Scientific Report:

The engineering geology of the Soltan Dam, Mateur (Tunisia)

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Abstract

The Soltan Dam on the river Soltan, a branch of Tine River, is located about 19 km of Mateur city in the northeast of Tunisia. The dam is now under Study and will be constructed in 2017. The Soltan Dam has been designed as an earth fill dam with homogeneous materials. The dam and its associated concrete structures are mainly founded on marl, shale and shale of Lower Miocene age, sandstone of the Hakima Formation of Middle Miocene and the Kchabta Formation of Upper Miocene age. These series are affected by high tectonic deformation due to the Post-Villafranchian compressive event. This paper discusses the site investigation for the dam.

Keywords: Site Investigation; Geotechnical Parameters; Soltan River; Dam; Tunisia.

1- Introduction

In Mediterranean climates, dry season agriculture establishment of food and cash crops could not be undertaken without large quantities of water. To rely upon stream flow at a time when temperatures and evaporation are often at a peak can be unrealistic and risky. It may become essential for a dam to be constructed on a river or stream to allow for off-season storage of vital water supplies. Therefore, the decision makers decided to construct a dam on the river Tine. The hilly dam site of Soltan is located upstream of the confluence of the river Tine in the northern region of Tunisia, downstream of the Medjardha Valley.

The site is administratively attached to the delegation of Mateur. The site is accessible from the road between Mateur to Fritissa. A 19 km from Mateur, the road is marked towards Joumine. The watershed is part of the natural region cold and rainy Tellian Mountain ranges. This area is bounded to the North by the Mediterranean and to the South by the Dorsal. Its terrain is very varied and consists of a juxtaposition of plains, basins, hills, and mountains links. This landscape very compartmentalized creates multiple climatic micro-regions rather nuanced. But the climate of our watershed, depends more on the longitudinal sway of the atmospheric circulation, as otherwise suffers the effect of latitude, continentally and relief. The islets of reliefs are very varied heterogeneous in their parts and provisions, and define themselves multiple islets climate. It is impossible to define with precision given the small number of stations for climate observations. The expected objectives of the creation of the development of this project on the River Soltan are essentially as follows:

1- Protection against silting of the reservoir of the great Tine dam located 8 km downstream of the dam.
2- The development of agricultural land located in the vicinity of the hill dam
3- Achieving a trough downstream of the hill dam.

4- Charging the aquifer constituted by Tertiary formations (Hakima Formation) dominated by sandstones and overlain by recent alluvial layers of small thickness.

The Soltan Dam has a crest length of 452 m, a maximum height above river bed level of 18 m, and a total storage capacity of 2 million m^3. The potential site has been identified and analyzed at first. A multi-criteria analysis has identified that this site offers the best conditions from the perspective of the realization that the future operation and rural development. The studies continued in the preliminary design phase and detailed design phase (homogeneous Embankment, concrete weir).

2-Regional geology

The region of Bizerte is part of the Atlas in North or diapirs zone. It shows Megastructures essentially formed during the post-Atlas Tortonian phase. Anticlines are faults folds overturned to the S-E. They are oriented NE-SW.The Triassic evaporate consists of gypsum, marl and dolomite, form a diapir and marking out the SW-NE accidents.The NW-SE accidents affect different geological structures (Fig. 1), formed these grabens with the same direction. The main geological structures are:

2.1- The syncline of the Tine River and Cretaceous Boulaouaj monoclinal

Both units belong to the eastern flank of the anticline of Bazina River who came to the East, jam against the Diapiric extrusion chainon of Lansarine injected into the Teboursouk accident crustal with SW-NE trend.The axis of the syncline of the Tine River is traversed by a dextral fault that appears in the south periclinal closing in the Ypresian limestone of the Rmal Mountain.

2.2- Lansarine Diapir

This extrusive mass takes scarf entire Tébourba map. In the north, it extends on the map of Mateur. In Sowth West, this mass encounters the Thibar diapir and takes the scarf Péritellian sillon of the Medjerda valley (Burrolet, 1956; Zargouni, 1985).

