Field Movements between Fes and Taza Risk of Landslides of an Embedded Passage of Highway Vehicles PV113 of the Oued Amlil -Taza section. Morocco Expertise and Stabilization Methodology

Alaoui Mustapha[1], Mehdi Khalid[2], Bendahhou Zourarah[2] Hamou Mansouri[3] Abdellah Bouhou[3]
[1]Sultan Moulay Slimane University, Sciences and Technologies Faculty Béni Mellal (FST)
[2]Chouaib Doukkali University, Faculty of Sciences El Jadida (FSJ).Morocco
[3]Public Laboratory for Studies and Tests. Soil Study Center (CES)-LPEE. Morocco

Abstract

Northern Morocco, landslides play a role in the evolution of slopes. The geological and geotechnical studies of the ground are most often motivated by the search for solutions to a movement said. Thus, the objective of this work is to study the stability of the embankment with the passage of the vehicle PV113 section of the A2 highway between Oued Amlil and Taza. Stability calculations have concluded that the break is sliding rotational type, and a circular type failure, the surface would be at 10m depth. Action of water in the embankment and into the substrate altered favored pore pressure exceeds the shear strength, leading to the development of the driving forces sufficient to move. Materials marly slope physical characteristics favorable to landslides. The development, the excavation and backfill weight unloading areas hampered by a general slope of the precarious balance. Ground the first is the sliding of Oued Amlil and the second is that of Taza. The purpose of this scientific approach is to establish, based on a specific slip case study, a methodology that can be used and transposed to geology for sites that can slide and have a similar material or lithology, the same predisposing factors and the same geomorphological and geological context, which above all makes it possible to identify the direct and indirect causes of this risk in a context of climate change. The approach of the study is both quantitative (calculations) and of course qualitative by field verification and validation from historical data. At the end of this work, the various geological, hydrogeological and mechanical factors were defined for each landslide in order to determine the triggering factors. Their studies have also improved the understanding of gravitational instability to propose possible solution to the problem.A calculation of the geotechnical parameters necessary for the justification of the work consists in the data of the shear parameters as well as the deformation modules of the Formations encountered. For this

landslide zone, we have determined a series of mechanical, structural and rainfalls characteristics, and pile modelling which allow to finally having a good understanding of the mechanisms that govern the rupture of embankment slopes and slopes with natural georisk.

Keywords: Geology, Geotechnic, Landslide, PV113, A2, Oued Amlil, Taza, Fes, Rif, North Morocco

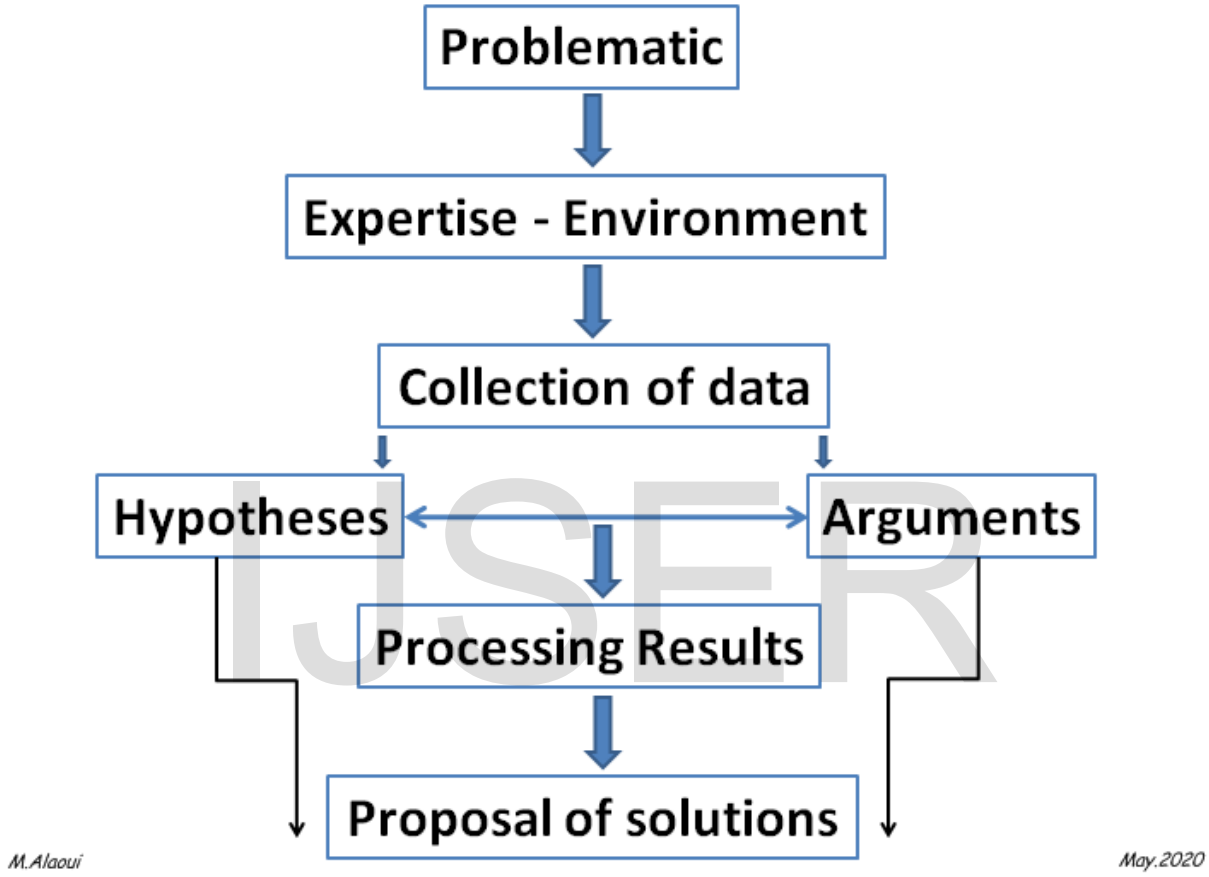
1. INTRODUCTION

Shallow landslides induced by precipitation are one of the most common and dangerous natural hazards, mainly due to their high temporal frequency, causing deaths and significant economic damage each year [1]. In recent years, concern has grown because the effects of climate change could exacerbate the impact of landslides. Due to the thermodynamic effect, a warming atmosphere results in higher moisture content in the air, which in turn can increase the frequency and intensity of heavy precipitation [2]. A landslide is a type of mass waste process that works on natural and artificial slopes. It is the movement of a mass of rock, debris or earth on a downward slope, under the influence of gravity [3-4]. Landslides involve sinking, sliding, falling, or spreading, and many landslides involve a combination of different types of movement, either at the same time or during the life of the landslide. Landslides are present on all continents and play an important role in the evolution of landscapes. In many regions, they also pose a serious threat to the population. [5] The Intergovernmental Panel on Climate Change (IPCC-2014) synthesis report provided assessments of the risks of flooding, and concluded that the number of people exposed to floods is expected to increase worldwide [6]. In Morocco, the reduction of river inflows downstream of dams causing insufficiency in the functions of recharging groundwater, circulation of fresh water and sediments, dilution of pollution and affecting the hydrodynamic balance of ecosystems [7] . Precipitation patterns vary from region to region while remaining dominated by a large irregularity in space and time, seasonally and interannual. The alternation of sequences of years of high hydraulicity and sequences of severe drought, which can last several years, is a defining feature of climatic and hydrological regimes [8]. Climate change inducing a modification of hydrological cycles having a direct impact on the piezometric regime of natural slopes and therefore on their conditions of stability. In particular with regard to active landslides in fine-grained soils [9]. And this is the case of landslides in the mountains of the Rif of Morocco which affect most of the geologically unstable slopes, such as the reinforcement of embankments and cuttings of the A2 motorway [10-11]. The stability of the slopes, particularly those affecting motorways and other infrastructure, has been achieved by bridges. [12]. Earthquakes and precipitation

have an indirect impact on the instability of slopes by rupture and displacement or by aggravation of existing cracks [13-14].

