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Ground improvement works on large scale projects in the North of Morocco

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ABSTRACT

During the past years Morocco has launched many important industrial maritime and infrastructure works especially in the North of the country. Tanger Med, Tanger Roulier and Tanger Med 2 harbors have for instance change the face of the North Morocco offering great opportunities in the maritime transport and services. Those projects involve further developments as highways and railways facilities.

Building such a new harbor (Tanger Med 2 is a 2.8 km length quaywall) implies large ground works for the platform where for instance the equipment for the containers transport should come. Beyond the classical problems, the scale of the project and the ground structure in Tanger Med pushed the vibrocompaction technique to its limits.

Bouregreg in Rabat is another example of the development’s will and involvement in major projects. Bouregreg could be compared to building an entire new city on an old waste storage. The general soil conditions were weak and not able to sustain any classical building loading.

This paper presents the ground improvement works applied at this large project scale in the North of Morocco for the projects that have seen the Belgian company Besix involved.

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1. Introduction

Morocco has seen over the last years a series of large scale projects with ground improvement involved. A clear and determined development thinking seen over the last years lead the country to invest in important infrastructure projects. Such projects do involve ground improvement techniques in a scale not common. This article deals with the application of those techniques on projects in which the Belgian Company Besix has been involved.

Tangier is by far the most developed Moroccan city over the last years. The complex of Tanger Med will offer more than three new harbors with container terminals and Ro-Ro terminals. It will offer the opportunity for the largest container vessels in the world to lean on the Moroccan coast. The realization of the nearshore quaywalls and the working platforms required the use of vibrocompaction technique.

In another infrastructure type of project, Rabat was also the theatre of an uncommon development. The project called Bouregreg had the intention of building a whole new city in the vicinity of Rabat on a soft soil area along the Bouregreg River. Stone columns have been used as foundation technique for the project.

The vibrocompaction technique has also been used for the Mazagan project. The foundations of this luxury hotel complex development close to the city of Al Jadida were initially designed with piles. An alternative proposal with vibrocompaction has been proposed accepted and realized.

Outside of Morocco, Besix has been involved in Algeria for the project Hamma (desalination plant). The stone column technique has here been used.

2. Bouregreg

As part of the urban development of the region around Rabat, a new neighborhood is to be build between Rabat and Salé in the Bouregreg valley close to the open sea. The project AMWAJ is the second sequence of a huge development project in the Bouregreg valley. The master plan on figure 1 gives the general layout of the project. The area includes many different structures as buildings, places, canals... The final function (administrative, public, offices, stores, hotels) of each building is not yet defined.

Figure 1: Master Plan

Sector SIB is the first part of the project to be built. The site is characterized by very poor geotechnical conditions as illustrated by the typical CPT test of Figure 3. So a foundation with stone columns installed with the wet method has been adopted for the project. 52000 stones columns concentrated under the foundations of the buildings have been installed following a scheme of figure 2.

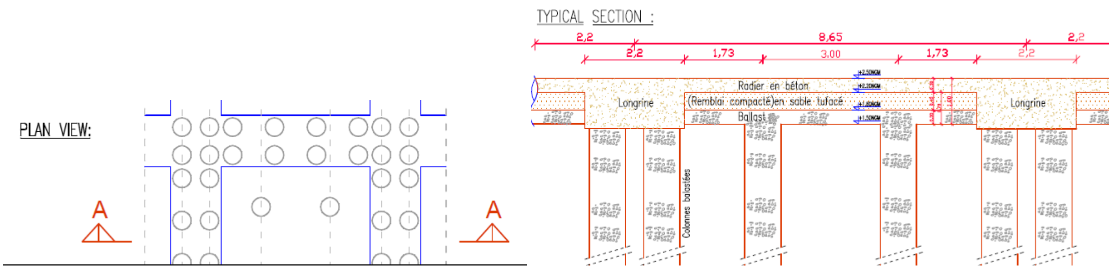


Figure 2: Plan view and typical cross section A-A

The depth has been determined based on the soil investigation CPT tests. It was possible to reach the resistant layer about 10m below ground level as show on the following typical CPT. The material used for the realization of the stone columns was a 10-80mm gravel.

