STABILITY ANALYSIS AND REINFORCEMENT OF A LANDSLIDE IN THE GUELMA'S WILAYA ROAD (EASTERN ALGERIA)

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The present article deals with the stability analysis of a slope affected by a landslide on the Guelma's wilaya road. The study focuses on the identification of an adequate reinforcement method. It begins with data collection and analysis, as well as the stability assessment using calculation software based on the limit's equilibrium theory "Geo-slope". The results show that the safety factor Fs is lower than 1 in both periods, dry and rainy. The method of reinforcement called reprofiling with berm proved very adequate to the case. For this purpose, a choice of a combination of pre-selected method with a draining system provided by drainage ditches is necessary.

Algeria is among the countries most affected by the movement of land, the most common types are landslide as shown by [1, 2, 3].While each landslide is considered as special case. In the same region, several types of totally different characteristics between slides could be observed. However, in this paper we discussed the most significant landslides in the wilaya of Guelma which is most affected by this phenomenon.

Our objective in this research is to analyze and address the instability situated at kilometer N 50 + 500, on the wilaya road №19 connecting the Daira Hammam N'bail and Guelma town. In this section, we focus on the analysis of the slope stability based on geology, hydrogeology, and hydro-climatology. The results of geotechnical investigations in the area, as well the investigated site including *in-situ* tests and those of the laboratory in 2011, there were no signs of instability on the upstream and downstream slope (fig. 1). Only a longitudinal crack in the axis of the road (cut and fill mixed profile) exists with a collapse of the embankment part. It could be that this crack is the result of a settlement of the embankment part recently executed [4].

Fig.1. Embankment crack (February 2011) (DTP Guelma)

April 2012; a collapse of about 300 m from the roadway embankment half rating (fig. 2).They are defined by UHF cracks with subsidence of up to 50cm and sometimes more. The rehabilitation of the road needs permanent mobilization maintenance teams STP KHEZARA [4].

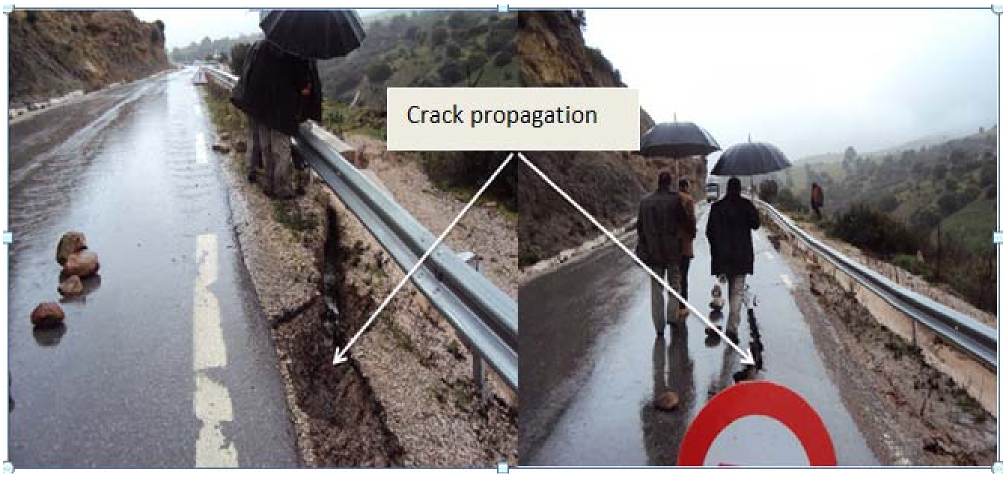

Fig.2. Degradation of the site at the rainy season of April 2012 (Zemouri& Arab, 2012).

Several visits to the site have showed:

- A longitudinal tensile crack at a distance of approximately 2.5m from the downstream side slope
- Circular landslide affecting the road platform over a length of 275m distributed over 3 zones that limit is upstream of the landslide
- An indicator signs of movement have developed downstream in the slope to the stream which is its share continues to accentuation of the movement by the Heave up of the slope foot.
- The damage observed in the three areas is metric subsidence of the half floor with UHF cracks delimiting upstream the slip limit.

The landslide, at present is still moving especially during the rain. Traffic is difficult through regular interventions of the DTP services of the wilaya of Guelma by refueling operations subsidence and patching cracks. The hydrological regime of the site shows that the surface water of the rain is clearly aggressive against the soft clay and marl formations, and the existence of the river downstream of the movement is a destabilizing factor that will be considered during the study.

