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Geotechnical Stability Analysis of the Quay Wall of Port Ksar Sghir, Morocco

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Abstract
Our paper consists in establishing a geotechnical stability study of the -4m/zh quay belonging to the Ksar Sghir Port. First of all, using the TALREN software for verification against large slips. the study presents a verification of the stability for the rear slope slip circles and for the front slope slip circles in the static case. Secondly, the stability was determined for the back slope slip circles and for the front slope slip circles in the seismic case. Moreover, PLAXIS software was used to model the displacements and constraints in the structure. Following the results of the safety coefficients, we notice that the stability of the structure gives acceptable values. In addition, the soil does not reach breaking stress.

Keywords: weight-block, stability, deformations, numerical modeling.

1. Introduction

The wharf (Quay Wall) is intended to receive several categories of ships (oil tankers, container ships, ro-ro ships, etc.) with their own characteristics. General access structures must take into account the most restrictive vessels[1].On the other hand, for specialized terminals, it is the characteristics specific to the category of ships concerned that are to be retained [2]–[4]. This is done from an analysis of the fleets of ships in service at the time of the development of the project [2]–[7]. But it is also essential to carry out a study of the trends in order to define the characteristics of the ships which will be in service in the future, the port installations, very expensive, being fitted out for several decades[8], [9] Berthing structures can fulfill a triple role:

- Provide the ship with a berthing and support device, and possibly allow its mooring.
- Ensuring the connection between the ship and the land (platforms of the quays, platform of the jetties); the connection device supports all or part of the handling equipment, the facilities for ship service, reception, and transport of goods or passengers: parks, hangars, ferry terminals, roads, railways, and transport pipelines, etc.
- Support the land at the water body limit:

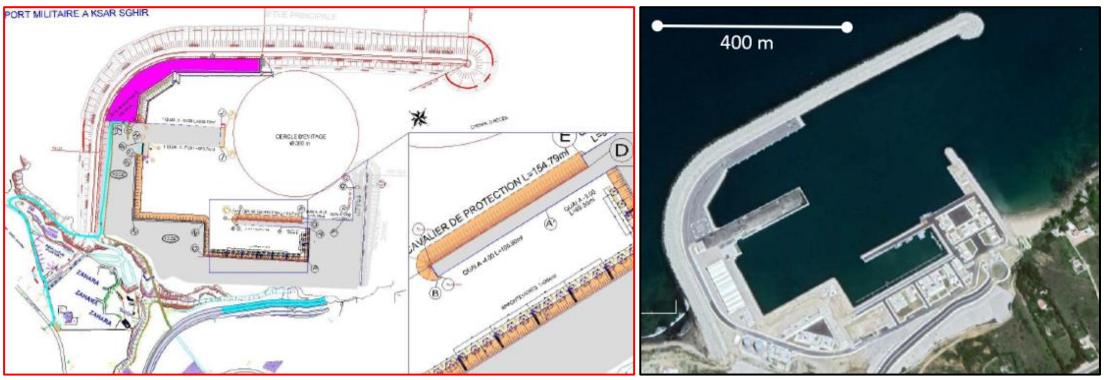

Figure 1. Quay situation -4/zh on the ground plan (left), aerial image of the structure (right)

