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Observation and Study of Landslides Affecting the Tangier – Oued R'mel Motorway Segment

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Abstract**—**The motorway segment between Tangier and Oued R'mel has experienced, since the beginning of building works, significant instability and landslides linked to a number of geological, hydrogeological and geothermic factors affecting the different formations.

The landslides observed are not fully understood, despite many studies conducted on this segment. This study aims at producing new methods to better explain the phenomena behind the landslides, taking into account the geotechnical and geothermic contexts. This analysis builds up on previous studies and geotechnical data collected in the field.

The final body of data collected shall be processed through the Plaxis software for a better and customizable view of the landslide problems in the area, which will help tofind solutions and stabilize land in the area.

Keywords**—**Landslides, modeling, risk, stabilization.

I. Introduction

THEterm "landslide" describes a wide range of ground movements, such as rock falling, deep failure of slopes, and shallow debris flows [1].

Morocco's Rif Mountains are often the scene of mass movements that cause instability. These instabilities are the result of the interaction of several factors:

- Aggressive harsh climate;
- A rugged terrain;
- Predominance of common land (Marl and Flysch);
- Aggravating anthropogenic factors...

These landslides can have a direct impact on road networks. The highway Tangier Oued R'Mel is a typical example of such risk areas. Several landslides have caused important damage. The Directorate of Roads and Road Traffic spends about 50% of its annual budget in reinforcement works and rehabilitation of the reinforcement and rehabilitation of roads and affected water-infrastructure by landslides [2]. These risks generate huge economic losses nationally and put development at risk.

The study of the causes of landslides, have a vital interest in preventive…Against this complex process action, and a good knowledge of the types of sliding encountered in the field will facilitate the solutions to choose in order to reconcile studies.

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II. Presentation of the Sector of Study

The main motorway between Tangier and Oued R'Mel through the mountains of the Rif is an important geological activity indicator.

The Rif Mountains is the closing place of an ancient sea under the action of plate tectonics. The merger of the two banks of the sea need, literally, the expulsion of sediment deposited on the bottom. While ancient sea would fall to Ceuta, sediments expelled have spread over the West Bank and are now on Flych's slicks which are touched by affected by the project.

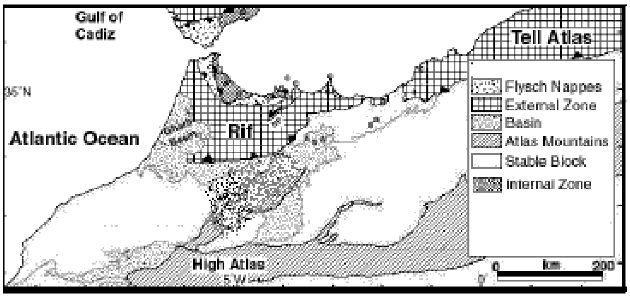

Fig. 1 Geological map of the peninsula of Tangier [3]

The tectonic setting is very complex because the area is in the region of a major contact between the African and Eurasian plates.

The region is highly seismic and travel related to the tectonic plates is about 1 mm per year by a shearing movement of east-west axis. Seismic homes are generally located in the Strait of Gibraltar - Tangier, but more broadly in associated with diverticula that may include the project area [4].

A seismo-tectonic study was conducted on the project area. This study shows that there is no active fault in the project's location.

The climate is sub-humid, the annual rainfall amounts are between 800 to 1000 mm and the annual average temperature varies between 17 and 20°C. The main rivers in the study area are: Oued Ksar Sghir, Oued Rhlâlâ, Oued Rmel.

III. Typology and Description of Instabilities Met on the Ground

This part covers the entire road alignment. It is there a description of different types of instabilities observed in the field and detected by photo-interpretation of aerial photographs.

Morphology has identified four types of instabilities. These phenomena are described in their cause and consequence and illustrated by field observations. These are:

- Glaciated areas by solifluction or cast clay;
- Trough at the bottom of ravines;
- Landslides;
- Drop blocks at rock horizons.