2. MATERIAL AND METHODOLOGY

In this study, it was mapped, at different scales to deduce the value of the slope conditioning the problem by a topographic background (mathematical demonstration by the tangent arc) and confirmation by the compass by measuring the dip of the large slope of the slipped part.



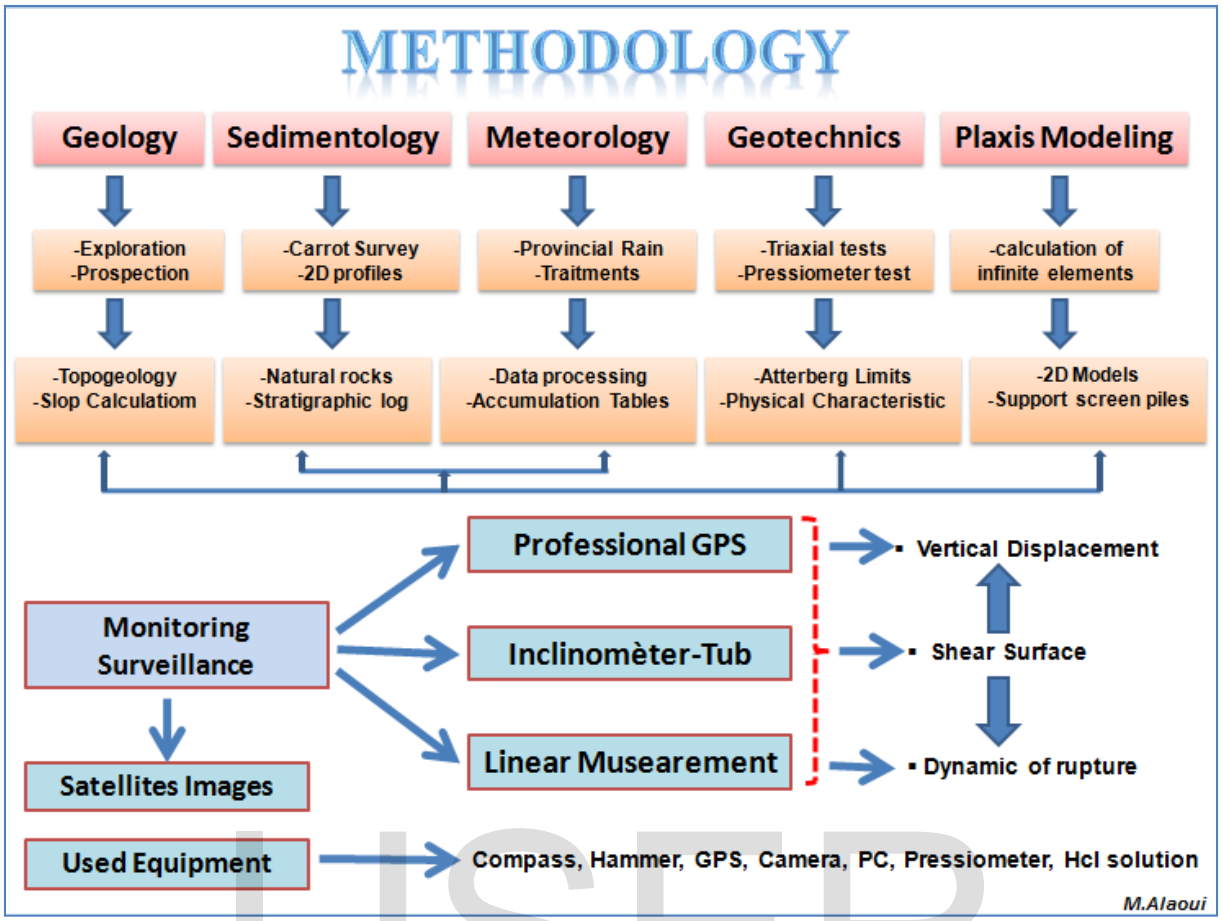


Figure1: Methodology of work

An analysis of the geological maps and the field research were carried out to give a precise idea on the hydrographic network which can intervene in a direct or indirect way on the evolution of the hazard in time and space.

All bodies, including wood, are subject to the action of various external forces, notably those of compression, traction and shear (Panshin and de Zeeuw 1980).

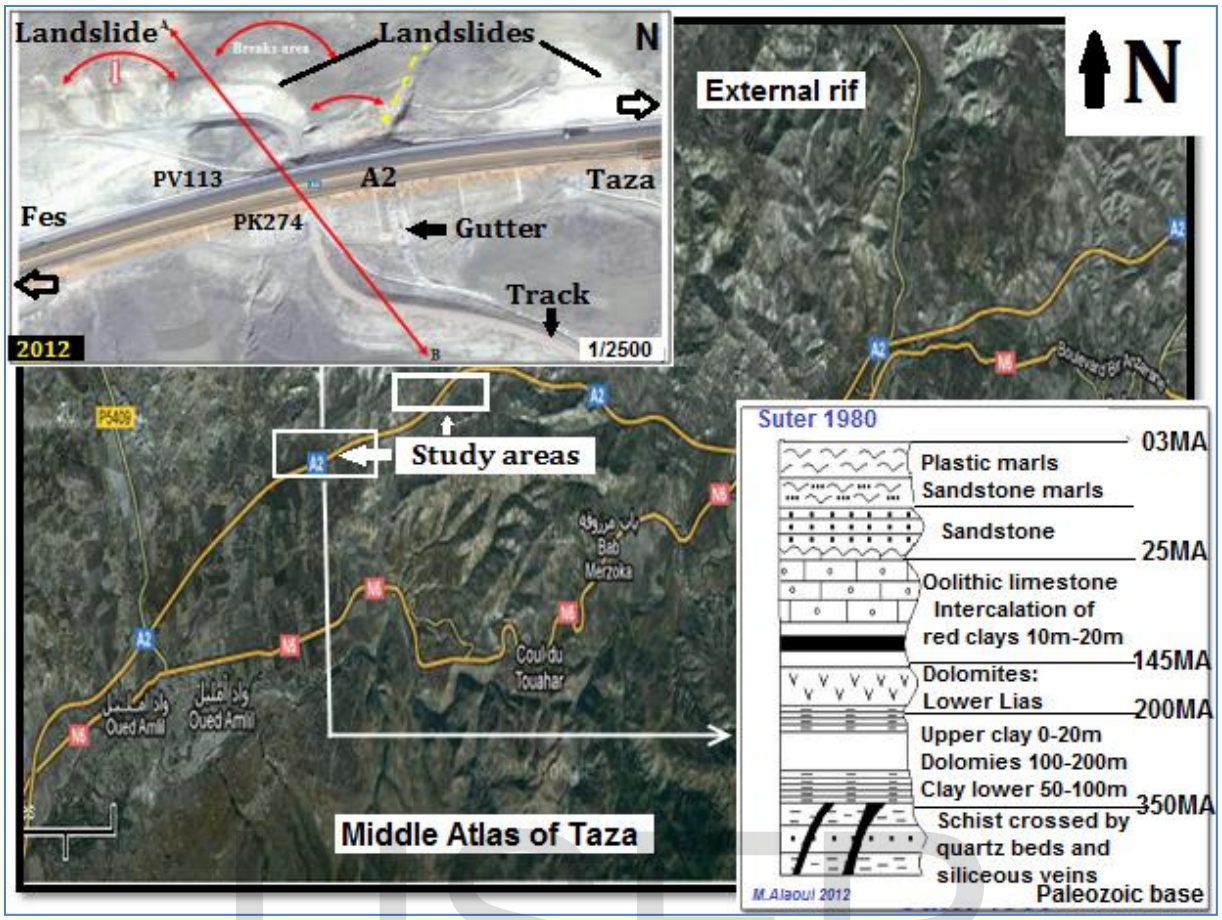


Figure 2: Topogeology and lithostratigraphic Log of the pre-Rif unit between Fes and Taza (extract from the note on the structural map of the Rif chain (Suter 1980)

From the combination of these three forces comes the bending force. In the early nineteenth century, a French engineer, Alexandre Colin, who was working on the construction of canals, noticed that the surfaces of fractures formed by landslides occurring in clays and marls along the banks of a canal adopted a curved shape. In 1846 he published a dissertation in which he suggested a static method of analysis based on a curved surface and measured the resistance of soils to shear. Since that time, various methods of analysis have been proposed. They led to the sliding circle method, developed by Swedish engineers specialized in ports and on which the techniques currently used are based. It is assumed that the failure surface affects the shape of an arc. Thanks to the comparison of the disturbing forces and the resistance forces, a safety coefficient is obtained for each probable breaking surface. It is recommended to perform several tests before you can determine, for a given slope, the most dangerous circle.