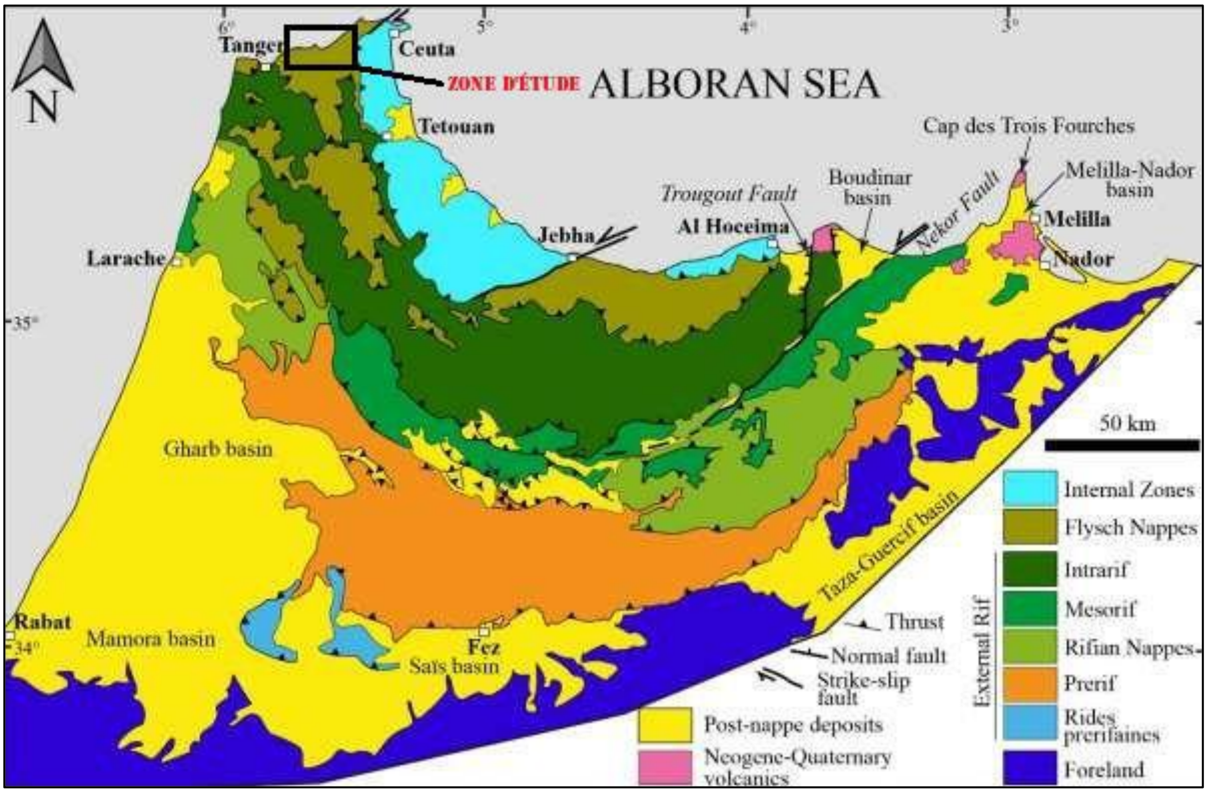

Figure 2. Structural map of the Rif chain representing the major structural domains and location of post-aquifer basins. Modified from Suter (1980) and Jolivet et al. (2003) [13], [14].

2. Methodology

This article will be devoted to the calculation of the coefficients of the external and internal stability of the structure, namely the stability with respect to overturning, decompression, sliding and punching and model the quay on Talren for stability with respect to the large landslide and finally the displacements and stresses in the structure using the PLAXIS software.

3. Results

3.1. Geological and geotechnical context

The chosen site is located in the Rif chain, in the so-called Domain rifain [10]. The Rifain domain, extends in the north of Morocco from the Strait of Gibraltar to the mouth of the Moulouya wadi (figure 2). The structure of the Rif chain corresponds to a stack of layers characterized by divergent overflows towards the outside of the Rif [11]. Classically, three main areas, one of which overlaps the other and are distinguished from the inside of the chain outwards: the internal zones (Domaine d'Alboran) which overlap the flysch sheets themselves carried on the external zones. Which in turn overlap a Paleozoic basement, pre-structured during the Hercynian orogeny (foreland)[12]. The construction projects are located in what is known as the Arc of Gibraltar. This structure is attributable to the convergence and collision between the two plates of Africa and Iberia. It is formed by the Betic Cordillera (southern Spain), the Strait of Gibraltar and the Rif (northern Morocco).

The quality of the foundation imposes a particular choice and design. Indeed, on a good foundation, the choice of a solid quay is generally the most appropriate. On ground that does not have a high bearing capacity, screen and pile platforms are the most suitable. Indeed, structures with continuous foundations can be adopted when the soil has a satisfactory quality ($\varphi \geq 30°$ or $C \geq 10$ t/m2). For our site, the core drillings have revealed good quality soil (Table 1), the lithological section shows from top to bottom;

- A superficial layer of gravelly sea sand 0.9 to 1.3m thick.
- A formation consisting of gray pelite until the end of the survey.