Survey results show that piezometric training is saturated with water with a water table of 0.3 m to 0.5 m in the rainy season [6].

As part of the study preliminary design, and according to the studies program and recognition of the LABORATORY Control and Expertise (L.C.E.E) Constantine, surveys were conducted along the area affected by the landslide (Fig. 3).

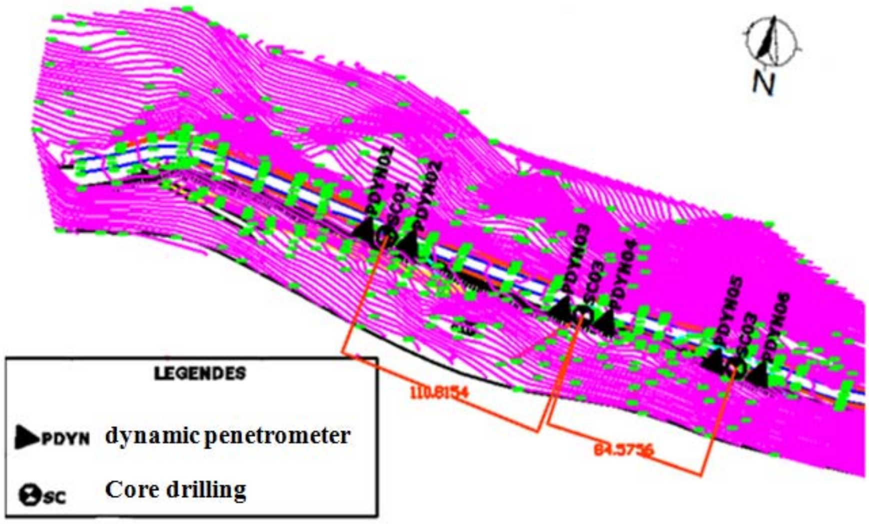

Fig.4. Plan view of the site with implantation of the drilling investigation (Zemouri& Arab, 2012) amended.

Within the meaning of the "NF P 94-202" standard, three core drillings were realized in (+ 389 PK50, PK50 + 500; PK50 + 585), the depth of each survey is 30m. According to the lithological sections of core drilling carried out, one can distinguish the following different formation (Tab.1).

Tab .1. The lithology of the ground

Drillings 1 depth (m)	**Drillings 1 depth (m)**	**Drillings 1 depth (m)**	**Average depth (m)**	**Type of land**
0.0 to 0.7	0.0 to 0.8	0.0 to 0.6	0.0 to 0.7	brown top soil.
0.7 to 7.6	0.8 to 7.8	0.6 to 8.0	0.7 to 7.8	Brown clay marl very plastic and swelling ocher.
7.6 to 14.2	7.8 to 16.4	8.0 to 17.2	7.8 to 15.93	salty marl gray gritty black plastic
14.2 to 23.7	16.4 to 24.5	17.2 to 25.3	7.8 to 24.5	marl more or less salty dark gray, medium plastic
23.7 to 30	24.5 to 30	25.3 to 30	30	very compact variegated marl

The main identification tests that were performed on samples of core drilling in this sector show:

• The higher formations(0à12m)

• The average liquidity limits WL vary from 52 to 70%, while the plasticity index is about 26 to 35% for higher composition which shows the plasticity of these formations.

• The average Ic consistency index ranges from 0.74 to 1.30; this interval represents a very compact ground.

• These compositions are classified in the land category for A3 according to the GTR classification

• The lower formations (>12 m):

average liquidity limits WL are around 41%, while the plasticity index is about 20%to 22% lower formations. The average consistency index Ic is 0.39, it characterizes a soft clay soil.

These formations are categorized by soil for classification A2 according to GTR.

For the mechanical characteristic of the silty clay which is characterized by low cohesion, the average cohesion of 17 kPa, with an average friction angle of 12 ° to an average depth of 0.7 to 5.8m (0.7m represents the layer of topsoil), going deeper at sunset "marl more or less silty dark gray, medium plastic" (depth varies between 5.8 to 9.6 m) the cohesion of this layer increases with an average of 22 kPa, but the cohesion remains low, with an average angle of friction of 16 °.

For lower formations (> 12m) the average cohesion and average internal friction angle of these layers increases, but they are still in the "low" class.