The landslide is located about 20 km west of Taza, via 8km via the national road RN6, is at an altitude between 400m and 600m, its latitude is [34,23010N] and its longitude is [-4,18781E]. It is a slope with possible landslide, the overall slope varies between 50% and 60%, by the contour lines and the scale, and verified by the compass .Fig4.

3. RESULTS

1.3. Morphological characteristics of the area

The relief of the region was modified for civil engineering works which generated slopes up to 65°. This domain includes groups affected by often superficial deformations, always with southern vergence. This section is characterized by a series of permanent and temporary watercourses, such as Oued Orgaz, Oued Amlil where he was obliged to make viaducts given their large and deep beds, it is distant about 28 km.

The study section takes place in the Rif's area, in particular, in the external Rif, it crosses land with sinuous topography, in general, we find soft marly hills of great amplitude.

2.3. Geological characterization of the region

The pre-Rifain aquifers (Aknoul, Senadja and Ouezzane) are uprooted. They advance to the Prerif. Their structural history is complex and also different from one tablecloth to another. At least for part, the mechanism of their establishment is gravitational (Salhi.A, 2004). The region between Fez and Taza belongs to the South Rif furrow which lies between the Rif to the north and the Middle Atlas to the south. The area between Fez and Taza is the narrowest part of the South Rif corridor.Fig3.

Starting from the inside towards the outside of the chain, in 1965 distinguished three juxtaposed zones:

-Intrarif

-Mesorif

-Prérif

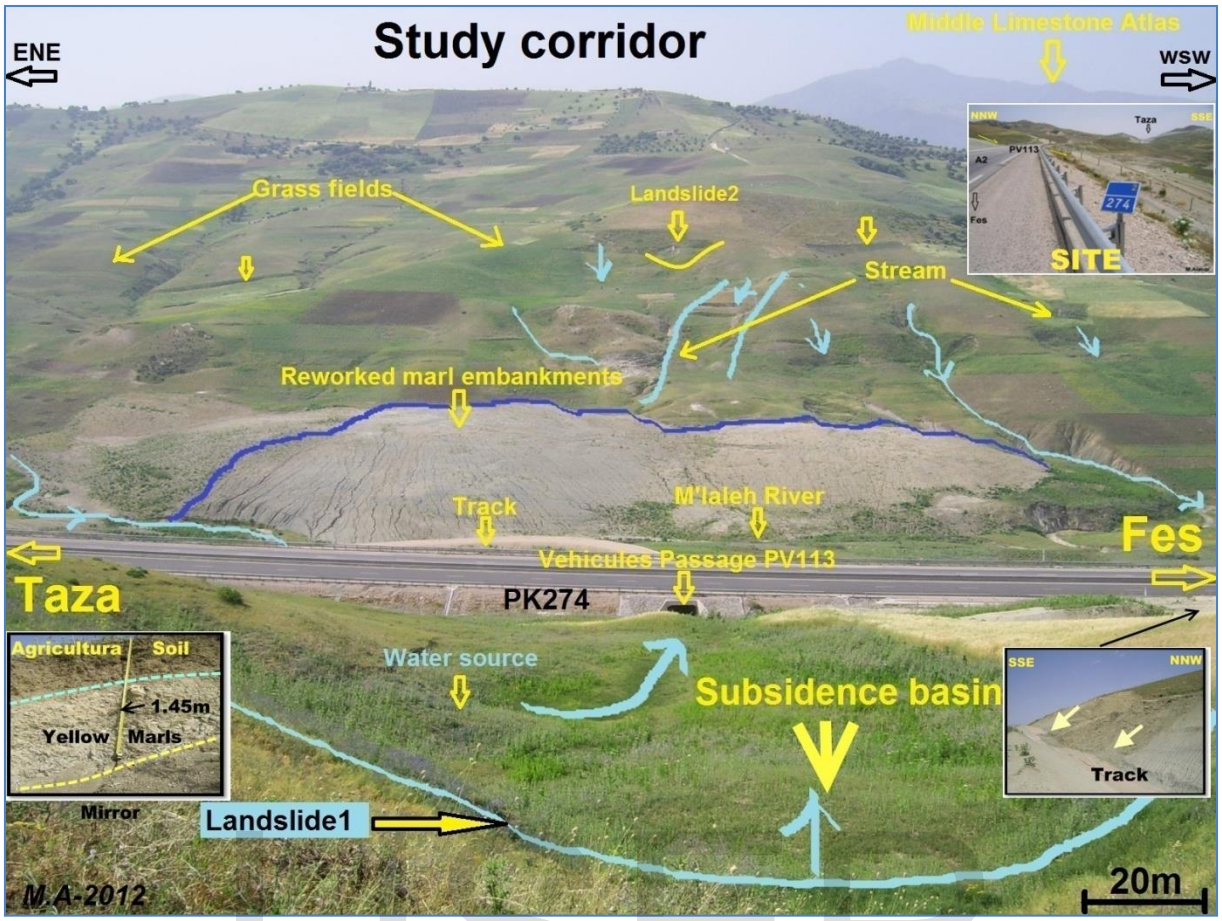


Figure3: North and South panoramic views of the study area

The section under study takes place in the Rif's area, in particular, in the external Rif; it crosses land with sinuous topography.

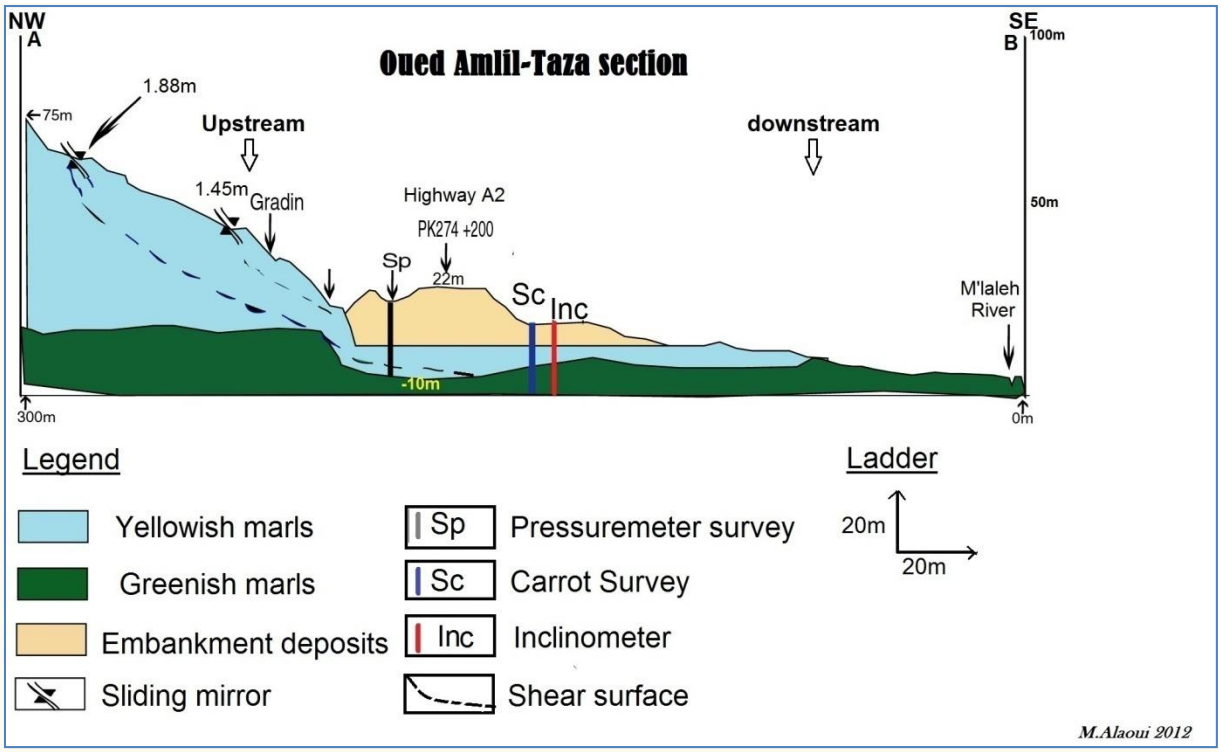


Figure 4: Topogeological section and sketch of location

3.3. Mechanical properties of soil

The comfort study of a structure affected by a landslide is based essentially on the first five tests. The tests are designed in particular between 12.70 m and 23.20 m from the cored borehole Sc. The properties of the sampled soils obtained in the laboratory are presented in Table 1 and are described below:

Settings Geotechnical	Water content (%W)	Volumic mass	Liquidity Limit WL	Plasticity Limit WP	Plasticity index IP	Shear stress (Kpa)	Friction angle (Φ)
Sc(m)	[12.70-23.20]	[12.70-23.20]	[12.70-23.20]	[12.70-23.20]	[12.70-23.20]	[23.20-28.00]	[23.20-29.00]
PV113	7-20	1691-2152	46-86	21-22	24-65	32-37	8°-10°

Table1: Physical and mechanical properties of soil samples

4.3.Slide kinetics and breaking surface

$$V = \int_{t1}^{t2} dx/dt \Longrightarrow \overrightarrow{V}_{m\ t_1 \to t_2} = \frac{d_{x_1 \to x_2}}{dt_{1 \to t_2}} = \frac{\text{Distance (mm)}}{\text{Time (month)}}$$

Integral speed equation

M.A 2018

(1)

According to the results of the inclinometer, the speed of movement is of slow type (Equation1-2), the depth of the deformation is localized at the level of 10 m Fig.4 and Fig.5.

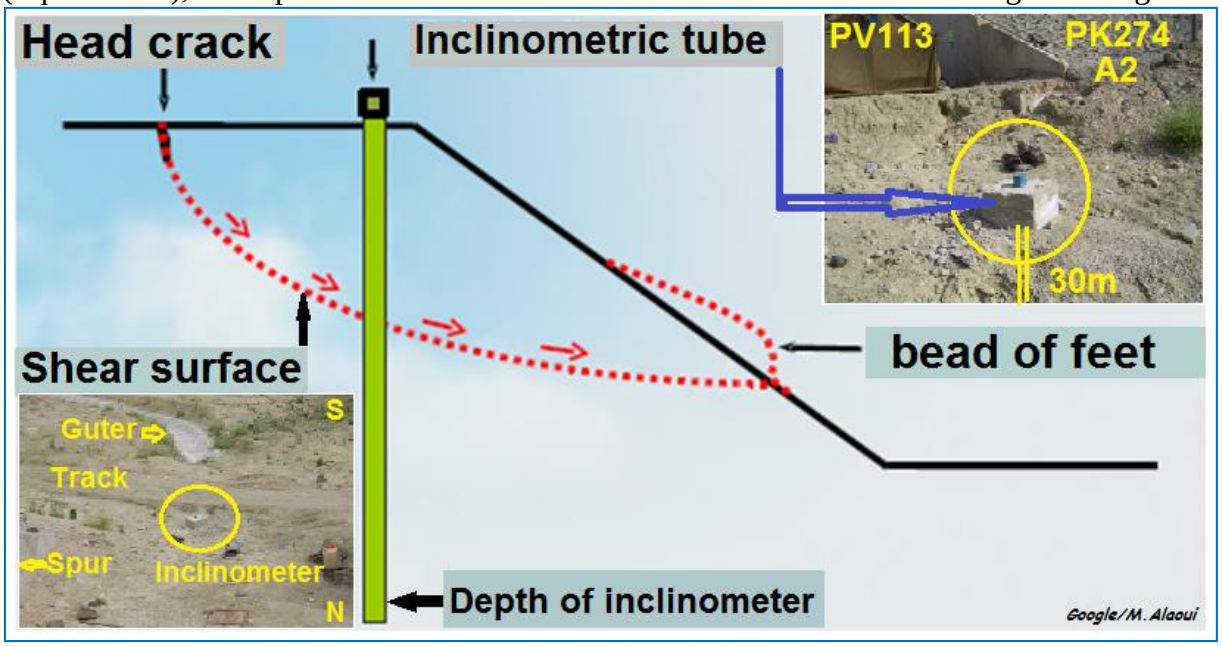


Figure 5: Fundamental principle of the inclinometric tube at the base of the sliding

To know the nature, the geometry and the evolution over time of a landslide, it is necessary to study the site. Topographic surveys, laboratory studies on the properties of the material and the placement of inclinometers are the techniques generally used to locate the shear surface and follow the intensity and evolution of the movement over time. (Feregotto, 2010).

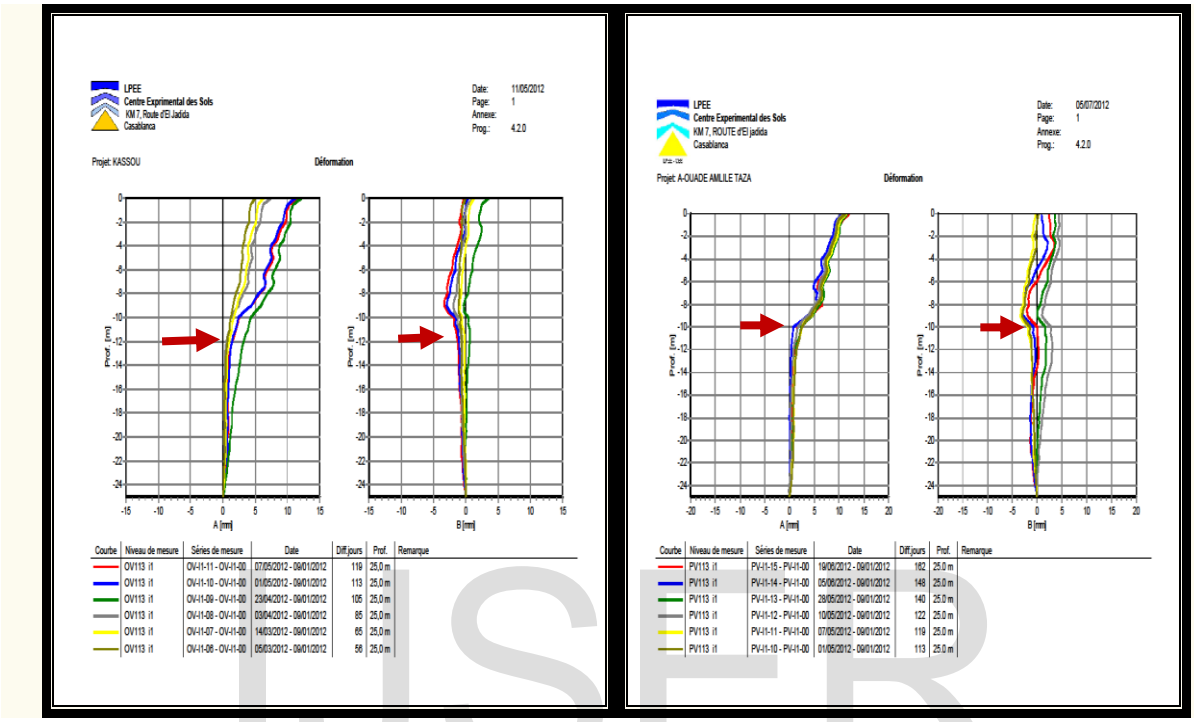


Figure 6: Inclinometric deformation results from 01/09/2012 to 06/19/2012

$$V = \frac{12}{5.5} = 2.18 \text{ mm/month} \quad (2)$$

5.3 . Regional Climate and Precipitation

The development of the various landslide processes in the North-South escarpment is conditioned by the climatic factor and its changes over time. The climate of this region is characterized by the violence of contrasts, locally repeating what occurs in the scale of the northern part of the Kingdom of Morocco. This climate is semi-arid with places with a sub-humid climate. While variations can also occur over time:

A dry and hot season from June to September

A wet and cold season from October to May.