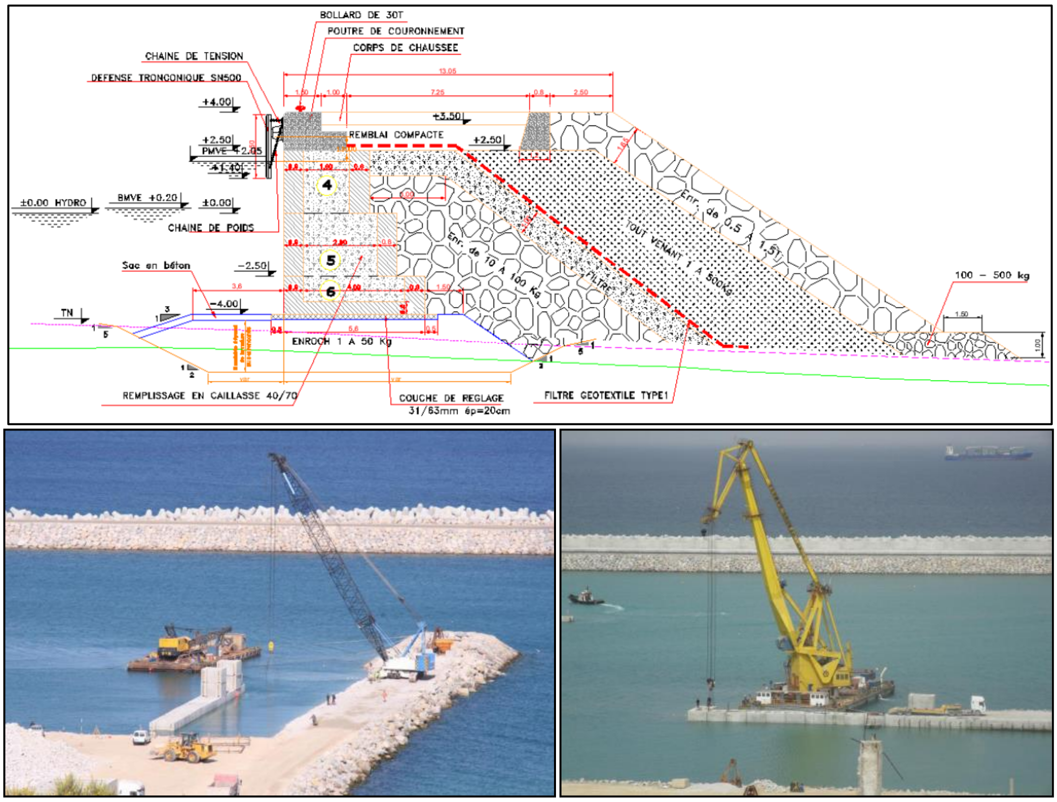

figure 3. Typical section of Quai -4.00 and the jumper (Section A'-B) and Geometry of the quay composed of three blocks and the crowning beam.

3.2. Structure characteristics

The type of quay used here is a weight quay. The structure consists of piles of 3 unreinforced concrete blocks, filled with ballast, placed on a distribution slab and surmounted by a crowning beam. The crown beam is 2.5m wide and 1.5m high. It is poured in place once the various blocks have been arranged (figure 3).

3.3. Verification for stability

3.3.1. Verification of large slip by modeling on TALREN

Retaining structures are very exposed to the risk of deep circular failure, which requires verification of the overall stability, which is done by the methods of calculating the failure of soil mechanics. It is a question of first modeling the structure and knowing the probable rupture by complete detachment of the structure by following a privileged sliding surface. This sliding surface is not known in advance and can be modeled in different forms (in our case it is a circular surface). The stability verification for the slip circles encompassing the structure is expressed by what is called the safety factor (SF/ or FoS). To study this overall stability (calculate the safety factor), the TALREN software is used. We studied the most unfavorable case by considering the water level at 0 meters in relation to the hydrographic datum. Once the geotechnical model is established (figures 3 and 4), In order to take into account the seismic effects, one is then led to enter the two components of the acceleration, namely:
(σh=0,5 $aN\ \tau/g$ σv=0,4 σh) and (σh=0.12 σv=0.048), With (an=$acceleration\ nominale$=0.24g).

Table 1. characteristics of the soil layers.

Linear Elastic		*Concrete -LE*	*Moh-Coulomb*		*Earth embankment*	*Backfill*	*All comers*	*Riprap 1/50kg*	*Pelite*	*Ballasts*
γ_{unsat}	[kN/m^3]	*14.00*	γ_{unsat}	[kN/m^3]	*19*	*11*	*11*	*11*	*13*	*11*
γ_{sat}	[kN/m^3]	*24.00*	γ_{sat}	[kN/m^3]	*19*	*18*	*18*	*18*	*23*	*16*
E_{ref}	[kN/m^2]	*33000000.00*	E_{ref}	[kN/m^2]	*5000*	*140000*	*7000*	*140000*	*6000*	*4200000*
ν	-	*0.2*	ν	-	*0*	*138077.33*	*138077.33*	*135972.14*	*0*	*0.2*
G_{ref}	[kN/m^2]	*13750000.00*	ϕ	[°]	*35*	*35*	*40*	*40*	*1*	*40*
E_{oed}	[kN/m^2]	*36666666.667*	C	-	*0*	*0*	*0*	*0*	*210*	*0*