We are interested in this part of the stability calculation after degradation with the methods of "Fellenius" and "Bishop". For the possibility of manual and computer calculation, as well for their easy convergence. GEO SLOPE software is used for calculations, and each time we give the result given to Fellenius and Bishop.

In summer, the water table level and the level of the river decreases; however, the pore pressure of the soil is also weakened. We calculate the safety factor of the slope with pre-collected conditions. The results show that the slope is unstable even in the dry season. This is confirmed by a 0,994 safety factor for Bishop and 0.952 for Fellenius (Fs<1).As a result, this slope requires reinforcement.

In winter, the water table rises to this is the saturated slope. Therefore, the state of the slope deteriorates with the decrease of the mechanical characteristics. Consequently the result of the calculation gives the factor of safety, FS = 0.785 and 0.811 for bishop for Fellenius (FS <1), the slope is unstable so the reinforcement is essential.

Reprofiling is a very economical technique [5, 6].it is easy to perform compared to other methods of reinforcement, as it does not require a long time for execution.

In the case of the CW19 area PK 50 + 500, the reprofiling is selected for several benefits(fig . 5).Firstly, and mainly, to get away from the area affected by the landslide, secondly to minimize the weight concentrated on the slope top, as a consequence ensuring stability of the slope.

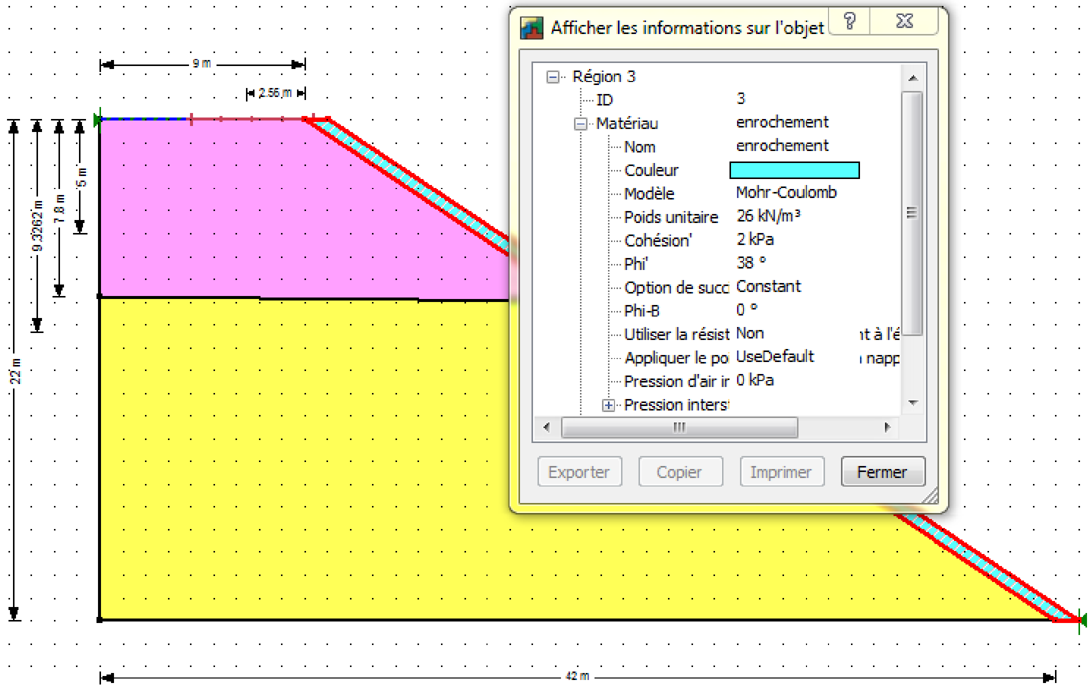

Fig.4. Property of the rock material used for the mask

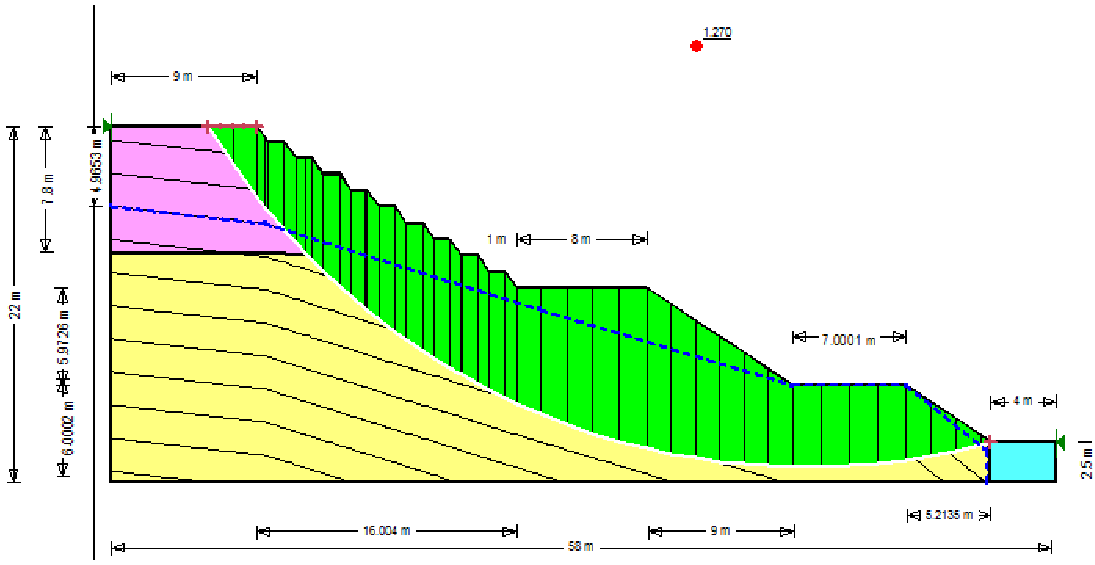

Fig. 5. The critical slip circle around the slopes after reprofiling in the dry period (result calculated by the method of Fellenius)

The table below summarizes all the obtained results:

Tab.2. Summary of results found

	Site conditions	Comment	Fs Bishop	Fs Fellenius
Befor confortement	**Dry season**	-	0.994	0.952
	Rainy season	-	0.785	0.811
Confortement with mask draining	**Saturated**	Width =1m	0.895	0.853
		Largeur=10m	1.285	1.227
Reprofiling with berms	**Dry**	Total stability	1.324	1.27
		Top banc	1.295	1.261
		Intermediate banc	1.663	1.567

		Inferior banc	1.949	1.955
	Rainy season	Total stability	1.177	1.162
		Top banc	0.980	1.006
		Intermediate banc	1.355	1.365
		Inferior banc	2.054	2.055
Safety factor Improved (%)			33.4	33.2

According to the study results, the safety factor before reinforcement is 0.994et 0952 for Bishop and Fellenius succession, by-addition, after reprofiling, this factors' increase with a rate of $Fs / Fs_0 = 33\%$.

