La Lettre

Terrasol in Africa

Special Edition – August 2017

terrasol

setec

Editorial

For several years TERRASOL has generated around 25% of its turnover on foreign projects, whether for local, international or French customers, with various types of geotechnical assignments including assistance to project owners, project management, assistance to contractors, etc. And Africa alone accounts for almost half of our international business, evidence that we know the continent well.

Africa is currently experiencing fast growth and clearly has substantial potential: TERRASOL intends to take advantage of its long experience of this region and its knowledge of the local markets to further strengthen its presence over the next few years as part of the global development of its international activities, whether directly for its customers, or within the integrated teams of the Setec group, or in consortia with local or international partners.

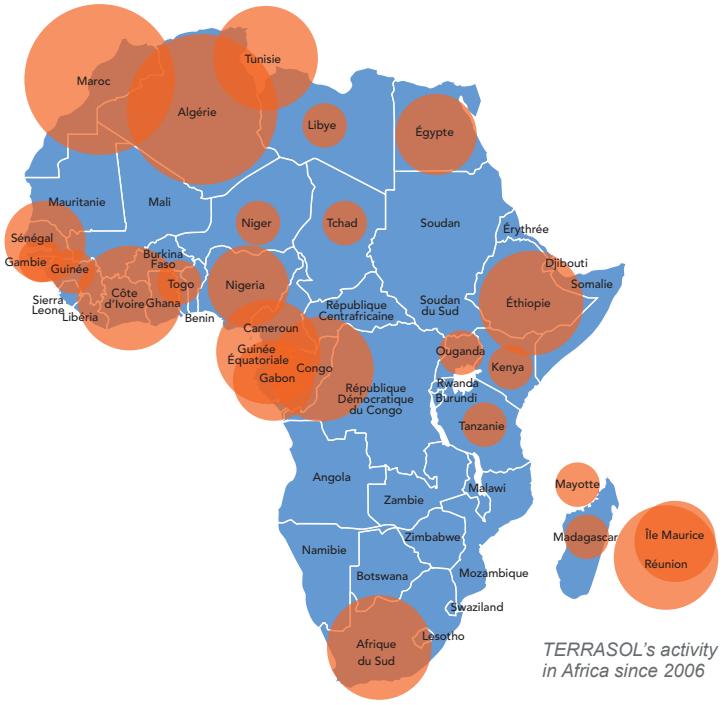
We have consequently chosen to describe for you our achievements and our ambitions in Africa in this special issue of our Terrasol Newsletter.

We hope that you enjoy reading it.

V. Bernhardt

Terrasol and the African continent

TERRASOL is proud of its long history with the African continent, and we wanted to use this special issue of the TERRASOL Newsletter to illustrate and highlight it.



TERRASOL's activity in Africa since 2006

The first involvement by TERRASOL in Africa dates back practically to the establishment of the company in 1979: TERRASOL experts were very soon called upon for assignments on emblematic projects that have contributed greatly to the development of this part of the world, including the "Transgabonais" Railway, motorways in Morocco, phosphates in Tunisia, etc.

Since the early 2000s, we have strengthened our local presence: establishment of TERRASOL Tunisia, large projects in Algeria, installation in Morocco, collaboration with the SETEC group companies over the whole area, distribution of our software, training courses, etc.

We have of course taken part in many road and engineering structure projects: East-West motorway in Algeria for CRCC, Brazzaville Corniche road with SETEC TPI and SGI, bridge over the Gambia River with SETEC TPI and STUDI, Bouregreg bridge in Morocco with SETEC TPI, Riviera-Marcory viaduct for BOUYGUES TP in Ivory Coast, etc.).

Training session on geotechnical calculation for excavations in urban environment and slopes reinforcement, Rabat (Morocco), April 2017

We have also increased our volume of services in a number of other sectors:

- transport: railway projects in Algeria, South Africa, or Senegal with the Dakar train (TER), tramway projects in Morocco and Algeria, …
- energy and industry: wind farms, dams, power plants, oil & gas and mining projects, industrial facilities, …
- harbours, buildings, natural hazards, ...

This special issue of our TERRASOL Newsletter presents a selection of these projects, and the map above shows the locations of all our assignments in Africa over the last 10 years.