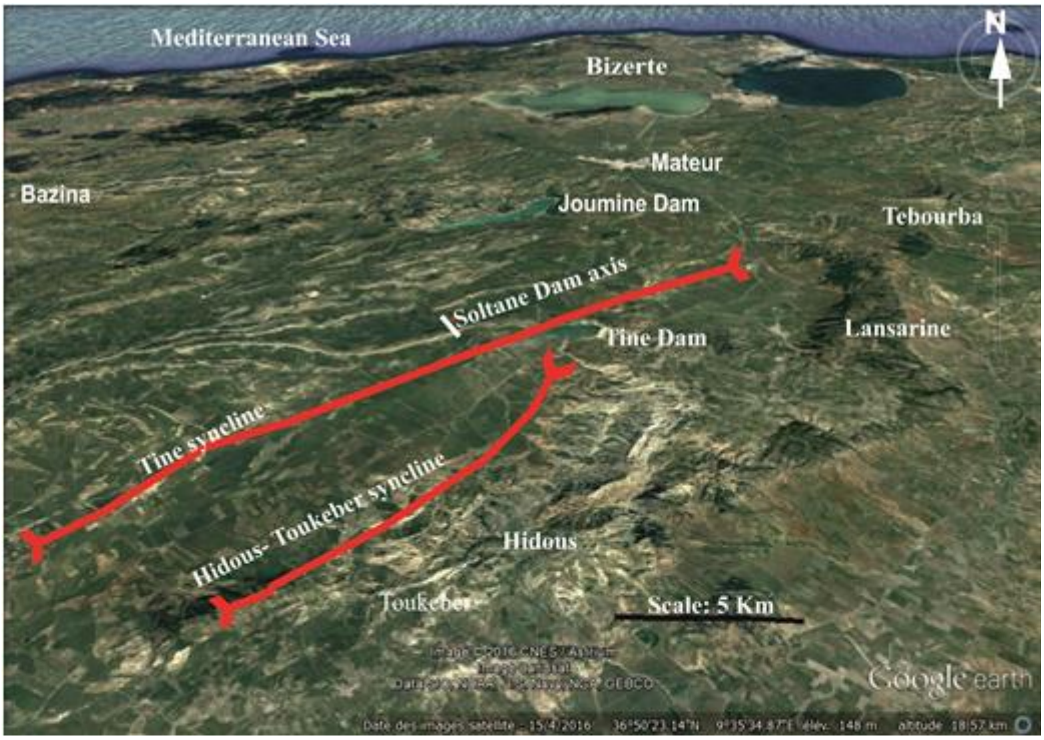

Figure 1) Location of the Soltan site.

2.3- The syncline of Toukeber-Heidous

In the south of Triassic extrusion of Jebel Fernene the Toukeber- Heidous structure is part of the structure of the Tine River, giving it an almost meridional trend (NNE-SSW). Structurally, the study area is centered on the diapirs zone that limits the area of scales (zone des écailles), in the N-W (Beja-Mateur region) (Fournet, 1999).