Note also the role of precipitation recorded during this spring period, falling in the form of thunderstorms and heavy showers, they can locally change the conditions of the dynamics, and they are always very aggressive.

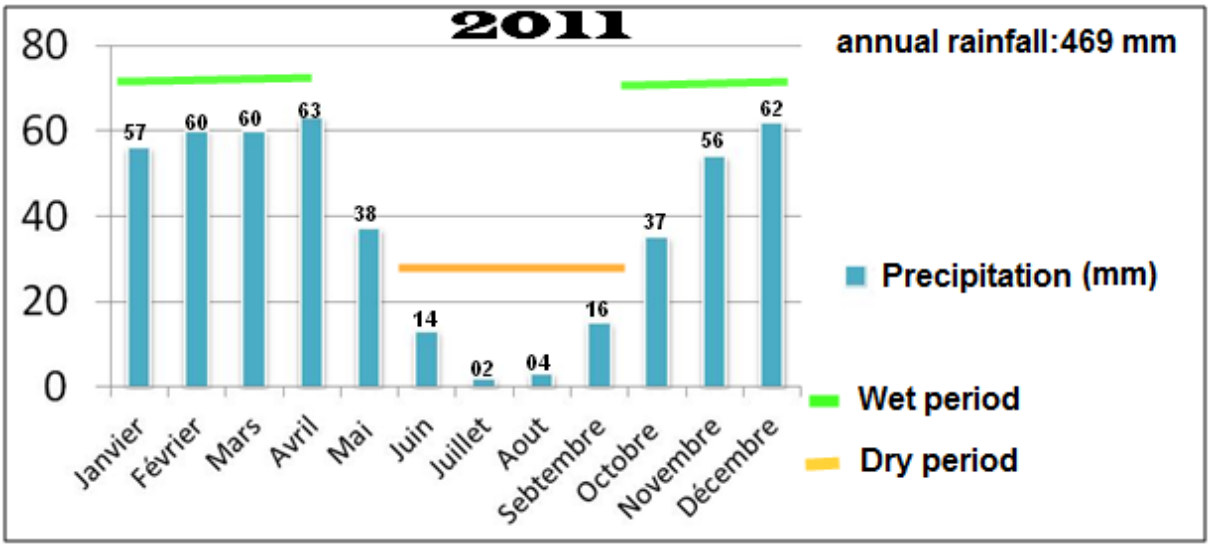


Figure 7: Monthly rainfall in the Fez-Taza corridor for the year 2011

The seasons play on the mode of circulation of the water, the rainwater rejoins the underground aquifers by infiltration. (Benoit REAL-2012).

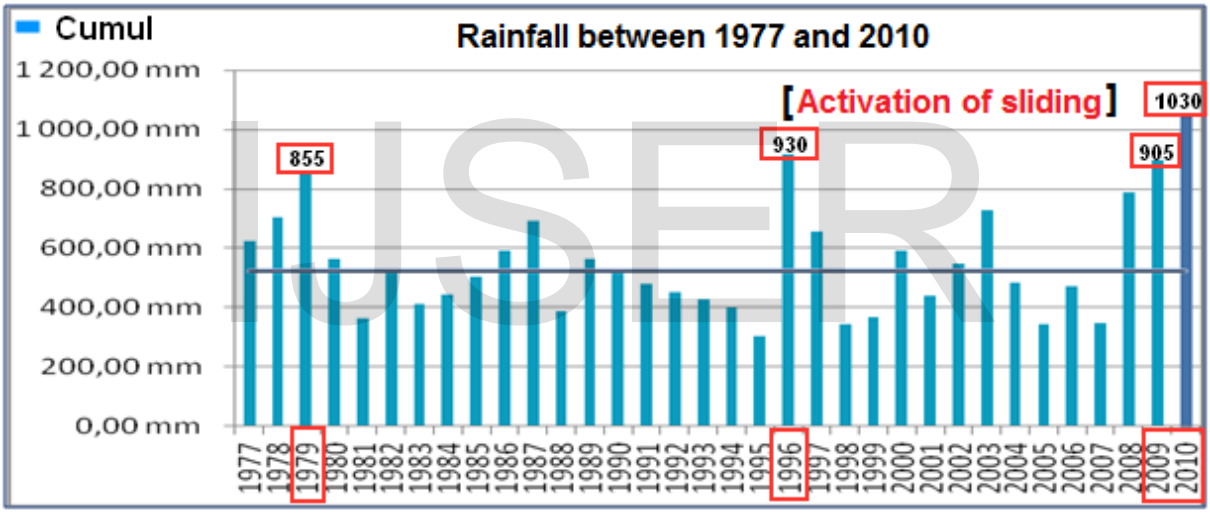


Figure 8: Annual precipitation for 33 years

6.3. Stability analysis and security factor

The geotechnical calculation parameters necessary for the justification of the structure consist of the data of the shear parameters as well as the deformation modules of the formations encountered in the field, as well as the friction angle deduced from the Mohr circle.Table1.

The resistance of a body to different external forces determines its mechanical resistance (De la Cruz, 2006).

Parameters	**τ : Shear stress**	**Φ : Frction Angle**
Average value	**32Kpa-37Kpa**	**8° - 10°**

Table 2 : Shear test Results

The safety factor is generally given by the following this ratio (3)

$$FS = \frac{\text{Available resistance}}{\text{shear breaking strength}} = \text{Value of rupture}$$

(3)

We can calculate the shear stress on the ground by the following formulas (4)

$$\tau = \frac{c}{F_{sol}} + (\sigma - u).\frac{\tan\phi}{F_{sol}} \quad \text{avec } F_{sol} \geq 1$$

(4)

When:

τ: shear stress

σ: total normal stress

u: pore pressure

C: cohesion deduced from the Mohr circle

Φ: friction angle

F_{sol} : safety factor on the ground

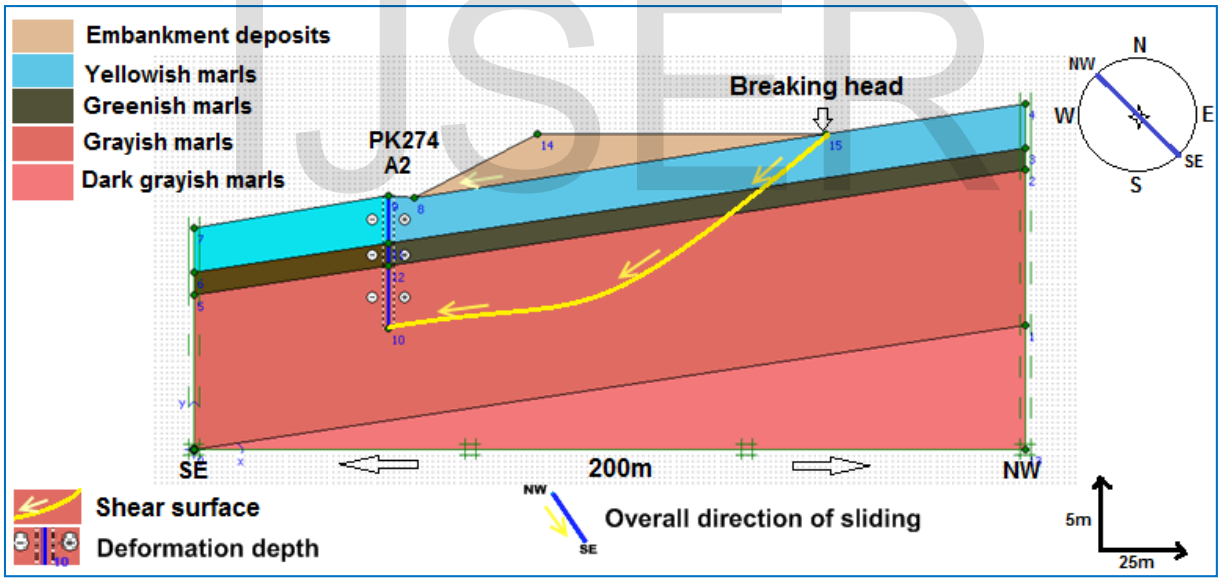


Figure 8: Section and 2D model of the landslide slope

We can eliminate some stabilization techniques due to certain criteria of the nature of the slip namely: - Given the vast extent of the sector affected by the landslide (200 m by 300 m)