In addition to our engineering activity, we also distribute our various geotechnical calculation software products in Africa, and regularly run training sessions on geotechnical modelling: application of standards, determination of parameters, use of the software, output analysis, etc. We also take part in conferences on the continent, through scientific presentations and exhibition stands, to strengthen our discussions and our links with the local stakeholders.

J. Drivet and V. Bernhardt

Brazzaville Corniche

Congo-Brazzaville

Photo credit: CRBC

The project consists in building a road link alongside the river Congo to improve access to downtown Brazzaville. The Congo government awarded the construction contract to the Chinese company CRBC. The SETEC TPI / SGI consortium was entrusted with the control of the project, and asked TERRASOL to deal with the geotechnical aspects: revision and adaptation of the geotechnical synthesis, checking the contractor's calculation reports for the foundation aspects, geotechnical stability, soil/structure interaction, geotechnical recalculations using Foxta and Talren software, signing off the contractor's documents (procedures, calculation reports, summaries), assistance to SGI's local control team. The project, 2,5 km long, had to overcome a number of geotechnical difficulties:

- alluvial environment of the river banks necessitating soil reinforcement,
- cable-stayed structure with heavy loads, necessitating deep foundations of large diameter,
- presence of compressible and changing materials.

The works included a major cable-stayed bridge, and embankments on compressible soils.

All the structures have been founded on deep piles of large diameter because of the poor characteristics of the superficial materials and the need to account for strong horizontal loads. The embankment sections have necessitated the use of retaining walls on reinforced soil (stone columns), and the high embankments the use of rigid inclusions in order to meet the stability and deformation criteria. The project also involved slopes protection against erosion and a hydraulic structure 200 m long below a high embankment.

Construction lasted from 2013 to 2015 and the project was inaugurated on February 5th 2016.

J. Drivet

Riviera – Marcory viaduct

Ivory Coast

For Ivory Coast, the construction of the third bridge in Abidjan was one of the most symbolic projects of the 21st century. It was finished in 2014. This 1,500 m long viaduct with 30 piers crosses over the large Ebrié lagoon and, as such, forms part of the global project linking the Marcory and Riviera districts. The project was carried out by BOUYGUES TRAVAUX PUBLICS and will be operated by the SOCOPRIM concession-holding company within the framework of a construction/concession contract. On request from BOUYGUES, TERRASOL became involved early on in the project for the definition of the geotechnical surveys and an assignment to monitor the soil investigations carried out on site in November 2011. These works were followed by the definition and analysis of static pile loading tests as well as by the preliminary and detailed design.

Given the depth of the boreholes that exceeded 80 m and the difficulties inherent in a lagoon environment, the soil testing campaign proved to be particularly complex. As a result, it was necessary to modify the initial programme which provided for at least one piezocone sounding per support and replace them with destructive and pressuremeter testing. The viaduct is founded on 2 m diameter piles bored using hollow augers. These piles are more than 80 m deep in the central part of the lagoon in order to be embedded into a layer of compact sand laying under a considerable thickness of muddy clay deposits. This compact layer also includes a layer of deep clay with a lesser bearing capacity that required a precise definition of its stratigraphy, a definition made difficult by the erratic sedimentation conditions and the problems encountered during the investigations.

Pile tests using an Osterberg cells were carried out to confirm the proposed assumptions, particularly insofar as the pile tip bearing capacity is concerned. This highly depends on an execution methodology that includes pile tip injections to recompress the soil.

B. Simon

Bouregreg viaduct foundations

Morocco

Photo credit: Olivier Panier des Touches

ADM (Autoroutes du Maroc) had for a long time wished to realize a cable-stayed bridge for the Kingdom of Morocco. After a first draft planed over the Oued Sebou, close to Fès which reached the stage of pre-detailed draft with a team composed of SETEC TPI, MAROC SETEC, the architect Hervé Vadon (STRATES) and TERRASOL, a second opportunity occurred on the highway bypassing Rabat as an alternative to classical viaduct with concrete segments. The same team presented an ambitious project with exceptional dimensions: total length of 952 m with a central span of 375 m, 100 m deck height and two main piles of 200 m height with an architecture inspired by the Arts of Islam.