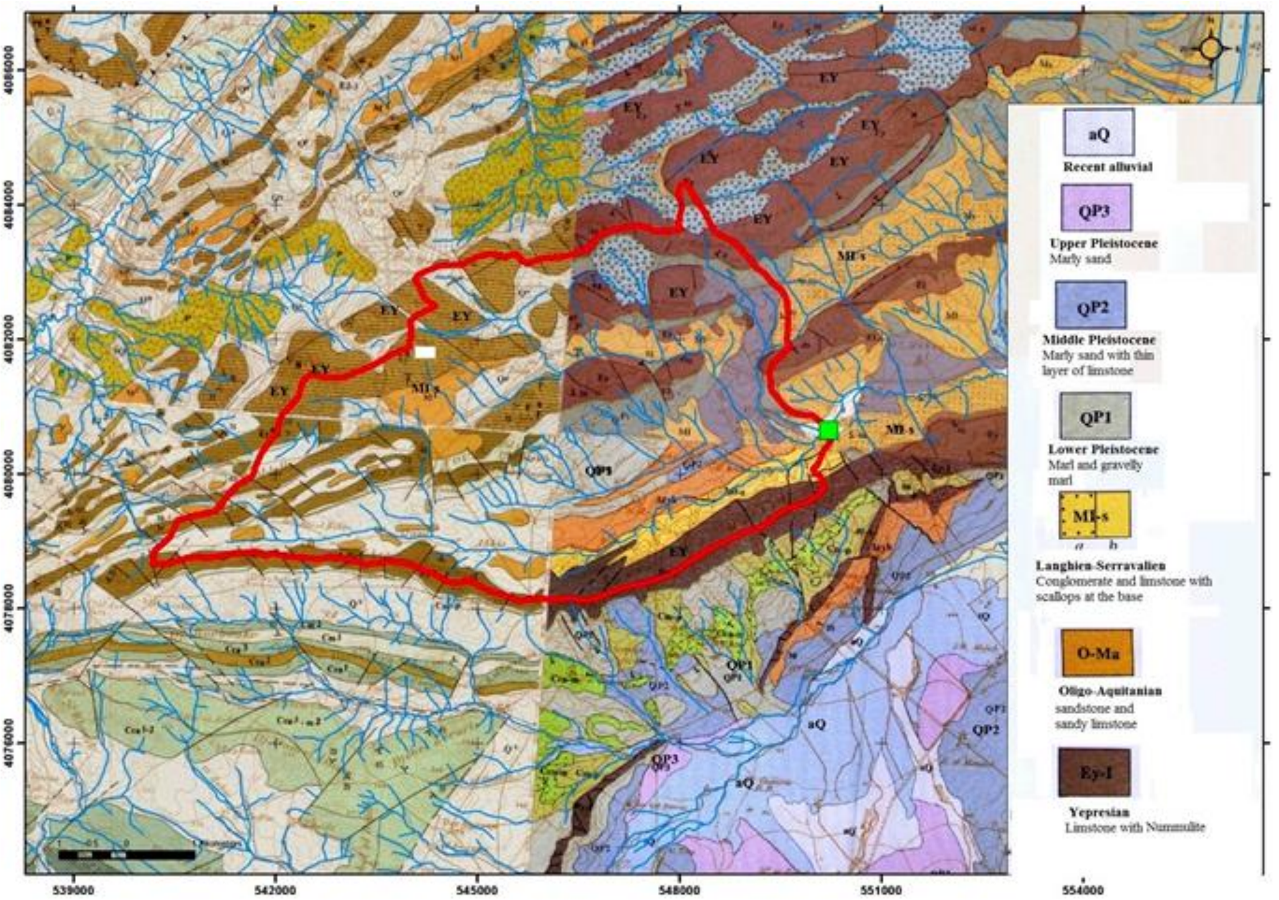

Figure 1) The geological map of the study area and Hydrology Basin of soltan Dam (limited by red line).

3-The geology of the studied area

Geological factors play a major role in designing and constructing a dam. Of the various natural factors that influence the design of dams, none are more important than the geological ones. Not only do they control the character of Formations, but they also govern the material available for construction. There exist numerous examples of projects where the conditions of the foundation were not sufficiently known and the cost of construction and treatment greatly exceeded the original budget (Ichikawa, 1999). The regional geology of the area has been studied by some researcher (e.g. Fournet, 1983; Masrouhi *et al*., 2008; Jauzein and Perthuisot, 1974). The dam and reservoir sites are located in an active tectonic region of rugged mountainous terrain with steep slopes of 25°-35° in left abutment and 45°– 55° in the right abutment.The main geological structures of the dam and reservoir areas are presented in Figure 2. The significant geological structures in this figure are the Soltan Syncline Axis. Soltan Syncline Axis with a trend of NW to SE is located at the North West of the reservoir.

4-Site geology

4.1- The medium thickness of terraces that are installed directly on foundation mainly on the left abutment is shown in Figure 3.