A. Glaciated Areas

This is the case is most frequently observed on the project area. Fig. 2 shows a representative case of landscapes encountered in the case of a pelitic substratum (Here Sector Ksar).

Fig. 2 Solifluction between Ksar and Oued

Fig. 3 Gullying in a trough in the sandstone - Lachbâa

Fig. 4 Gullying in road embankments in mudstones - Oued R'mel

The hummocky slope aspect does not prevent the development of vegetation. The main cause of the solifluction formation comes from the presence of water in the surface layers which are made of very plastic clays, the ultimate product of weathering of the underlying mudstones.

The thickness of the layers movement generally does not exceed those of clay formations covers (maximum 2-3 m).

Stabilization of such slope passes including a drainage layer (using spurs, masks, trenches) and recovery.

B. Gullies

Fig. 3 shows the typical shape of a large gully erosion in the sandstone beds. During important rainfalls, water runs off the soil and is collected in the ravines of this type. The weathered sandstone blocks are pushed down slope because of the kinetic energy of the water, caused by the steep slope, together with a large volume of water (depending on the watershed) in motion. After some time, the bed of the trough stabilizes the massive sandstone unaltered. Erosive cycle will resume once the new bed is altered during a stormy new episode.

Fig. 4 shows another form of typical pelitic gully areas. As mudstones are slightly permeable materials, the entire (or almost) precipitation will flow on the surface. The pelites deteriorate outdoors in fine materials tovery fine (GTR class: A1, A2 or A3). With slope, water carries these clays altered atthe foot of slope and leaves flow paths thatcan be deep (here: about 20 to 50 cm between the peak and the bottom of ravines).

Gully is detected on a specific topographic base (approximately 1/1000th). Note the need for significant rainfall events and runoff velocities sufficient to cause soil particles (more or less large). This is regressive and can cause landslides or casting.

A gully can be stabilized by:

- Limiting the rate of runoff by creating slope failure in the ravine;
- Facilitating the infiltration of precipitation sumps or drainage trenches; [5].
- Developing evapotranspiration with a resistant plant tissue;
- Evacuating faster precipitation in watertight concrete example ditches.

C. Landslides

Fig. 5 presents the case of landslide identified on the geological map. It is an old slide (known fossil) which can move again according to changes in hydrogeological conditions, mechanical characteristics, evolution of the mechanical characteristics of materials and other factors such as topographic changes during earthworks.

Fig. 5 Landslide interesting pouring - Valley Ksar es Srhir

The fracture surfaces in this case may be quite deep (generally greater than 5 m but sometimes beyond 10 m deep).

Two sectors directly affected by the project have particularly been a specific study and tracking movements:

- The rise of Lachbâa (KP 0 to KP about 3,000)
- Valley Ksar especially near the viaduct south Ksar (8 PK 700 PK 700 9)

Other landslides exist along the project but they are minor or do not have a direct influence on the project. They were located on the mapping established by photo-interpretation.

Engines landslides elements are:

- Water
- Alteration of topographic relief profile with foot and / or overload of the head.

The detection of instability is made by the use of aerial photographs and field observation. In the two areas where a shift is suspected, inclinometers were established.

To stabilize a shift, the work required is generally proportional to the moving amount and the moving speed.

Slip Photography featured on 4 would be difficult to stabilize. Because the strain rates are very low (stabilization phase,) a solution would be there to limit overload and do not alter the hydrogeological conditions, unless to improve them. However, in the absence of a sufficient decrease in the observation of this shift, the bias was to remove the route of this area.

For lower importance slides, it is possible to play on the different causes of instability (drivers) by performing the following work (in part or in whole, as appropriate):

- Drainage upstream and downstream of the slide by drainage ditches
- Unload the head of sliding and / or reload the foot slip

D.Drop Blocks

Fig. 6 shows the final form of slope instability: rock falls. The blocks come from regressive erosion of an outcrop, consisting here of sandstone. Blocks down the slope and are classified grano-foot slope. [6].

