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Study Of Instability Risks On The Eastern Slope Of The Beni-Haroun Dam In Mila Province, Eastern Algeria

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Abstract
The eastern slope of the Beni-Haroun Dam exhibits several unstable zones caused by significant ground movements. A combination of several factors triggers these movements, including lithological nature, topography, rainfall, and human activities (excavation within the village, road embankments, embankments related to dam reinforcement at the foot of the slope, and overloading of buildings and embankments).
These ground movements have caused significant damage to road infrastructure, particularly National Road 27, and to buildings in the locality of Sibari on the right bank of the Beni-Haroun Dam. They also pose a major problem of siltation within the dam. An accurate diagnosis of these movements allows for the implementation of more appropriate solutions.
Keywords *slope, unstable zones, ground movements, reinforcement, landslides, mudslides, tectonic accidents, crushing zones, collapses, settlements*

I. INTRODUCTION

Slope stability issues are commonly encountered in the construction of roads, canals, and dam embankments. Natural slopes can become unstable, leading to instability problems that can be catastrophic, causing loss of human lives and considerable material damage [1].
A ground movement is a more or less abrupt displacement of soil or subsurface material with highly variable volumes ranging from a few cubic meters to several million cubic meters. This displacement occurs due to natural factors (erosion agents, gravity, seismic activity, etc.) or human activities (excavation, alteration of water regimes, deforestation, earthworks, etc.). These activities can disrupt the natural equilibrium of a site and initiate a mass rupture process on a previously stable site [2].
In principle, ground movements are well understood: they occur when the resistance of the soil is lower than the driving forces generated by gravity and groundwater or by human activities. Their dynamics naturally follow the laws of mechanics, but predicting them remains an area of ongoing research.

II. STUDY OF THE ENVIRONMENT OF THE STUDIED AREA

The locality of "SIBARI," located on the eastern slope of the BENI HAROUN dam, is administratively attached to the commune of ANNOUCHE Ali, Daïra of GRAREM, Wilaya of MILA (Northeast Algeria). It is bordered to the north and west by the site of the BENI HAROUN dam, to the east by National Road 27, and to the south by the village of ANNOUCHE Ali (Fig. 1).
This locality covers an area of 14 hectares and includes approximately 420 dwellings occupied by around 5000 inhabitants [3].
The locality of SIBARI exhibits numerous unstable zones marked by a succession of significant landslides occurring in the downstream part of the reservoir, on the right bank, about 500 meters from the BENI HAROUN dam and 300 meters upstream from the confluence of the Oued DIB with Oued EL KEBIR. These landslides affect the deviation of National Road 27 connecting JIJEL to CONSTANTINE and the constructions in this locality [4].

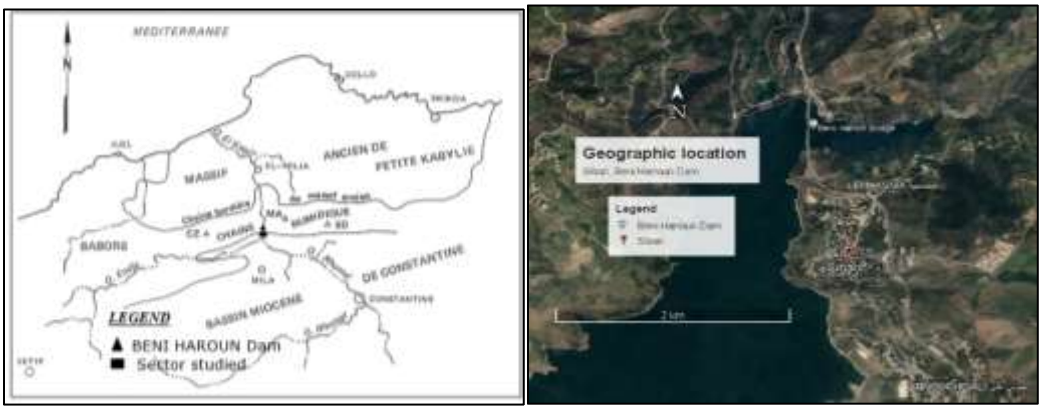


Fig. 1: Geographic location of the study area [5].