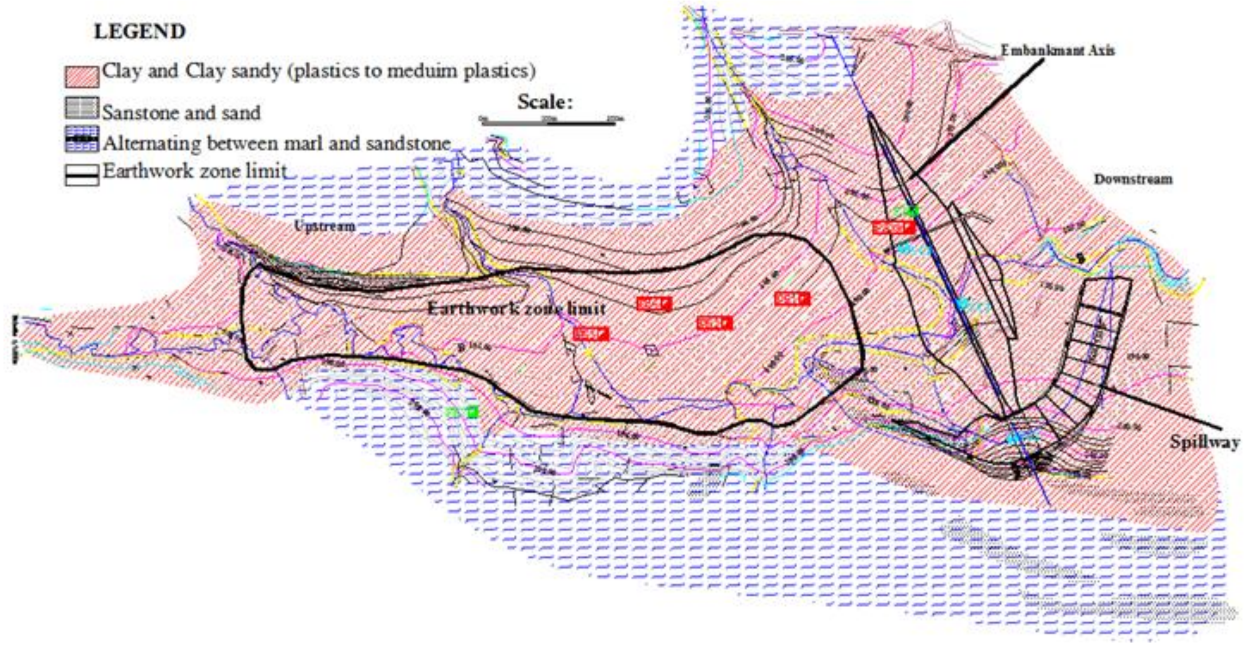

Figure 3) Geology of the reservoir area and plan of dam.

Existing materials are:

a. Quaternary deposits which essentially are formed by recent alluvial layers of small thickness resting directly on bedrock in alternating marl and sandstone.

b. Middle Miocene series (Hakima Formation) that mainly consist of sandstone visible in several places demonstrating the rigid nature of the material facing the erosion phenomenon (Fig. 4).

Figure 4) Deposit of Middle Miocene (Hakima Formation) in the reservoir area.

4.2- The right abutment

Existing materials are:

a. Quaternary deposits that essentially formed by recent alluvial layers thin and lies directly to the substratum alternating marl and sandstone.

b. On the heights there are consolidated sandstone lenses of middle Miocene age that could imply a Ypresian age for Eocene limestone facies.

4.3- The left abutment:

Existing materials are:

Quaternary deposits that formed by recent alluvial occupied by agricultural parcels, brownish clay, colorful clay with presence of pebbles, clay beige to yellowish, grayish clay and grayish marl.

5- Site investigation

During this study, geological and geotechnical exploration was carried out by two geotechnical survey;

5.1- Geotechnical survey to mechanical rig

This campaign was aimed thorough recognition of the foundation of the dam, spillway and the intake tower.Three core holes were performed:

1- Core drilling (S1) at the outcrop of sandstone at the influence of the dam pushed to 30m depth without exceeding this horizon.
2- Core drilling (S2) at the site of the spillway of pushed to 15m deep.