-Since the highway is already in service at the beginning of 2010

7.3. Proposed Stabilization Method

En se basant sur les données géomécaniques du sol de l'ouvrage, surtout, les contraintes, la cohésion, et l'angle de frottement qui sont déduites à partir de la courbe intrinsèque du cercle de Mohr. Choosing a method for stabilizing a landslide requires the judgment, experience and

reflection of the treating geotechnician. An effective solution can give a lifespan for bodies and geological stabilization models.

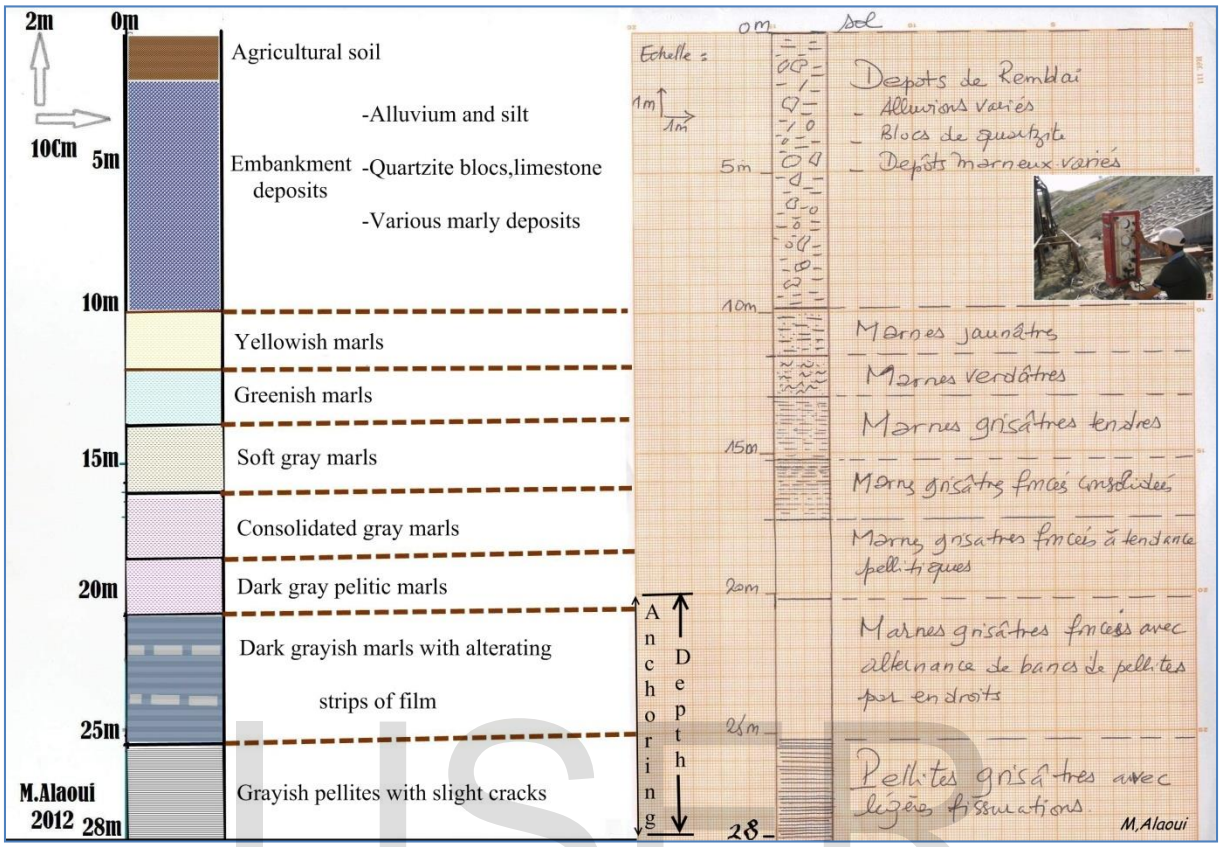


Figure 9: Stratigraphic log of the downstream part of the slide by vertical coring

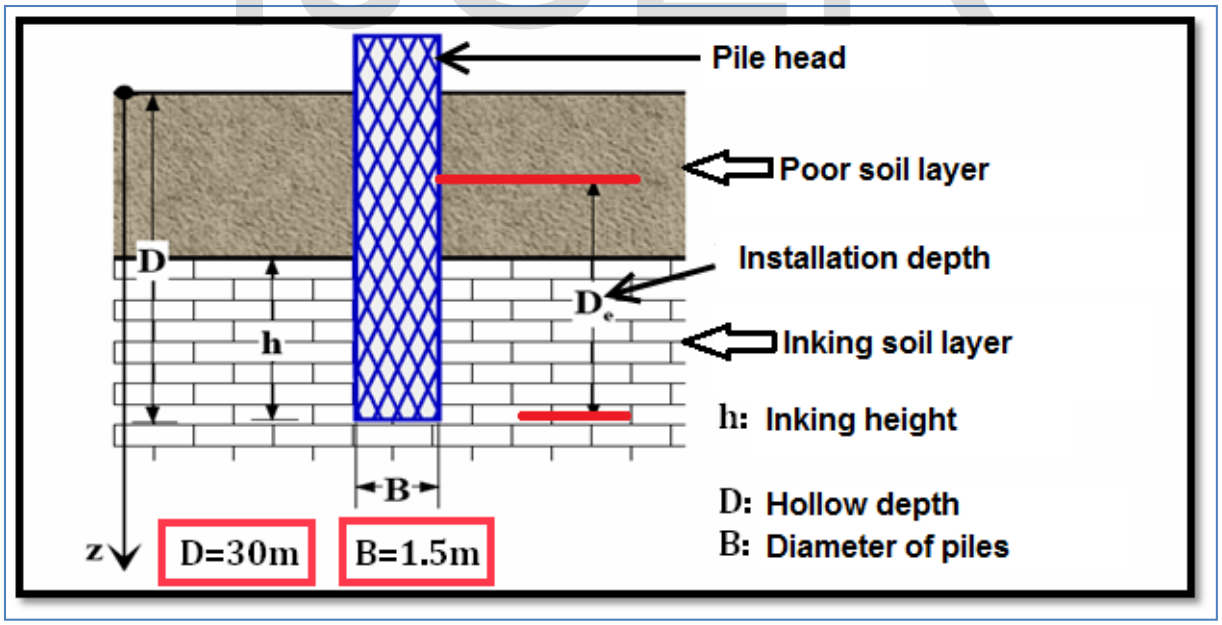


Figure 10: Simplified diagram of a joining pile

This solution allowed us to reach a safety factor greater than 1.4 and thus stabilize our embankment of the vehicle passage. The principal results of a computation of finite elements are displacements with the nodes and the stresses at the stress points. **(**Plaxis treatment).

