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Landslide area stabilization by geogrids at low deformation

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ABSTRACT: The present paper introduces an intervention of landslide stabilization carried out through the technique of the soil-reinforcement with geotextiles. On account of the poor mechanical properties of the local soils and the necessity to reduce the soil deformations to the lowest during construction as well as in service, geogrids at low deformation were used for the carrying out of the work in soil-reinforcement. Two years later since the carrying out, the work looks in perfect conditions confirming that using this technical solution has been effective.

1 INTRODUCTION

In winter 2003, because of heavy rainfalls, a landslide occurred in Cocconato d'Asti (Italy). The instability involved a slope of about 40 m long, partly damaging a car park placed on the top of the landslide (Figure 1). According to the Purchasers' wishes who wanted to enlarge the car park area and to use low environmental impact solutions, the design was directed towards an intervention through the technique of soil reinforcement with geotextiles. Therefore, the design planned the carrying out of steep slope of 12.6 m high at most with a gradient of about 63° (2:1) in order to favour the vegetation growth on the front side.

Figure 1. Landslide area.

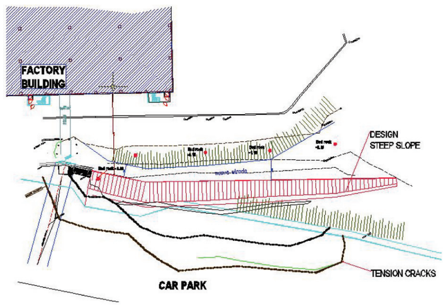

Figure 2. Design area plan.

2 GEOLOGICAL ARRANGEMENT AND DESCRIPTION OF THE LANDSLIDE MECHANISM

The examined area is situated to the south-east of Cocconato (Asti – Italy), at an average height of about 275 m above sea level. The area of Cocconato belongs to the hill belt of West Monferrato bounded northwards by the fluvial plain of the river Po. Three main stratigraphic units particularly marks the interested area: the *Gypseous-Sulphurous Formation*, the *Marls of S. Agata Fossili* and the *Formation of Baldissero*. Baldissero is the oldest formation and it is made up of silts and clays with rare arenaceous intercalations. On that formation rests (Serravalliano Superiore) the formation of the Marls of S. Agata Fossili formed of marls and grey-blue clays passing below a few centimetres thick successions of blue clays and reddish sands. Finally, it is taken into examination the Gypseous-Sulphurous Formation (Miocene Superiore) mostly formed of clays and typically grey or whitish coloured marls which are locally gypseous and with intercalations of marl limestone and sands or sandstones. The erosion activity of the small streams has deeply influenced and moulded such formations, by depositing at the same time, on the depressed areas, recent sediments bounded to the stream entrainment. The valley floor areas are clearly influenced by the granulometry of the materials forming the sides. Therefore, there are Pleistocene and Holocene sediments formed of rather heterogeneous deposits which in the examined area are mostly formed by slime-sandy terms with a typical layer of grey-brown coloured alteration.

The interested area is hit by gravity phenomena overloading the covering blanket of the grey-blue marls substratum which geologically characterise the place itself. The instability phenomena followed one another over the time and led to the sliding with a roto-translational kinematic mechanism of part of the car park which was built downstream from the main road. By then, as time has passed since the beginning of the instability, the material, mainly in the store area, was still very saturated with water.

In the part of the mountain immediately below the crowning there were distinguishable fractures with some decimetres wide and rather deep openings.

The fluidification of the alteration layer, which is locally very powerful, was helped by the introduction of a sliding process, from the slidebase conformation of the marl substratum as well as from the forming of an evident level of relative permeability caused by the passage from an alterated quite permeable blanket to the solid and much less permeable substratum. Therefore, a contrary condition of the neutral strengths of the ground began and was made worse by the lubrication of the plane of the marl sliding.

The landslide events finished, after following one another over the years, the only intervention of reclamation consisted in a simple filling in of the niche of the landslide by using filling material which was systematically transported to the valley by the landslide following event.

Moreover, the kinematic mechanism of the landslide proceeded with a typical back movement, continuing the erosion towards the mountain, moving the niche of detachment through a very worrying movement towards the main road over. In the period before the intervention the landslide body had reached a development of 31 m with a difference of level of 11 m; the wideness was about 65 m.

3 DESIGN CHOICE

3.1 *Convenient geotechnical model*

To define the convenient geotechnical model on which carrying out the necessary stability analysis, the place was subject to geological and geotechnical research through geognostic drilling and laboratory tests, planning to use again the slided material.

On the basis of the obtained data a convenient model (Figure 3) has been defined and formed as follows (Table 1):

- reinforced soil;
- the soil behind the soil reinforced (backfill soil);
- bed rock on which founding the steep slope (foundation soil).

Table 1. Design soil parameters.

	γ_{des} (kN/m^3)	ϕ'_{des} (deg)	c'_{des} (kN/m^2)
Reinforced soil	19	22°	0
Backfill soil	19	15°	20
Foundation soil	22	0°	200

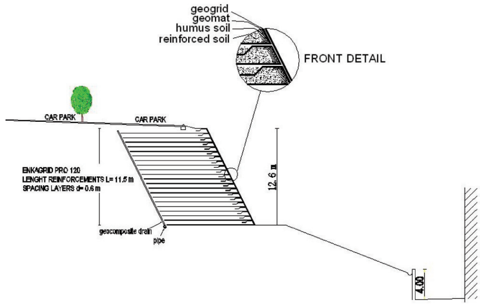

Figure 3. Design choice.