The studied area is located at the junction of two different climatic regions: a temperate and humid climate to the north, characterized by a dry and hot summer and a mild and humid winter with annual precipitation ranging between 900 and 1200 mm, and a semi-arid climate to the south marked by a significant temperature difference. In summer, temperatures reach around 40°C, while in winter, they can drop below 0°C, with precipitation around 400 mm/year [6].
The vegetation cover in the studied region is very limited, consisting mainly of herbaceous vegetation and a few eucalyptus trees. This sparse vegetation cover has significantly contributed to soil erosion [6].
The hydrographic network of the region is represented by a number of chaâbats (temporary streams) that collect and drain surface water towards Oued EL KEBIR located at the foot of the slope. Oued EL KEBIR flows from south to north parallel to the axis of National Road 27 and receives numerous tributaries, mainly Oued Dib to the north of the study area, Oued Rummel to the southeast, and Oued Endja to the southwest [6].
The studied region has a notable orographic aspect, marked by very rugged terrain with remarkable topographic contrasts, including high peaks and deep ravines and valleys. Additionally, it features slopes ranging from 35 to 60% [6].
According to seismic records available at seismic stations, the site of the BENI HAROUN dam, although located at the boundary between two geological provinces (Fig. 2 and 3), appears to have less significant seismic activity compared to neighboring regions such as the Constantine zone or the BABORS area [7].
The BENI HAROUN region is situated in a seismic region classified by BOCKEL as capable of experiencing tremors of intensity VI to VII. This zone is bordered to the northwest and southeast by two more active seismic zones with possible intensities greater than VIII [7].
Among the epicenters located within a radius of 30 km around the BENI HAROUN dam site, the most significant earthquakes occurred as follows [7].:
The earthquake of 23/08/78 in the SIDI MEROUANE overlap zone, 16 km from the dam site, with a magnitude estimated to be less than 3.5.
The earthquake of 20/12/83 in the SIDI DRISS massif, approximately 27 km east of the site, with a

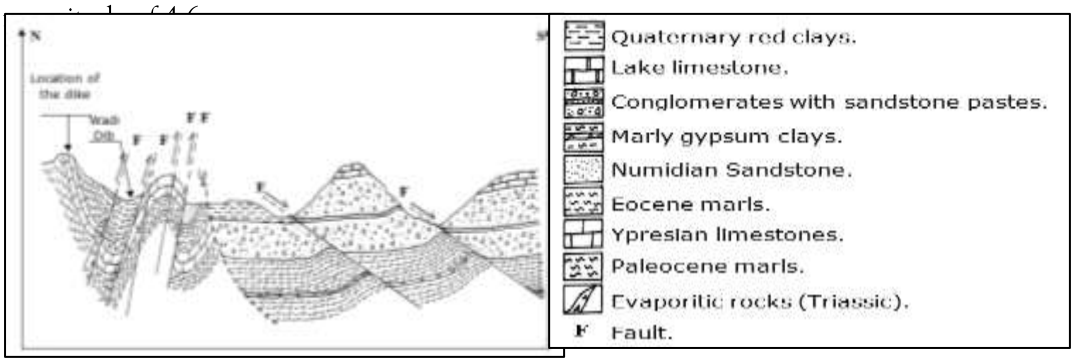


Fig. 2: North-South geological cross-section of the studied sector.

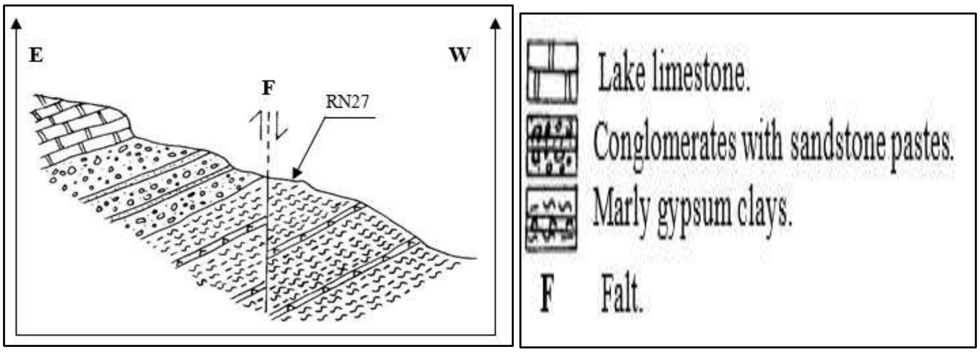


Fig. 3: East-West geological cross-section of the studied sector.