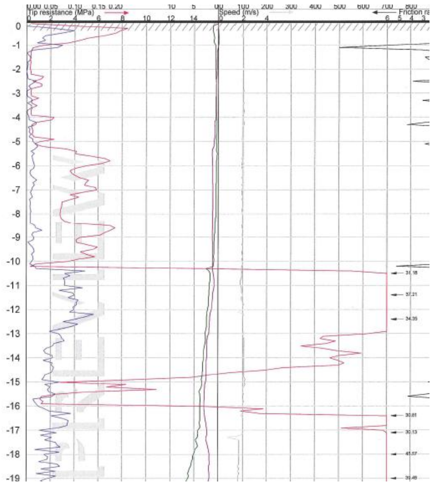


Figure 3: Typical CPT test result for the project Amwaj

Due to the presence of compressible layers underneath the bottom level of the stone columns (-15.00 m/-16.00 m), preloading has been necessary to limit the settlements to the allowed value of 50mm.

3. Mazagan

The realization of the luxury Mazagan beach resort in Morocco close to the city of Al Jadida has seen ground improvement works under the different buildings of this entertainment center.

Figure 4: Overview of the beach resort

The specifications in terms of settlement are quite stringent to make sure the luxury buildings would not suffer from settlements. The subsoil consists of relatively clean sand with 5 to 15% particles < 74 μm but the cone resistance in the upper layers was smaller than the minimum value of 6 MPa normally required for strip footings. The original design consisted of a pile foundation. As alternative, the vibrocompaction technique has been proposed. In order to validate the solution proposed and determine the distance between the compaction points, two preliminary tests have been completed. The typical execution procedure is shown on figure 5 where three grids are tested.

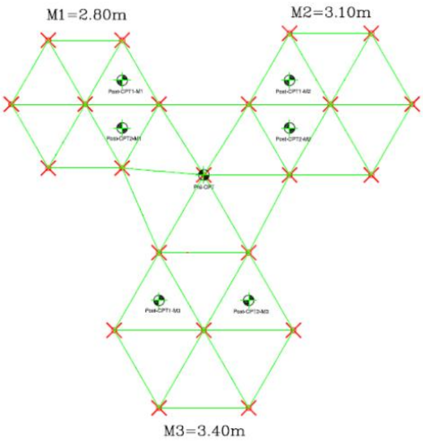


Figure 5: Preliminary test grid and post CPT's positions

During execution of the vibrocompaction a crater is formed on top of the layer as seen in figure 6. It has been decided to study the influence on the results if the crater's fill is made with sand or gravel. Therefore one test field has been realized with addition of in situ sand during compaction. For the other test field gravel has been added during compaction. The tests gave comparable results and it has been decided to do the fill with sand.

Figure 6: Crater due to execution

CPT's are used to control the works by comparing results before and after compaction. During the beginning of the execution it was not possible to reach the specified depth. Looking at the site investigations, it was thought that the probe should be able to reach a depth of 6 to 7 m. The first tests done were blocked at a depth of 3 to 4 m. This was probably due to the presence of old pavements but mainly due to an inappropriate execution method. In fact the water flushing was not sufficient. The ground is then compacted rapidly and prevents the probe to go deeper. A bigger pump allowing more flushing has been used during the further works and the predicted depths could be reached.

Figure 7: Example of the compaction points localisation

4. Tanger Med

The complex of Tanger Med consists of building three harbours in front of Gibraltar on the Moroccan coast where the Atlantic Ocean meets the Mediterranean Sea. The container terminals of Tanger Med Port 1 and Tanger Med Port 2 should accommodate the largest container vessels in the world.