3.1.1 *Choice and design of the reinforcement*

Considering the car park presence on the steep slope top and the local soil properties it was decided to design according to Serviceability Limit State (SLS). On that purpose the following conditions for the choice of the reinforcement to be used were imposed:

- low deformation of the steep slope during construction and for a 120 year work life;
- low deformation of soil (mostly clayey) in order to avoid tension cracks and consequently water infiltration.

For such a reason it was used a geogrid in polyester tapes welded by laser technology. This reinforcement is characterised by low deformations at high long-term strengths: in detail, on the basis of the curve of Figure 4, by imposing a total deformation of 5% and a service deformation of 0.5% between 1 and 120 years, it was obtained a percentage of 54% of UTS of the reinforcement.

Then, on such value the partial safety factors were included according to the BBA Certificate so defining the design tensile strength of reinforcement.

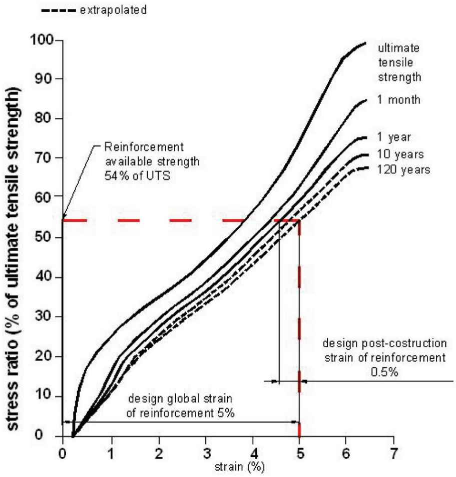

Figure 4. % Ultimate Tensile Strength (UTS) load established by design deformation (BBA certificate n° 03/R133).

Table 2. Partial safety factors.

	Design conditions	Safety factor
Design life fm	120 years	1.10
Installation damage fd	sandy silt	1.02
Environmental fe	pH 4.1-8.9	1.00

3.1.2 *Design steep slope*

The steep slope design analysis were carried out through the ReSlope programme realized by Prof. Leschinsky by including the characteristics of the soil and the planned reinforcements. The programme provides for a simplified model with three kinds of soil and analyses the "tieback" and "compound" tests through potential stress surfaces at logarithmic spiral and the global analysis using the Bishop method following circular surfaces. Moreover, the programme carries out the direct sliding analysis at the base of the slope through a two-part wedge method. With common software, the designer have to put for each reinforcement layer the model and the length to find convenient safety factors; ReSlope is of practical use because, by imposing preliminarily the safety factors for the different analysis and the characteristics of the usable reinforcements, it is possible to obtain automatically the lengths and the model of the necessary reinforcements.

The calculations were carried out for the different conditions of the design with a maximum height of 12.6 m by placing a thickness of 60 cm for every reinforcement layer (Fig. 5).

On the basis of the calculations made and the will of simplifying the executive stage it was adopted the scheme in Figure 3 by using a geogrid with final strength of 120 kN/m which can provide a design strength equal to 57.75 kN/m (Table 3).

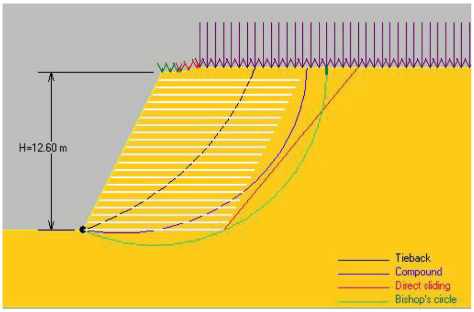

Figure 5. View software layout configuration.

Table 3. Geogrid properties.

	kN/mr
Tensile Strength (at ultimate)	120
Tensile Strength (at 2% strain)	42
Tensile Strength (at 5% strain)	80
Tensile Strength (at 5% strain after 120 years with safety factors of Table 2)	57.75

4 CARRYING OUT

4.1 *Building stage*

To carry out the work the slided soil was excavated until reaching the pseudo-integral bed rock by making a support plain surface for the reinforcement soil (Figure 6).

Figure 6. Base construction.

At the base it was laid a thermowelded geotextile working as filter/separator, while back the work two draining geocomposites were put; the first at the end of the geogrids of the reinforcement and the second connected with the excavation slope, each having at its base a pipe carrying waters (Figure 7).

Then, some layers in soil-reinforcement were carried out by using two diggers and one soil compactor machine.

The used technique for the front side is that of wrap-around using a steel mesh formwork (15 × 15

Figure 7. Construction.

Figure 8. Actual stage.

cm – d 8 mm), an antierosion geomat in polyamide and a layer of rich in humus soil in order to favour the vegetation growth.

4.2 *Present situation*

Over two years later since the carrying out, the slope and the overlaying car park look stable without any traces of deformation or any damages. The front side of the examined area has reached a good level of vegetation growth and become perfectly part of the surrounding environment.

5 CONCLUSIONS

The obtained results have confirmed the effectiveness of the adopted design choices. Particularly, the use of a geogrids at high performance allowed to reduce the total deformations by granting at the same time an high tensile strength.

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