Fig. 6 Scrap blocks and talus cone - Lachbâa

The areas affected by this phenomenon have a steep slope, and thus are very limited. They can easily detect the landscape.

Two types of protection are possible for this problem:

- Passive protection: creating barricade traps, rocks and / or installation of net Anti-Submarine (usually called ASM)
- Active protection: periodic purge, protection of the cliff

In the case of this project, passive solutions have been favored with the creation of traps stones and barricades.

IV. Summary of Observations Inclinometer

A. Mounted Lachbâa

Table I summarizes the main findings relating to inclinometers measured by the rise in cervical Lachbâa movements over a period of seven months

TABLE I
Summary of Inclinometer Measurements

Survey	OE	Speed	Rupture	
			Type	Depth
SC1779	DB01	1.5 cm/year	Surface	About 4m
SC1789	RB01	2.2 cm/year	Surface	About 6.5 m
SC1803	DB03	nonsignificant	None	-
SC1815	DB03	0.5 cm/year	to be followed	8m rupture inclino
SC1826	RB03	1.3 cm/year	Plastic	
SC1840	RB03	nonsignificant	to be followed	small rotation to 5m
SC1852	DB05	nonsignificant	to be followed	About 4m
SC1865	RB05	nonsignificant	none	small rotation to 5.5 m
SC1887	RB06	nonsignificant	none	-
SC1918	DB07	nonsignificant	to be followed	small rotation to 6m

It should be noted that the common denominator between all the breaks, such sliding more or less rapid is geological horizon which develops out: green marl (marl # 51 of geotechnical model). For pelitic horizons (41 and surface alterations products), the movements are generally movements solifluxions.

The most unstable areas are located at the beginning of the project, but doubts remain for some inclinometers. It is essential to continue the inclinometer and piezometric monitoring, obviously for work but also beyond, in the early years of commissioning of the highway.

The definitions of constructive provisions for this sector are provided in the booklets relating to embankments and cuttings of the current section of the sector.

B.Valley Ksar

Table II summarizes the main findings on measured by inclinometers in the valley of Ksar movements. It should be noted that monitoring covers only a short period of time from mid-July (see some inclinometers, late July) to 5 November 2004, a little over 3 months.

TABLE II
Summary of Inclinometer Measurements

Survey	OE	Speed	Rupture	
			type	Depth
SC1226	OA-C0	0.9 cm/year	surface	About 23m/TN
SC1229	RB13	0.5 cm/year	to be followed	About 6 m/TN
SC1233	DB13	nonsignificant	none	-
SC1505	DB13	0.7 cm/year	to be followed	About 8 to 9m/TN
SC507	RB13	nonsignificant	to be followed	Movement to20m

The access to the abutment C0 viaduct Ksar presents a slipping hazard because of the movement natural slope is slight (about 1 cm / year). It will be necessary to continue this monitoring and pair it with a piezometric monitoring. The presence of a zone of rupture of about 23 m indicates that the depth is deep and the sliding stabilizing solutions require substantial work.

Regarding the slip Valley Ksar, this shift in historical terrain is listed on the geological map of the area. The inclinometer monitoring shows that this shift is a phase of slow motion (about 0.5 cm / year). It will be necessary to continue monitoring to see if the speed of movement is amplified depending on rainfall. Stabilization of such a shift does not seem possible without reasonably heavy and expensive work. The solution is to follow the glide path and spread the foot sliding into the valley.

V. Conclusion

The survey and classification of landslides from existing data allowed us to distinguish four types, which in order of importance are:

- Scree debris 66%;
- Solifluction 26%;
- Complex Movements 6%;
- Mudflow2%;

Characterization predictors of mass movements show that the most favorable movement factors are:

- The slopes of moderate to steep slopes (between 5° and 15° with 79% slippage) in vertical drop,
- Golf lithology mainly composed of Flysch and sandstone (91% slippage).
- The distance to the water system; movements are always close to rivers and streams (50 to 300 m with 82% slippage).

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