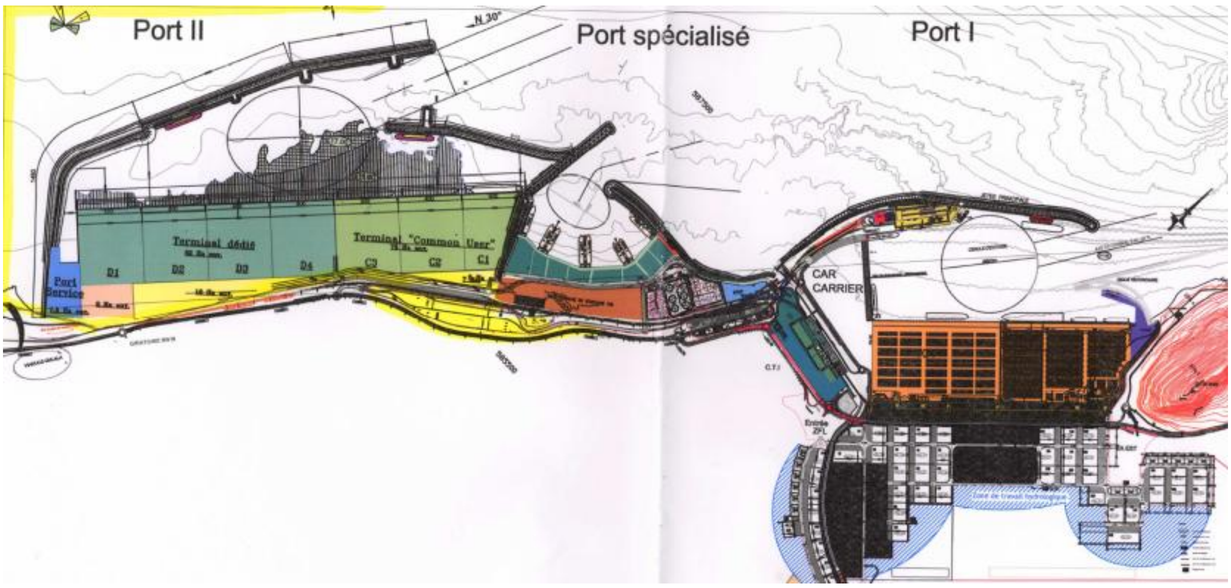


Figure 8: Complex of Tanger Med

The working platforms is made in sand backfill that is vibrocompacted to obtain a CPT cone resistance q_c = 10 MPa. More than 2 million square meters are to be compacted. The details of the realisation are not discussed here. The intention is to focus on a more specific ground improvement problem encountered in some areas for the foundation of the quaywall at Tanger Med1. The main quaywall is made of concrete prefab blocks on top of each other from level -18mZH/-16mZH up to +4.5 mZH.

Such a gravity quaywall generates important foundation stresses which require a strong foundation layer especially in a high seismicity region as Tanger. In general the existing subsoil in the vicinity of the harbors is very stiff to rock. The rock is mainly composed of mudstone and sandstone. It is typical in the region to find in some areas the rock dug by ancient rivers coming from the hills on land to the sea. Tanger Med 1 quaywall was thought at first to be build with the bedrock at foundation level but additional site investigations have shown the bedrock level as seen on figure 9. Three areas with soft soil under the foundation level have been found.

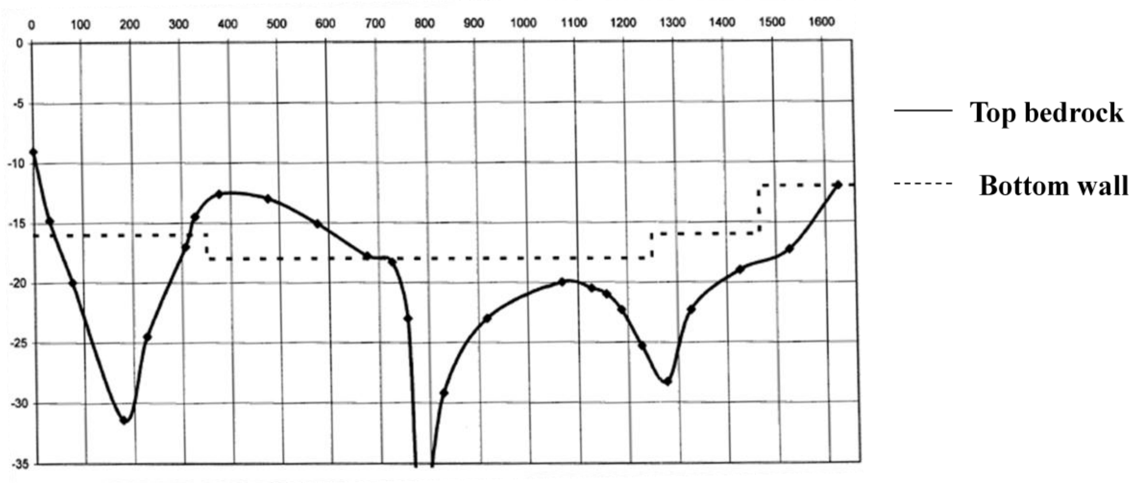


Figure 9: bedrock level along TM1 quaywall

Since such a soft soil would not be able to sustain the stresses at the foundation location, the following solution had to be adapted. The soft layers have been removed by dredging and replaced by stones (max.200mm) until foundation level. To avoid major settlements and differential settlements of this stone layer vibrocompaction has been applied.