III. DESCRIPTION OF UNSTABLE AREAS ON THE EASTERN SLOPE OF THE BENI HAROUN

III.1 Historical Overview of Landslides in SIBARI

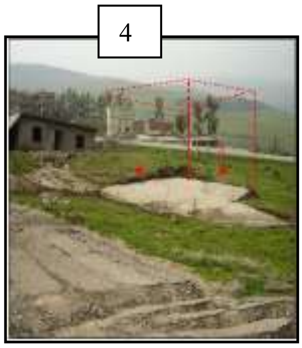
The eastern slope of the BENI HAROUN dam is characterized by a series of landslides. These landslides have occurred along several main axes located along the corridors of major tectonic faults primarily oriented east-west [8].

According to gathered information, the instability of the eastern slope of the BENI HAROUN dam predates the start of the initial dam construction works. However, these works may have played a significant role in exacerbating the phenomenon. Furthermore, water circulation and infiltration in sensitive formations prone to instability, primarily represented by Quaternary red clays and marly clays with gypsum, have likely accentuated the phenomenon [4].

Indeed, several signs of instability are visible on the surface of the SIBARI slope. These signs mainly include significant detachment niches, mass movements, tilting of constructions, and significant leaning of trees and utility poles.

The creation of a water reservoir at this location, by submerging the lower part of the SIBARI landslide, as well as fluctuations in water level, will affect the slope's stability. Therefore, it is essential to carry out reinforcement measures [9].

Due to the availability of geotechnical data, our study primarily focused on the Dragados company workshops landslide and the Chinese company landslide. These two landslides have been studied and monitored by the engineering office of the National Agency for Dams and Transfers ANBT/ALGER [10].



Photos 1 and 2: Detachment niches observed below National Road 27, beneath the ANB base camp.
Photo 3: Tilting of buildings and leaning of certain trees.
Photo 4: Subsidence of a house.

Photo 5: Ruins of a building and leaning of utility poles.
Photo 6: Tilting of a building near a water source.

Fig. 4: Position of landslide observations.

III.2 Description of the SIBARI landslides

The village of SIBARI is located on formations primarily consisting of Quaternary red clays, clayey marls with gypsum layers, and conglomerates with sandy layers. Three main axes of landslides mark the locality of SIBARI from North to South [11]:

The Ateliers Dragados landslide to the North, where a significant detachment zone was observed during the excavation works carried out in 2003, confirming the actual activity of the superficial part of this landslide.

The Chinese landslides to the South, where two inclinometers, I2 and I4, were sheared off after a period of heavy rainfall in the winter of 2003, also confirming the real activity of the superficial part of this landslide.

Landslides in the upper part of the village located to the South of the Chinese landslide, confirmed by numerous visible surface indicators and collected during the housing survey, but whose depth extension is not precisely known today due to the lack of geotechnical data in this landslide zone.

First axis of landslide

This concerns the landslide known as "Ateliers Dragados" observed on the slope of SIBARI between elevations 125 and 240 NGA. This landslide, with a width of 250 to 300m, is particularly active and presents a series of nested detachment niches, with the main tongue of the landslide centered on a larger thalweg. This thalweg serves as the outlet of a natural watershed of about 0.5 km2, which receives not only rainwater but also the continuous flow of discharge water mainly from the northern half of the village of SIBARI. Additionally, some trees and electric poles are inclined, and significant cracks are visible on some houses, confirming the real activity of this landslide [12].

This active landslide appears to be controlled by tectonics. Indeed, it is located along a corridor of a major east-west tectonic fault and marks the contact zone of Neogene deposits with their substratum formed in this area by marls and flint-bearing limestones of the Eocene.