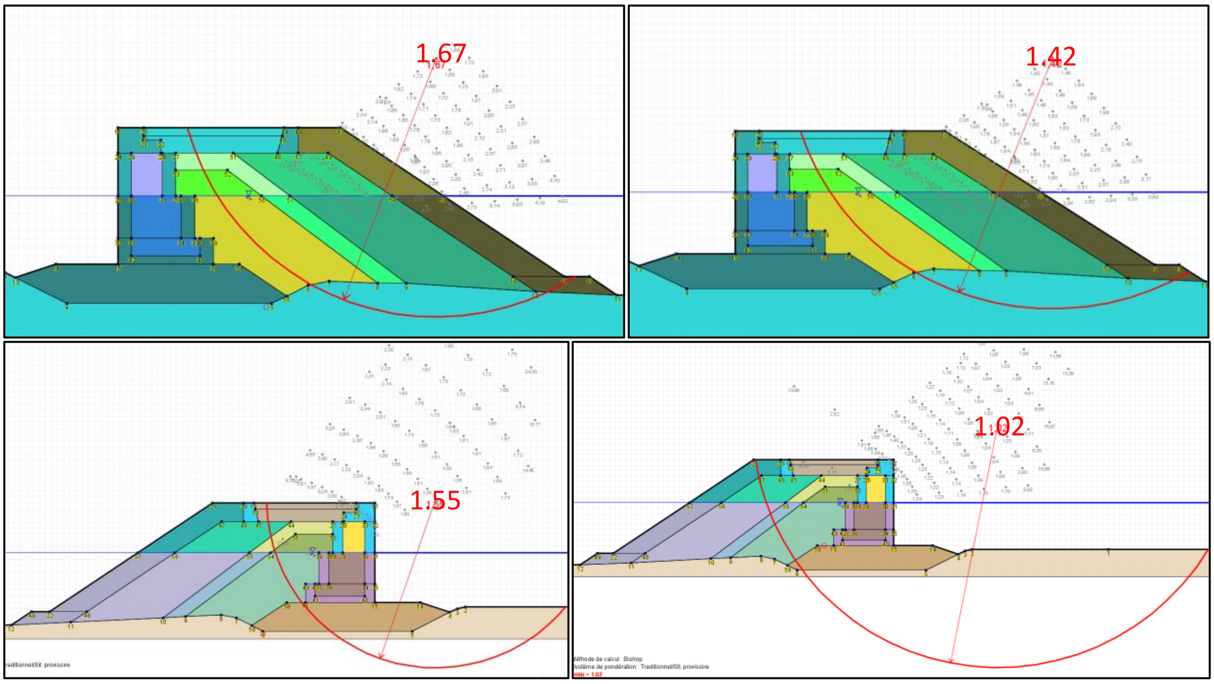

Figure 3: Stability verification for slip circles back slope static case (top left), verification of stability back slope seismic case (top right), stability verification for slip circles front slope static case (bottom left), stability verification for slip circles front slope seismic case (bottom right)

According to the mentioned above step-by-step construction, every step of the safety factor (FoS) can be calculated by strength reduction method. Firstly, a safety factor is assumed and soil shear strength parameters *c* & *Phi* of the potential slip surface decrease by safety factor time. Then, using TALREN program interaction to calculate stress and deformation of the slope that was given the load and boundary conditions until the system balance stable state. Find out resistant shear force and sliding force of all units on the potential slip surface and judge its convergence.

As the simulation analysis with front & back slope in static & seismic cases, the safety factor of quay slope by steps are shown in the figures (3). As seen in figure (3 top); The safety factor (FoS) is 1.42 to 1.67 when the quay simulated on the back slope; At static case is 1.67, at seismic case is 1.42. And as seen in figure (3 bottom) the safety factor (FoS) is varying between 1.05 to 1.55 when the quay simulated on the front slope; At static case is 1.55, at seismic case is 1.01. Consequently; we could find that the two cases therefore show a stability of the quay wall.

3.3.2. Finite element modeling on PLAXIS

A stability study by construction stage was carried out using the PLAXIS program which applies the finite element method (FEM). The numerical analysis program quantifies the deformations of the quay wall according to their stage of construction and analyses the characteristics of the behaviour of the quay wall. To do this, the study was carried out in stages over time; dredging of soil and laying of rock foundations, laying of embankment materials and wave action.