3- Core drilling (S3) at the foundation of the tower taking pushed to 10m deep.

5.2- Geotechnical survey with the excavator

This geotechnical surveywas aimed thorough recognition of the borrow area and ensure the availability of quantity and quality materials for the construction of a homogeneous embankment. Five exploratory wells were realized in borrow area and at the axis of the dam (PE1 to PE5) deep between 5m and 6m. This was done to recognize the mechanical parameters of the embankment of the dam.

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6- Lithostratigraphic interpretation

Lithostratigraphic correlation from North to South based on well data S2, S1 and S3 show the following facts (Figure 5):

a. Quaternary deposits: is crossed by three holes, consisting of topsoil, sandy marl clay brown to blackish, the thickness is 4m.

b. Upper Miocene deposit (Kchabta Formation):consisting of marl clay moderately moist. The thickness is 5m.

c. Middle Miocene deposit (Hakima Formation): as much consolidated sandstone. This formation was only encountered in well S1 at the river bed. The thickness is greater than 25m.

d. Lower Miocene deposit: marl clay with variegated, little wet, little consistent with the presence of pebbles millimeter to centimeter.

Based on this correlation, the proposed site will be built on a foundation laterally heterogeneous; lithologically two symmetrical abutments are formed of clay and marl, but the middle of the axis of the dam consists of consolidated sandstone. For sealing of the dam, a clay mask upstream of the dam is performed to prevent the infiltration of water in the anchor.

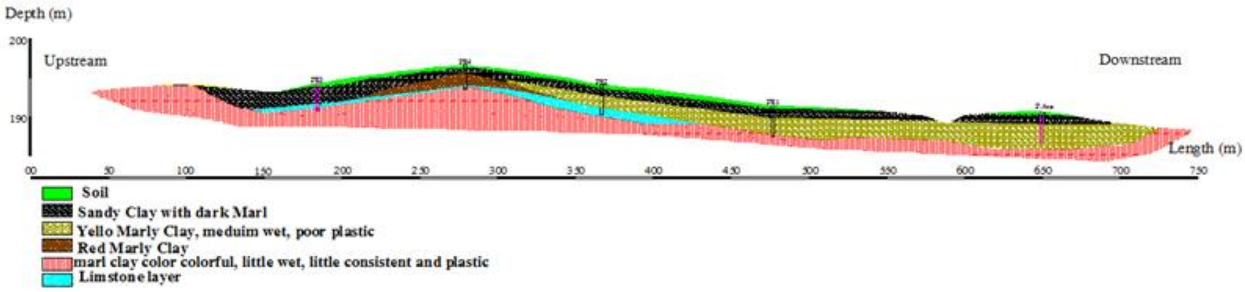

Figure 2) lithostratigraphic area along the dam's upstream to downstream.

The fault F1 has a length of 600 m in the massive limestone of Eocene is inactive and does not show signs of movement in the Quaternary deposits in the region (Fig. 6). The impact of faults particularly fault F1 is almost negligible for the lithology of the foundation that is formed of clay, marl and sandstone. And the bedrock of carbonate fractured Eocene is very deep.

7- Geotechnical interpretation

Analyzes made on some samples of the materials through which these surveys have shown at survey sample S2 at a depth between 3.5m and 3m a 60% liquid limit, a 25% plastic limit, a plasticity index of 36% and a consistency index of 1.6; according to the chart Casagrande classification of fine soils, the soil is clayey, very plastic; class soil (CH) (Table 1).

Figure 3) A geotechnical survey by rig with the presence of a fault F1 with traces on of Eocene age and embedded in the Reservoir.

Table 1) geotechnical analysis of materials of construction.