This landslide exhibits spectacular instability phenomena, linked on one hand to the excavation of various platforms that were carried out without particular caution during the construction works of the dam (poor compaction of embankments, water discharge, etc.), and on the other hand, to the presence of water sources that have been reported upstream of this landslide [12].

This landslide area has been active for a long time. It was characterized by muddy flows carrying bundles of gypsum and trees, often causing blockages on the old National Route 27.

The upper detachment niche of this landslide has multiple lobes, with one extending beyond the deviation of the new National Route 27 [12].

The driving force behind this landslide may be influenced by several factors: tectonics, uncontrolled surface water flow on sensitive terrain, and the gradual erosion of the base of the slope by the BENI HAROUN reservoir.

Second Landslide Axis

To the south of the Ateliers Dragados landslide, the Chinese landslide develops in parallel, which appears to be more superficial than the first [10]. The onset of this landslide coincided with the beginning of construction works on the BENI HAROUN dam. This landslide, which occurred at the foot of the slope, affected the old facilities and access roads intended to receive screening and crushing installations, built by a Chinese company in the early 1990s. Hence the name: "Chinese Landslide".

This landslide extends between elevations 130 and 215 NGA with a width ranging from 100 to 200 m. It presents a series of nested detachment niches, with the main tongue of the landslide centered on a thalweg forming the outlet of a natural watershed of about 0.2 km2, which also receives wastewater runoff from the central part of the village of SIBARI [12].

The axis of this landslide also corresponds to a major east-west tectonic fault. Ground movements along this axis are characterized by muddy flows, fissuring, and tilting of structures.

The lower part of this landslide axis experienced movement only in 2003 when two inclinometers were sheared off during the winter after a period of heavy rainfall.

The triggering of this landslide is caused by the combined action of head reloading due to the temporary deposition of TVO stocks during the construction of National Route 27 and the decrease in mechanical characteristics of the lower part of the slope due to erosion at its base under the influence of the reservoir [12].

Third Landslide Axis (Zone)

A third significant landslide zone exists to the south of the living quarters of the National Agency for Dams and Transfers and the Dragados company. This zone exhibits the most critical ground movements on the slope of SIBARI. Indeed, this zone corresponds to a node of three major fault lines oriented N-S, E-W, and NW-SE, affecting various lithological formations (microconglomerates, sandstones, marly clays with gypsum, and lacustrine limestones).

The initial ground movements in this zone began in the lower part of the slope, where several houses were displaced and overturned in a single night in December 1998 during a rainy period [11].

The upper part of the slope experienced movement only from 2003 onwards. Stabilization works carried out on National Route 27 are believed to have exacerbated the situation as they contributed to the destabilization of the area by creating additional loads on the sliding terrain. This landslide caused a collapse of a section of National Route 27, accompanied by bulges downstream resulting in the sinking of nearly 25 houses and the tilting of some trees and electric poles. This ground movement appears to be quite complex. Indeed, it exhibits characteristics of a rotational landslide [11].

III.3 Direct Causes of the Studied Landslide

The mechanism triggering the landslides appears to be a loss of cohesion resulting from deformation, itself caused by various actions:

- Site heterogeneity and the presence of clayey-marly formations.
- Confirmed presence of faults (zones of low resistance).
- Rapid tectonic movement (earthquake).
- Erosion at the base of the slope by the oued EL KEBIR and by the BENI HAROUN reservoir.
- Loss of support due to downstream sliding on the slope leading to upstream sliding.
- Uncontrolled flow of surface water (rainwater, leakage from the water supply network, pipeline rupture, etc.).
- Stabilization works carried out on National Route 27 worsen the situation, as they contributed to further destabilizing the area by creating additional loads on the sliding terrain.
- Excavation within the village.

IV. STUDY OF THE STABILITY OF THE EASTERN SLOPE OF THE BENI HAROUN DAM

IV.1 Stability Calculation

The stability calculation was carried out where the landslide occurred using the Fellenius method. In this calculation, we proposed two levels of the water table: the first level corresponds to the current level of the BENI HAROUN dam (178.24 NGA), and the second corresponds to the maximum level of the dam (200 NGA).