Table 2. Materials used for the construction of the quay wall.

Layer	*Materials*	ϕ	$\gamma (T/m^3)$	$\gamma' (T/m^3)$
full earth	*Compacted backfill*	*35*	*1.8*	*1.1*
Quay shoulder	*Riprap 10/100 kg*	*40*	*1.8*	*1.1*
Internal backfill	*Ballasts*	*-*	*1.8*	*1.1*
Base layer	*Riprap1/50 kg*	*45*	*1.8*	*1.1*
Blocks	*Concrete C 35/45*	*45*	*2.4*	*1.4*
Crown beam	*Unreinforced concrete C35/45*	*45*	*2.5*	*1.5*

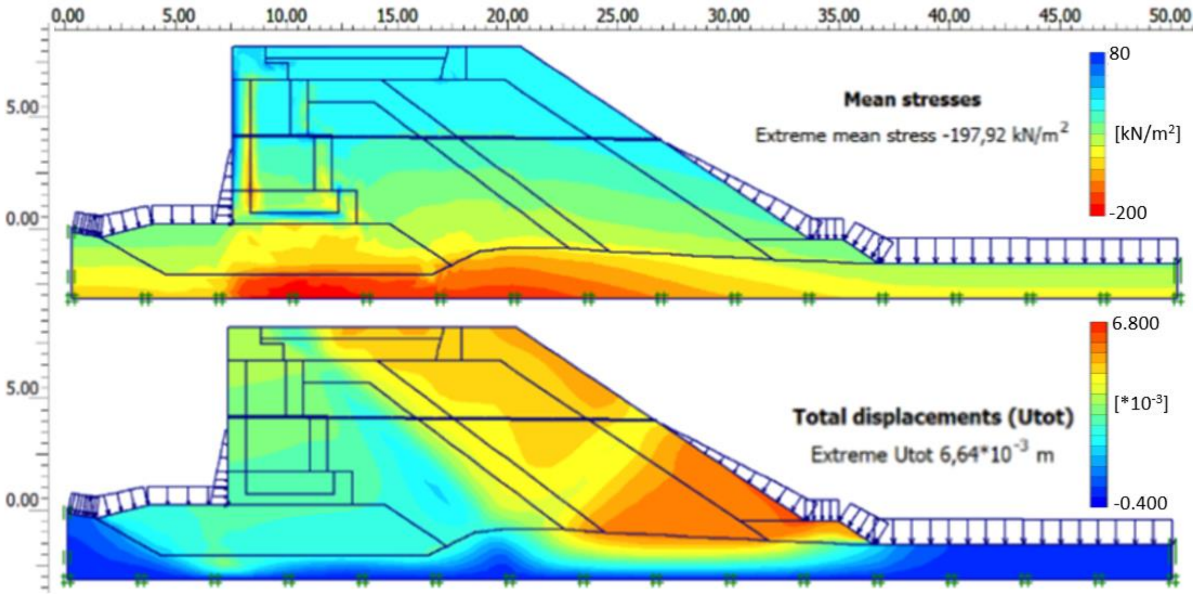

Figure 4. Total constraints(stress) under Plaxis software (top), Total displacements under Plaxis software (bottom)

The final settlement was studied at the lower quay level. In order to assess the stability of the jetty, the main structure of this project, it is necessary to first define the level of admissible settlement. Allowable settlement and bearing capacity of applied soil. In addition, the safety factor with respect to applied breakage is 1.0. The maximum stress is around -197.92 KN/m2 below the rockfill (figure 4 top). The maximum total displacement is of the order of 6.64 mm (figure 4 bottom). Following the results provided by the PLAXIS software, we note that the displacements of the structure are low, below the admissible values. In addition, the stress in the soil does not reach the breaking stress.

4. Conclusion

This paper focuses on the geotechnical study and the calculation of the static and dynamic forces which act on a quay wall, the modeling of this quay on the TALREN software as well as the verification of stability with respect to overturning, sliding and punching has been addressed, also the verification with respect to large sliding, displacements and stresses in the structure using the PLAXIS software. We started with the static and dynamic study of the quay by calculating the linear forces applied to the quay wall, then we modeled the structure to extract the resultants of the forces as well as the moments applied to the quay wall. Finally, the limit safety factors were calculated in order to verify the stability of the structure. Also; The study revealed good stability of the quay in accordance with the standards and recommendations required.

5. Acknowledgement

In this section you may write the detail of your funding research (if any), or some agency, institution, and another part that you want to acknowledge.

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