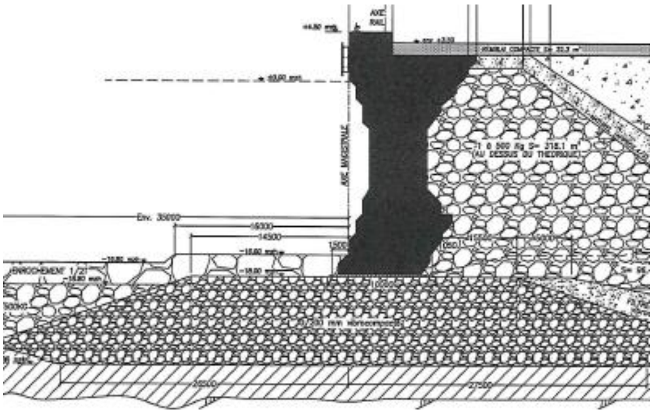


Figure 10: Typical cross section + foundation gravel vibrocompacted

A large vibro probe has been used in Tanger Med 1 to be able first to go to the required depth and second to vibrocompact gravel with important stones of 200mm. The sieve analysis from this gravel was situated on the limit of the applicability of the vibro technique. The intermediate distance between the compaction points has been chosen based on available experience (from the extension of the Monaco harbour) on similar works with large depths together with a large thickness of the fill to be compacted. A triangular pattern of 3.10 m has been adopted.

To control the works, the realization of CPT's was not possible due to the size of the stones. Therefore, the method adapted is to measure the settlements on the top of the fill. It was expected to have a relative density Dr of the fill of approx. 45 % for the stones dropped in the water. This Dr is increased to 75 % due to the vibrocompaction. This leads to approx 7 to 8% of settlement.

The differential settlements were avoided and the quaywall realized with the same foundation level for parts on bedrock or on a former loose layer replaced by vibrocompacted stones.

5. Hamma

Hamma Water Desalination Spa (HWD) has awarded the construction of a Desalination Plant to provide potable water to the city of Algiers, Algeria. The facility is located close to the port of Algiers, on the site named '' les sablettes'', district of Hussein Dey, municipality of Belouizdad. Hamma seawater desalination facility will produce 200.00 m³/day of potable water for municipal distribution. The main features of the plant are: offshore, undersea screened seawater intake, onshore seawater pumping station, pre-treatment of raw seawater, reverse osmosis desalting, remineralization for potable water delivery, product storage and delivery. The general layout with the different structures is given on the figure 11.

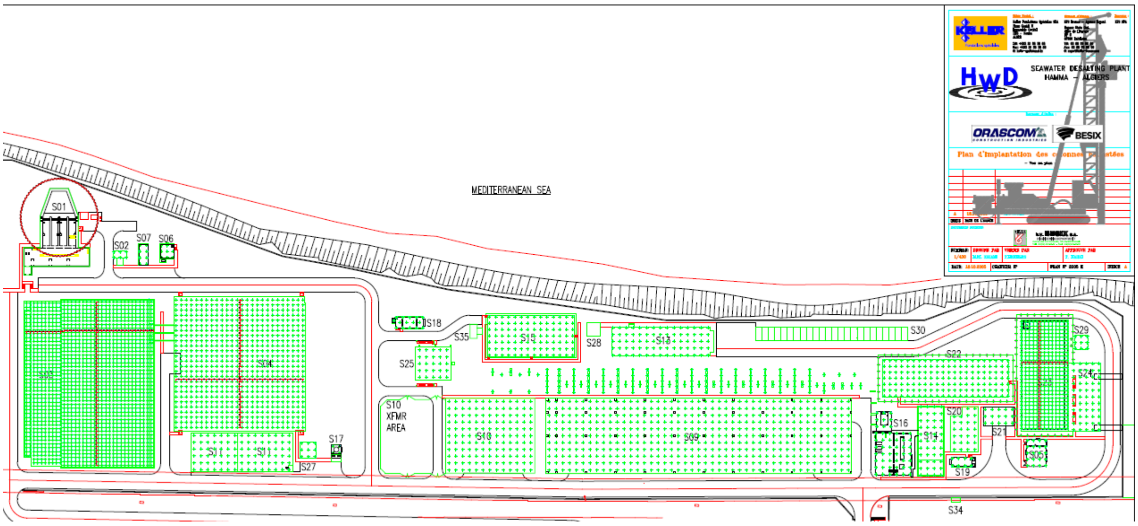
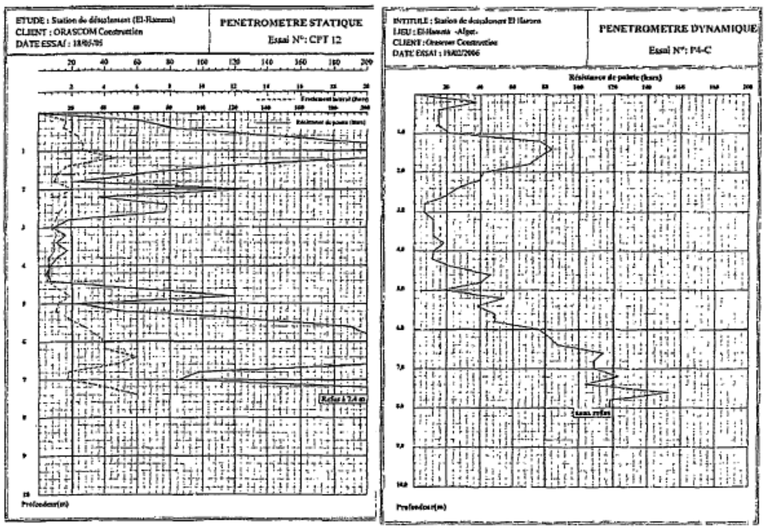