To simplify the calculation, we assumed that the unstable slope is primarily composed of three homogeneous layers represented by:

- Red clays: located on the surface, with a highly variable thickness ranging from 0 to 12.50m.
- Marly clays with gypsum: located beneath the red clays with an average thickness of 30 to 50m.
- Compact marls: located beneath the previous formations, typically found at very significant

depths (beyond 50m).

- In order to better study and analyze the unstable slope of SIBARI, three profiles, primarily oriented along the main axes of the previously determined landslides, were studied in the calculation:
- Profile 01 and 02 oriented EW and positioned to intersect the first two identified landslide axes in the slope, namely the landslide of the Dragados company and the landslide of the Chinese company.
- Profile 03 oriented ESE - WNW intended to intersect the third landslide zone encountered in the slope.
- We supported our stability calculations by using the GEO-SLOPE software, which utilizes the limit equilibrium theory based on the Fellenius, Bishop, and Janbu slice methods.
- The data used by this calculation software includes:
- Slope geometry: topographic profile, geometric arrangement of the different layers constituting the terrain. Once entered, this data forms the basic framework for the calculation.
- Geotechnical characteristics of slope materials (c_i, φ_i, and γ_i).
- Hydraulic data: concerning the hydraulic regime and encountered piezometric level. In our calculations, the choice of hydraulic conditions was made in the same way as the manual calculation, meaning the calculation was performed for both levels of the water table.

The geotechnical characteristics of the materials entered into the calculation by this software, for each profile, are reported in Tables 1, 2, and 3. For safety and convenience reasons, the selection of these values is done to introduce the most unfavorable case into the calculation.

Table 1 : Profile 01

Soil	γ_h (KN/m^3)	C (KPa)	φ (°)
Red clay	19.7	0	11
Gypsum-rich marly clay	21.8	4	7
Compact marl	22	50	15

Table 2: Profile 02

Soil	γ_h (KN/m^3)	C (KPa)	φ (°)
Red clay	20	0	11
Gypsum-rich marly clay	22.9	10	2
Compact marl	22	50	15

Table 3: Profile 03

Soil	γ_h (KN/m^3)	C (KPa)	φ (°)
Gypsum-rich marly clay	22.9	4	2
Compact marl	22	50	15

Note: As previously mentioned, no laboratory testing has been conducted in the third landslide zone where profile 03 was installed. Therefore, the geotechnical parameters necessary for stability calculation are selected by extrapolating data from the lower part of the slope, considering the identical geology of these two parts of the slope (continuity of the same formations encountered).

Table 4: Safety factors obtained by the GEO-SLOPE software according to Profile 01 (current level of the retaining wall).

F_S					
1.512	0.903	0.774	0.704	0.455	0.281
1.493	0.873	0.770	0.703	0.347	0.281
1.431	0.788	0.740	0.697	0.332	0.263
1.378	0.788	0.720	0.674	0.311	0.259
0.910	0.785	0.720	0.654	0.310	0.246

0.906	0.781	0.718	0.616	0.296	***0.244***

Table 5: Safety factors obtained by the GEO-SLOPE software according to Profile 01 (maximum level of the retaining wall).

F_S					
1.535	1.074	0.844	0.750	0.632	0.529
1.485	1.030	0.844	0.740	0.620	0.468
1.422	0.987	0.841	0.736	0.618	0.428
1.363	0.983	0.805	0.731	0.614	0.382
1.266	0.955	0.804	0.750	0.632	0.357
1.184	0.939	0.783	0.722	0.613	0.327
1.182	0.932	0.771	0.718	0.609	0.308
1.175	0.871	0.757	0.715	0.601	0.288
1.134	0.867	0.755	0.676	0.597	0.267
1.076	0.865	0.752	0.655	0.592	***0.251***

Table 6: Safety factors obtained by the GEO-SLOPE software according to Profile 02 (current level of the retaining wall).