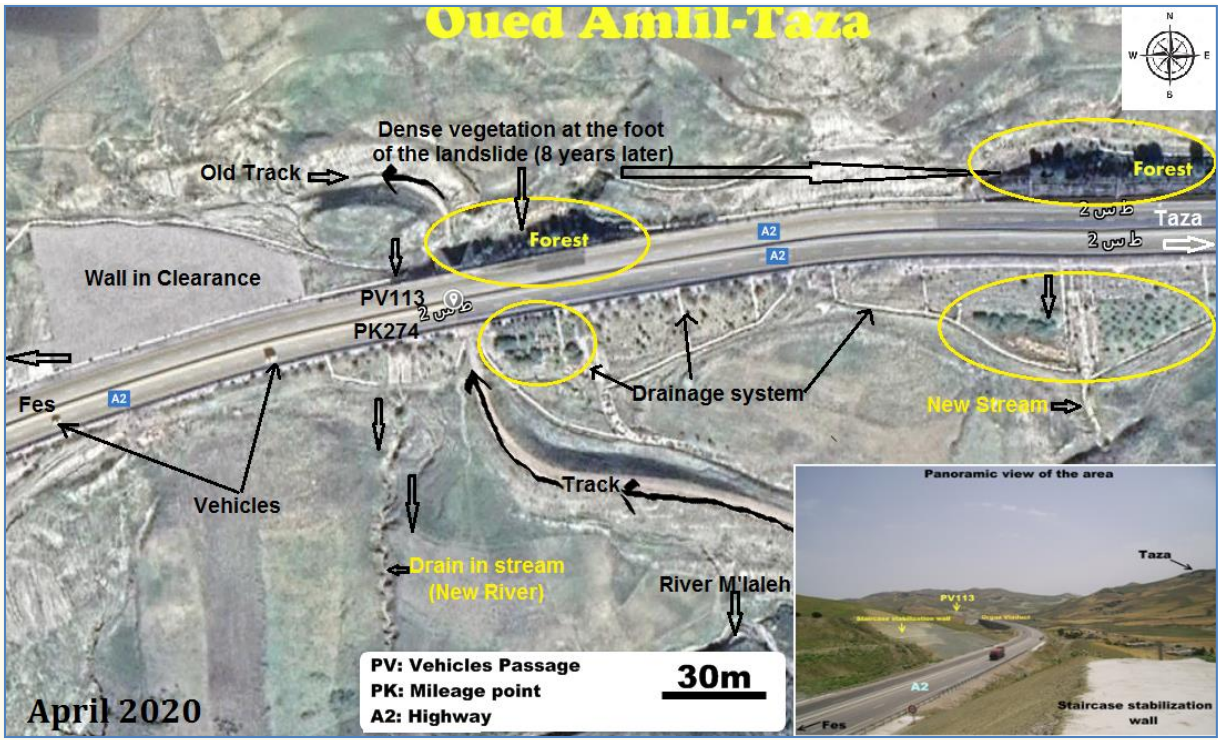


Figure 11: Aerial view of the study area after 8 years

4. DISCUSSION

From a geological point of view, the area is formed by marly deposits and greyish marls, the age of these formations dates back to the Jurassic and Cretaceous. For the morphological analysis of the study on a hill, it was essential to have a detailed topographic map of the terrain more attached to the real one and the relief of the surface at the time of the study was presented.

The angle relative to this slope varies between 31° and 33°, this domain, which belongs to the African margin, is much larger than the internal domain. It is largely carried by the tablecloths of the flyshs and the limestone ridge on the internal side. It is subdivided into three large distinct sets by their paleogeographic history (Salhi.A 2004). The highway axis between Oued Amlil and Taza generally develops in a zone of contact with the South Rifain furrow characterized by post-orogenic molassic marl deposits of the Alpine chain and the Atlas especially the limestone plateaus of Taza in South. (Piqué and Bouabdelli, 2000).

Morphologically, in general, we find soft marl hills of great amplitude, cut by ravines and deep torrents. In this area the national road [RN6] forming with the A2 a bevel, explained by the presence of two large hills going south.

Soil samples have been collected from open pits, and the soils analyzed are classified as a modified type. In order to reproduce the conditions of the natural soil, tests of natural humidity and the volumetric weight of the place were made. Mechanical soil results were

obtained based on simple compression tests and triaxial compression. In the triaxial compression test, we tried to reproduce the real conditions to which the ground is subjected, thus applying pressure confinement similar to those in the field.

The comfort study of a structure affected by a landslide is based essentially on the first four tests. The tests are designed in particular between 12.70m and 23.20m. The average values obtained are set out in table 1. We do not forget the particle size analysis; indeed, the grain size can give us an idea on the shape and the weight distribution of the classes of a material given by a curve. For example, the D max varies between 31.50 and 50 mm at a depth of 16.50mm, and 6.30mm between 22.90m and 23.20m. Also, the values obtained from the Atterberg limits show that the marls on our site are relatively plastic. (Table1)

The graph (Fig. 6) above gives us the variations and the evolution of the activity of the slide from 09/01/2012 until 19/06/2012. The slide had started towards the depth of 10 m it is activated at the level of the yellowish marls just below the embankment. We can deduce the average speed of our sliding, by dividing the length of the deformation by the number of days (162 days = 5.5 months) .The average speed (Equation 1-2) is 2.18mm / month, so it is a slow type. The phenomena of instability in the external Rif are conditioned by three main factors: -

--The geological formation of the region, due to the overlap of very different physical and mechanical properties

-The geometry of the structures they are generated by the activity of the Tazzaka fault, and c--

--The runoff effect which increases the pore pressure in the marl materials. (Fig4).

The seasonal rhythm is much nuanced according to the sectors considered, and a dry year can succeed a rainy year. The total number of rainy days is around 65 days on average. Two periods thus regulate the current dynamics (Fig.7).

In wet weather, it is the intensity of the rains, concentrated on a relatively small number of days, with an average of 10 days per month, with showers spaced for short periods, which is the main factor with three nuances.

The first downpours of autumn, which are generally brutal, arriving on a ground made impermeable, it results from it a strong an initial runoff while the water infiltrates in the cracks and prepares sliding plans which will be active by the after. (Veronica Ochoa Tejeda and Monique Fort 2011).

Winter rains are more regular and moisten the soil more permanently, subsequently facilitating the phenomenon of solifluxion.

The violent spring rains arrive on a more or less saturated ground which blocks the infiltration and allows the gully to accentuate.

In summer, on the contrary, the influence of high temperatures takes over, coinciding with the minimum rainfall, and temperatures generally exceed to 30°c, which promotes excess evaporation and exerts an intense influence on the soil water regime. The phenomenon can be accentuated by a wind coming from the South-east Arabic called “Chergui” which brings a drying heat wave, which in general, one week per summer to 10 days. Fig 7 and Fig8.

In this case, where the highway has been in service since the beginning of 2010, so the only solution to stabilize this structure is "the adjoining piles" which will be installed at the base of the structure. Indeed, the other solutions remain ineffective and risk a catastrophe in the vicinity of the "PV113" embankment. For example, if you dig to install a support device, the structure can be moved to Oued Mlaleh. (Mathivat J. 1973)

Thus it was possible for us to determine the optimal comfort solution in view of the constraints which were imposed on us. PV113 was therefore chosen for the solution involving the creation of adjoining piles.

Structural geology requires, in some cases, a stability analysis based on a combination of curved and planar failure surfaces. We can classify the information necessary for the execution of stability analyzes according to the three headings:

-Slope geometry,

-Surface andgroundwater,

-Groundmass-of-resistance,

Of these three elements, only the geometry of the slope can be determined between the narrow limits from ground surveys or using maps established using aerial photogrammetry technical (Ulrich Kniess- Alpes francais). It is by drilling and exploring geotechnical tests that we can determine the situations of surface and groundwater. It is necessary to identify all the layers of the soil and determine their resistance using the soil testing methods. It is important to pay close attention to inclined layers, cracks, and any structural features that may affect stability. The processing by Plaxis is done by the phasing of calculation adopted simulates at best the history of the construction of the structure:

-initialization of constraints in the absence of backfill (earth at rest),

-construction of the embankment with the short-term parameters of the soil in place,

-installation of the pile curtain

-application of service overload

It should be noted that other comfort solutions could have been considered well before the embankment was put in place. However, given that the A2 highway is in service, such intervention could not be envisaged at present, therefore, the proposed solution is the most

suitable. So we got to know the region of our study area better, both geological, geomorphological and geographical.

