of existing foundations by micropiles

- deep foundations on micropiles for new constructions : pylons, storage tanks, industrial and residential buildings,…
- Berlin walls

The usual reinforcement bars are tubular armatures of various diameters (73 mm, 114 mm, 139 mm), or metal profiles type HEB / HEA, more recently self-boring bars Titan Ischebeck brand.

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