F_S					
1.988	0.961	0.738	0.460	0.334	0.183
1.720	0.946	0.730	0.459	0.321	***0.167***
1.564	0.932	0.711	0.442	0.301	
1.414	0.870	0.693	0.432	0.284	
1.103	0.820	0.551	0.407	0.257	
1.005	0.811	0.534	0.354	0.223	
0.998	0.790	0.531	0.354	0.199	

Table 7: Safety factors obtained by the GEO-SLOPE software according to Profile 02 (maximum level of the retaining wall).

F_S					
1.713	1.029	0.914	0.692	0.509	0.271
1.659	1.021	0.909	0.653	0.506	0.196
1.582	1.010	0.893	0.601	0.491	0.179
1.485	0.984	0.853	0.598	0.463	0.140
1.471	0.950	0.842	0.577	0.456	0.126
1.225	0.941	0.836	0.537	0.372	***0.110***
1.107	0.920	0.757	0.520	0.358	
1.070	0.919	0.702	0.513	0.321	

Table 8: Safety factors obtained by the GEO-SLOPE software according to Profile 03 (current level of the retaining wall).

F_S					
1.892	1.065	0.434	0.363	0.296	0.217
1.765	1.008	0.433	0.337	0.280	0.216
1.690	0.955	0.427	0.331	0.273	0.216
1.680	0.837	0.427	0.331	0.270	0.207
1.670	0.639	0.426	0.328	0.258	0.177
1.632	0.480	0.423	0.324	0.241	0.173
1.616	0.443	0.423	0.320	0.230	0.171
1.587	0.439	0.396	0.316	0.223	***0.169***

IV.2 Interpretation of Results

The stability analysis of the slope using profiles 01, 02, and 03 under both hydraulic conditions (full reservoir and current reservoir level) yields very low safety factor values, especially when the reservoir level reaches its maximum.

The minimum safety factor corresponding to the critical circle was found to be 0.123 for profile 01, 0.366 for profile 02, and 0.135 for profile 03. These values are below the acceptable safety factor threshold of 1.5, confirming the instability of the slope.

The precise location of the critical circle, which provides the minimum value of the safety factor (Fs), and corresponds to the actual failure surface, is accurately determined using the GEO-SLOPE calculation software. The advantage of this software lies in its ability to plot a large number of potential failure circles and quickly identify the most unfavorable one with better approximation.

The stability analysis conducted by the GEO-SLOPE software provides numerous safety factor values, with their minimum values corresponding to the critical circles as follows:

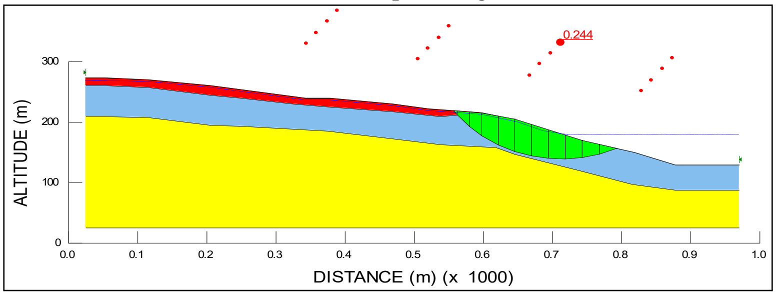


Fig. 5: Critical circle obtained according to Profile 01 (current level of the retaining wall).

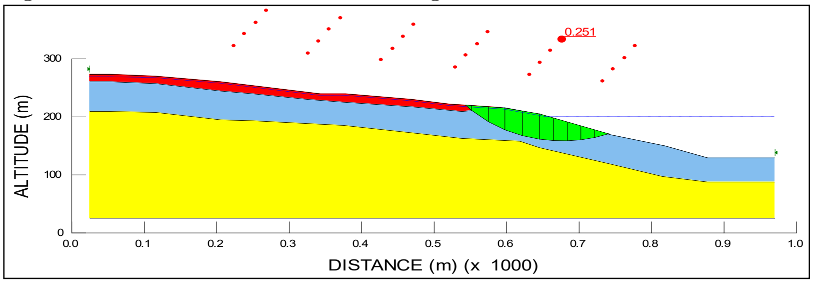


Fig. 6: Critical circle obtained according to Profile 01 (maximum level of the retaining wall).