Giving a result of 1.324 and 1.270, Aware that:

- Fs_0: safety factor befor reinforcement.
- Fs: safety factor after reinforcement.

We conclude that the instability of the slope is affected by the dice balance of the top. So confirmation should focus in this portion, this instability is due to the saturation of the layer. And so we can ensure the stability of the embankment so ensures good drainage system composed of:

It is to fold the groundwater level, by: The drainage ditches implantation on the site so as to arrive the water streams, so all along the roadway with a depth of 3m, a width of 0.6m and a length of 300 m.

The filling is made of drainage material 40/100 mm (about) the choice is made according to standard NF P11300 and specifications 11 [7]. Drainage trenches must be assembled with outlet to evacuate water out of this massif.

The establishment of an effective drainage system to preserve the foundation soil and embankments, with organization of water runoff by harvesting the water in ditches concreted to the planned outlets.

- In embankment head, two pits in concrete trapezoidal shape collect the water from the floor to evacuate it via down pipes on the slope to the river.
- At the foot of each step a small trapezoidal concrete pit will also be implemented.
- On the small steps of the upper part of the downstream side of the slope, where mechanical properties are poor, it is proposed to plant trees because of the stabilizing roles of vegetation cover due to several factors:
- The anchoring by the roots
- The drainage by evapotranspiration
- Retention of rainwater
- Protection against erosion

The stability analysis with "Geoslope" confirms the instability of the slope in the two seasons, dry and rainy, that the safety factor is less than 1 in both periods, so a reinforcement slope is required to ensure the balance of this bank. By choosing a method of reinforcement that is reshaping and eliminating two proposals for different discussed, the safety factor increases with a rate of 33%, exceeding the minimum value is "Fs = 1.2" so stability is maintained during the dry period, but less sufficient during the rainy period.

This requires a combination of this method (reshaping) with one or other confortation method for drainage and therefore the stability.

In our case, we chose the trench drains, for its effectiveness in this kind of problem.

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