By installing a GPS antenna in the village of Maca (Region of Arequipa) to monitor the deformation, researchers from the IRD and the Peruvian INGEMMET (Instituto Geológico Minero y Metalúrgico) have just made the first observations of a ground movement reactivated by an earthquake, which occurred in July 2013 in the south of Peru. GPS measurements show that the response of the ground is both concomitant to the shaking, with a simultaneous displacement of 2 cm, but also post-seismic. The slide did indeed last for five weeks, during which the range of ground displacement tripled, reaching 6 cm. This study is published in the journal Geophysical Research Letters. (P. Lacroix)
Here again, it is the vibration of the soil elements and the modification of the gravity conditions "g" which can be at the origin of the destabilization of the masses in place. The degree of tectonic seismicity of this region of the Rif varies between [0 and 4] magnitudes (Seism tectonic Map of the Arab Maghreb), without forgetting the jolts from time to time from 3 to 4 Richter degree (Example of 07/11/2012). So we can say that this area is quite stable indeed the use of a GPS is useless to misuse the vertical displacement

Regarding the safety coefficient of this structure, it must reach the value of 1.4 depending on the type of reinforcement and the quality of the concrete that will be used in the piles for the reinforcement of the fill of the PV113 vehicle passage (Equation 3-4). (Agmbogba.2015)
After 8 years the road did not show any phenomena of gravitational instability along the passage, certainly the solution which was used as connected piles in parallel with the planting of trees with roots which maintain the grounds in permanent stability , without forgetting the subhorizontal drainage system used to get rid of shallow waters as indicated in the aerial photo dated 2020. Fig11

5. CONCLUSION

The events described illustrate the extent to which intense rains can cause not only the triggering of small water-saturation landslides, but also very complex and large-scale mass movements. We have shown, for the years [2010-2012], that there is a clear relationship between the spatial distribution of rainfall and the distribution of these landslides observed and their variation in shape. In our case, constructions and fields were destroyed, washed out tracks and viaducts were damaged. Thus, the passage of vehicles PV113, it appears as an area representative of the risk run by the volume of the moving masses of the unstable part often hit by heavy precipitation.

In this work, the purpose of the expertise mission and its intervention is to confront the origins of the land movements affecting the route of the motorway [A2] and more precisely the section [Oued Amlil - Taza] by the through geomorphological studies of the site and the exploitation of the results of the tests carried out and to give effective and adequate proposals to stabilize this ground movement.

The geological complexity of the region being what it is, we recommend a more geological study of the embankment area, given the tectonic accidents which run through the Jurassic and Cretaceous substratum in the region and which can induce faults within of the interface. These faults cannot be easily located because the plastic marly facies of the region do not allow us to observe precisely the play of the fault. However, the abnormal arrangement of the layers of yellowish marl and greenish marl suggests the possibility of a fault crossing the motorway right through to the very place where the cracks appeared.

From a hydrogeology point of view, marly soils are generally permeable, favouring no significant aquifer level. Tiny temporary sheets, fed during the wet period, exist between the yellowish marls and the greenish marls; for example, wells dug in the vicinity of Orgaz village to the west [34.00 N]/[- 4.00 E] offer a low flow rate and water with remarkable conductivity by the presence of halites. To control these waters in order to avoid creep and solifluxion at the level of the road margins, a vertical and subhorizontal drainage system was carried out along the area in order to minimize the risks of instability.

The most critical problems of slope stability usually arise, first, on fine-grained soils and particularly on clays and marls. This is partly due to the fact that it is difficult to drain them and that, on this kind of soil, the processes of erosion by runoff bring many slopes to the breaking point. (S. Bomont 2001).

BIBLIOGRAPHICS REFERENCES

1. Melchiorre, C. y Frattini, P. Modellingprobability of rainfall-inducedshallowlandslides in a changingclimate, Otta, Central Norway. Clim Chg, 2012, *113*, 413– 436. **DOI.** https://doi.org/10.1007/s10584-011-0325-0 D.E. Benouis 2010. Étude d'un glissement de terrain par différentes méthodes. Université Saadi Algérie,

2. Trenberth, K. Conceptualframework for changes of extremes of the hydrological cycle withclimate change. Clim Chg, **1999**, 42, 327–333. Available online: http://www.cgd.ucar.edu/staff/trenbert/trenberth.papers/ClimChg42_327-339.pdf (accessed on 14 September 2017)

3. Cruden D.M. ; Varnes D.J. Landslide types and processes in Turner & Schuster, Landslides, Investigation and Mitigation, Special Report 247, National AcademyPress : Washington, D.C. USA ; 1996 ; pp. 240-241

4. Hungr, O. ;Leroueil, S. ; Picarelli, L. The Varnes classification of landslide types, an update. Landslides, 2013, 11, 167–194, DOI. http://dx.doi.org/10.1007/s10346-013-0436-y.
5. Petley, D. Global patterns of loss of life fromlandslides. Geology. 2012, 40, 927–930. DOI. http://dx.doi.org/10.1130/G33217.1.

6. IPCC – Intergovernmental Panel on Climate Change, 2014. Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland pp. 151. ISBN : 978-92-9169-143-2.
7. Zeino-Mahmalat E. ; Bennis, A. Environnement Et changement climatique au Maroc : diagnostic Et perspectives. Konrad-Adenauer-Stiftung : Morocco, 2012 ; Available online :http://www.kas.de/wf/doc/kas pdf?120705170939 (accessed on 01 Novembre 2017)

8. Bzioui, M. Rapport National (2004). Les Ressources En Eau Au Maroc. UN Water/Africa (2006), African water development report 2006, Econ. Comm. for Afr., Addis 2004. Available online : http://www.albacharia.ma/xmlui/bitstream/handle/123456789/30433/0178Rapport%20national%202004%20sur%20les%20ressources%20en%20eau%20au%20Maroc%20(Novembre%202004).pdf?sequence=1 (accessed on 04 Novembre 2017)

9. Rianna, G, Zollo, A. Tommasi, P. Paciucci, M Comegna, L. Mercogliano, P. (2014). Evaluation of the Effects of Climate Changes on Landslide Activity of Orvieto ClayeySlope, ProcediaEarth and Planetary Science, 2014,9, 54 – 63**. DOI.** https://doi.org/10.1016/j.proeps.2014.06.017

10. Salhi A. (2004). Etude de la Vulnérabilité à la Pollution des Ressources en Eaux Souterraines /Etablissement de la carte de vulnérabilité et la carte de Risque/cas de l'aquifère de l'Oued Laou (Rif septentrional, Maroc)- El Kadiri K., Chalouan A., El Mrihi A., Hlila R., Lopez-Garrido A. C., Sanz de Galdeano C., Serrano F., &Kerzazi K.,(2001) : Les formations sédimentaires olistolitiques de l'Oligocène supérieur – Miocène inférieur dans l'unité Ghomarides des Béni Hozmar, secteur de Talembote, Rif septentrional, Maroc)

11. Durand – Delga M, Hottinger L, Marcais J, Mattawer M., Milliard Y. & Suter G. (1960-62). Données actuelles sur la structure du rif (Livre, Mémoire. P. Fallot)- Nhiem T.V., Dagnaux J.P. (1983) : Renforcement des remblais et déblais de l'autoroute A41, Annales d'ITBTP, série Sols et Fondations

12. Mathivat J.(1973). Le nouveau pont de Saint –Cloud sur le plongement de l'autoroute A13, de Saint-Cloud à Paris- Cartier.1985 : Méthodologie d'étude des glissements de terrain rapport interne du Laboratoire Central des Ponts et Chaussées

13. S. BOMONT (2001). Le drainage profond pour la stabilisation des glissements de terrain par drains siphons et drains électropneumatiques14. *Veronica Ochoa Tejeda et Monique Fort (2011).* Relation entre la pluviométrie et le déclenchement des glissements de terrain dans La Soledad, Sierra Norte de Puebla, Mexique.

14. P. Lacroix IRD (2013). Séismes et Glissements de terrains : Un comportement similaire. Etude du glissement de terrain du village Maca dans la région d'Arequipa au Sud du Perou.