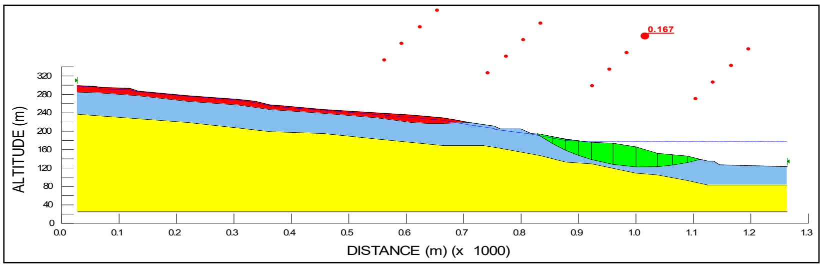


Fig. 7: Critical circle obtained according to Profile 02 (current level of the retaining wall).

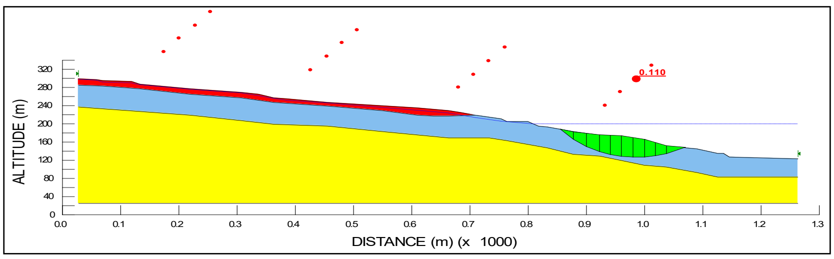


Fig. 8: Critical circle obtained according to Profile 02 (maximum level of the retaining wall).

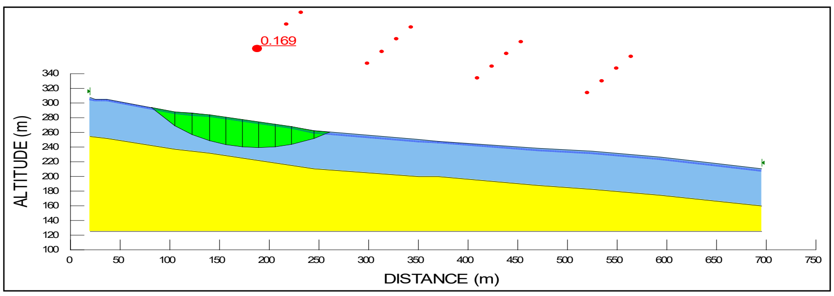


Fig. 9: Critical circle obtained according to Profile 03 (current level of the retaining wall).

The observation of these circles leads to the conclusion that the SIBARI landslides mainly affect marly and gypsum-rich clay formations with very significant and variable depths, which can be summarized as follows:

Profile 01:

- Depth of sliding = 51.72m (current level of the retaining wall).
- Depth of sliding = 41.37m (maximum level of the retaining wall).

Profile 02:

- Depth of sliding = 44.44m (current level of the retaining wall).
- Depth of sliding = 44.44m (maximum level of the retaining wall).

Profile 03:

- Depth of sliding = 40m (current level of the retaining wall).

The depths of sliding obtained by the software for the three profiles are very close to those obtained by inclinometers. These depths should be taken into consideration during the execution of any reinforcement system.

V. CONCLUSION

Based on the geological and geotechnical characteristics of the eastern slope of the Beni Haroun dam and the results of stability calculations for this slope, two types of landslides can be distinguished:

- Superficial landslides: Typically observed between 5 to 12.5m in depth, these landslides mainly affect the Quaternary red clay cover. They are characterized by significant mudflows and surface slippages. In addition to the geological nature of the encountered terrain, the site topography, and anthropogenic activity, infiltration water plays a crucial role in triggering these landslides. It rapidly saturates the clay cover and lubricates the contact surface between this cover and the underlying formations, represented by the less permeable and often encrusted marly clay, thereby facilitating the initiation of slip surfaces.
- Deep-seated landslides: According to inclinometer data, these landslides are observed between 21.5 to 48m in depth and mainly affect highly sensitive formations in the presence of water, represented by marly clay with gypsum.