Well No.		PE1	PE1	PE2	PE3	PE1
Sample No.		1	2	2	1	1&2
Depth (m)		0,4 à 1,5	1,5 à 3,7	1,3 à 2,8	0,4 à 2,6	0,4 à 3,7
moisture Content	W (%	21			21	22
Atterberg test	WL	64	60	54	62	60
	Wp	30	21	22	24	25
	Ip	34	39	32	38	35
	Class soil	CH	CH	CH	CH	CH
Particle Analysis	P>2mm	3			9	4
	P<400µm	89			74	88
	P<80µm	57			45	54
	P<2µm	18			14	24
Proctor Normal	Wopt				27	22
	ɣ d max				1.51	1.58
Shear UU	C				41	68
	φ				30	17
Shear CD	C’					14
	φ’					30
Odometer	ei				0.809	0.731
	C_C				0.260	0.276
					Highly compressible	Highly compressible
	CS				0.018	0.028
	CV				$3.12*10^{-3}$	$3.01*10^{-3}$

These analyzes made on some samples of the materials traversed by these wells have shown at the PE1 sample at a depth between 0.4m and 1.5m a liquid limit is 64%, a 30% plastic limit, a plasticity index is 34% and a consistency index is 1.5; according to the chart Casagrande classification fine soils, the soil is clayey, very plastic; class soil (CH). Further analyzes on other well samples showed almost the same values, hence the search for another borrow pit or marriage with silty materials is essential.

Table 2) The Dam geometry.

Dam height	18m
Height normal restraint	15 m
Upstream slope	3.5/1
Downstream slope	3/1
Crest width	6 m

Indeed, some materials encountered showed some visual parameters, fine sandy. This allowed us to test the mixture of two materials at once, which has allowed us to determine the parameters of a less plastic material. This material is suitable for making the Embankment (Table 1).

7.1- Stability of the dam body

Seepage will always occur with an earth dam and will depend upon site soil conditions, the embankment itself and the depth of the water.

The embankment inclination of the slope is due to mechanical properties of the earthwork and the foundation of the structure. Analysis of slope stability with different type of stress (end of construction stability, steady state stability, rapid drawdown stability and stability in earthquake "pseudo-static) and global experience in this area will allow us set design outer slopes of the embakment (Table 2).

Table 3) Mechanical analysis for materials of construction

Geotechnical parameters of the foundation				Geotechnical parameters of the earthworks	
Clay			Sandstone	Clay	
	A Short term	A long terme	A Short term	A long term	A Short term
Friction Angle	38°	17°	25°	30°	17°
Specific weight	19.5 KN/m^2	*	23 KN/m^2	*	19.3 KN/m^2
Cohesion Cu	136 KN/m^2	*	10 KN/m^2	*	68 KN/m^2
Cohesion C’	*	26 KN/m^2	*	14KN/m^2	

7.2- Approach and results of stability calculations

The Geoslope model of Geoslope Office allows the slope stability calculation using the method of Bishop. This method consists in search of the most critical circle through systematic scanning with the change in position of the center of the circle and its radius (Tables 3 and 4) by determining the minimum value requires the calculation of several hundred to several thousands of circles.

The values of safety factors were adapted to the following scenarios:

- End of construction stability Fs> 1.5.
- Stability steady Fs> 1.5

The case of rapid emptying a safety factor is adapted to 1.2. Geotechnical laboratory analyzes performed on samples of earthworks and the foundation, have shown that the risk of breakage and possible seepage hazards arereduced to a minimum.

Table 4) Results of the stability calculations (Geoslope finalized).

	Upstream slope	Downstream slope
Short-term stability	5.13	5.38
Long-term stability	2.76	1.91
Stability in fast draining	1.51	-
Pseudo-static stability	-	1.32

8- Conclusion

The regional and local engineering geology have played a major role in the planning, design, construction and preference of the Soltan dam. The dam site and reservoir are situated in an area underlain by Eocene, Miocene sediments, and Quaternary deposits. The dam axis intersects a fairly narrow valley of clayey slopes and alluvial bottom. Although this area is tectonically active marked by decametric faults, the presence of Triassic extrusion and the possibility of existence of deep fault under the dam site in the Eocene Formation that is very deep below the dam, the geotechnical parameters of materials for the construction of this dam are good ensure its sealing and stability, its sufficient and very close to the site. All these conditions will encourage the Tunisian General Direction of dams to perform this project.

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