Figure 11: General layout and stone columns localisation

From the site investigation (CPT and dynamic penetrometer on figure 12) it has been deduced that the upper layers consists of loose fills and soft layers with a thickness of about 5m. So a ground improvement was necessary for the foundations of the different structures. Seeing the depth needed to reach the resistant layer, stone columns installed according to the wet method were chosen. The design has been kept simple. The number of stone columns and intermediate distance is determined taking the weight of the structure divided by the capacity of one column limited to 350 kN whithout doing a trial test before the works.



CPT Dynamic penetrometer

Figure 12: typical CPT and dynamic penetrometer result

The coarse material used for the stone columns did not allow the CPT tests for the control. A control on the energy comsumption during the placing of the stone columns is done but also loading tests have been performed. Two different procedures were used for the loading tests: one following the Keller procedure and one following the Terracon. The two procedures are shown on figure 13. The Keller procedure consists of loading the column at the top by means of a steel plate having the same diameter as the stone column and the Terracon procedure consists of loading the column and some gound around the column.

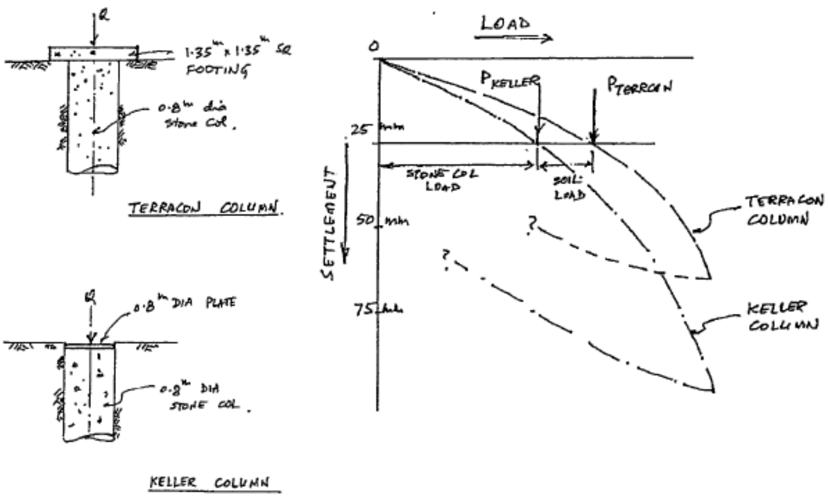


Figure 13: Plate load test Keller and Terracon procedure

Appropriate acceptance criteria had to be defined for the interpretation of the results of the loading tests realized according to the two methods.

6. Conclusion

The examples given above clearly illustrate the applicability of ground improvement techniques for different problems and applications. It should however be clear that every application of ground improvement necessitates a detailed study and preparation of the execution and a specific control. Only in this way the quality of the realized ground improvement works can be guaranteed.