In general, the eastern slope of the Beni Haroun dam is affected by a series of nested circular landslides triggered along multiple main axes. These landslides are accompanied by other large-scale ground movements. The spatial distribution of these movements reveals a close connection with the nodes and corridors of major tectonic faults oriented primarily E-W. The circulation of water along these tectonic corridors weakens the Neogene formations and causes the dissolution of soluble rocks (carbonates, gypsum, and salt). This dissolution is also accompanied by intense material extraction, leading to the detachment of detrital elements in conglomerate formations and the creation of voids in marly clay and gypsum formations, resulting in collapses and/or deep-seated subsidence, accompanied by mass displacements at the surface.

The proposal of solutions to remedy these movements must imperatively take into consideration these factors. Therefore, the analysis of slope safety in terms of safety factor is significantly insufficient to predict anything from a safety perspective. It is more logical to call it a "performance factor" since it only reflects the slope's performance and does not consider all stages of its life.

Slope safety analysis clearly demonstrates the relationship between performance, remedial measures, and economic considerations. It enables optimization of the structure within a decision-making framework. However, several factors have made such an approach even more challenging, including:

- The complexity of the structure.
- The probabilities of certain events are difficult, if not impossible, to evaluate.
- Considering remedial measures that can significantly reduce the risk.
- Utilizing all available information regarding the project.

REFERENCE LIST

[1] Bendris, N., Gherboudje, L., & Bouhanouna, A. E. (2013). Inventory of Unstable Areas in Mila Province (Study of Some Cases) (Doctoral dissertation, University of Jijel).

[2] Aoun, M. (2002). Geological and Geotechnical Issues in the Mila Basin: Their Impact on Infrastructure. Magister Thesis, University of Tébessa (Algeria), 156 p.

[3] Marouf, N., & Remini, B. (2019). Impact Study of Beni-Haroun Dam on the Environmental and Socio-Economic Elements in the Kébir-Rhumel Basin, Algeria. Journal of Water and Land Development, (43).

[4] Khlifi, S., Bouazi, R., & Bouftouha, M. E. (2005). Geological and Geotechnical Study of Slope Movements on the

Eastern Slope of the Beni Haroun Dam (Milla) (Doctoral dissertation, University of Jijel).
[5] Harza Engineering Company. (1986). Detailed Pre-Project Study of a Dam on the Wadi Kébir or one of its Tributaries. Unpublished Report, Algiers, National Agency of Dams.
[6] Deffous, K., Bouketta, I., & Kabeb, H. E. (2016). Tunnel Boring Machine Excavation, Geological, Hydrogeological, Geotechnical Study, and Performance Prediction: Case of the PK09 Tunnel Transfer from Beni Haroun. Mila Province (Doctoral dissertation, University of Jijel).
[7] Michel, J.P. (2000). Roller-Compacted Concrete Techniques. Technical Day of June 07, 2000, Beni Haroun Dam, pp. 01-06.
[8] Marouf, N., & Remini, B. (2019). Impact Study of Beni-Haroun Dam on the Environmental and Socio-Economic Elements in the Kébir-Rhumel Basin, Algeria. Journal of Water and Land Development, (43).
[9] Zouaoui, S. (2008). Geological and Geotechnical Study of Landslides in the Neogene Basin of Mila: Sibari Landslide (Doctoral dissertation, University of Batna 2)
[10] Oleaga, L. (1982). Construction Company Execution Experience: Dragados y Construcciones, SA. Seminar on Concrete Pavements, 1981, Barcelona.
[11] EDF - TEGG. (2003). Beni Haroun Dam - Sibari Landslide - Interpretative Sections and Potential Sliding Surfaces. Unpublished ANB Report.lageollet, J.C. (1989). Landslides and Their Prevention. Ed. Masson. Paris, 224 p.
[12] EDF - CIH. (2002). Stability Analysis of the Right Bank of the Beni Haroun Reservoir