The geological and geotechnical context is characterized by the presence of metamorphic ground (Carboniferous shales) covered by sedimentary formations (calcarenites, limestones, mudstones). The quality of the soils below the main pillars led to favor a supporting solution with shallow foundations, however with impressive dimensions (25x30m, about the size of a tennis court).

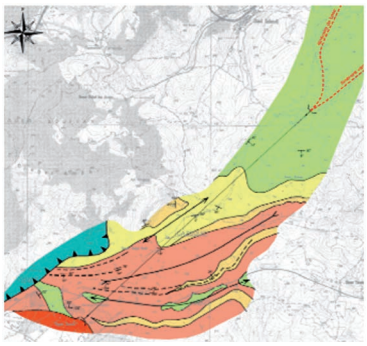
TERRASOL carried out various missions between 2008 and 2014: definition and follow-up of soil investigations, foundations pre-design, geotechnical assistance during works (earthworks, foundations), and control of detailed design. The contractor in charge of the works was a Chinese consortium (COVEC and MBEC).

The bridge named "Mohammed VI", presently the longest cable-stayed bridge in Africa, was inaugurated on July 7, 2016 by the King of Morocco.

H. Le Bissonnais and J. Marlinge

Ganntas tunnel

Algeria



In the context of its contract with CCECC, contractor in charge of the construction works for the doubling of the railway track with alignment adjustment between the El Affroun and Khemis Miliana stations (east of Algiers), TERRASOL produced the Ganntas tunnel detailed design. This is a 6.7 km twin-tube tunnel through Djebel Ganntas, peaking at about 800 m, between Oued Zebboudj to the north-east and Ain Soltane to the south-west. It has a section of 41 m^2 and a maximum cover depth of 390 m. It was excavated using the traditional method.

Even before the start of works, TERRASOL was mobilised to update the longitudinal profile, given the geological uncertainties revealed during the preliminary design phase. TERRASOL performed a parametric analysis using a finite element approach (CESAR) to approximate the behaviour of the surrounding rock according to the geological context (variation of the layers encountered, depth), and the excavation methods/phases. On completion of this study, TERRASOL compiled a catalogue of support types to be used according to the observations made during excavation works.

Works monitoring, with geological recording, convergence measurements as well as soil testing on progress, enabled to adjust the calculation assumptions and to adapt the methods in the fault area expected in the southern part of the tunnel.

By August 2017, works had progressed to 98% of the length: there are 114 m to go on the North part and 170 m on the South part before connection is reached.

M. Yahia-Aissa, P. Brossier and F. Binet

Gautrain project

South Africa

TERRASOL was entrusted by BOUYGUES TP with the geotechnical aspects of one section of the Gautrain project (80 km of a new railway line in South Africa), between 2006 and 2009. This railway line was inaugurated on June 8th 2010.

Along this section (6 km long), heavily karstified dolomites are overlain with extremely variable altered layers with a thickness ranging from 0 to 80 m. Sinkholes of about tens meters in diameter occur regularly and thus represent the most unfavorable load case for the design of the viaducts foundations and of the earthworks.

The challenge was to design these structures with respect to the « design sinkhole event », which has been defined, after a risk analysis, to be a sinkhole with a diameter of 15 m; a load case which is not accidental considering the high frequency of the sinkhole events, while the project specifications include strong operational and security requirements.

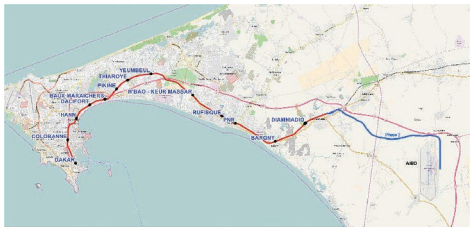
The structures design allowed proposing various technical construction solutions considering the scale of the soil heterogeneity: for the viaducts, possible solutions ranged from superficial footings to shafts 7 m in diameter and 50 m deep; for the current section, prestressed concrete beams 180 m long supporting the track. These structures were combined with a whole variety of soil improvement techniques, water management solutions and monitoring equipment.

The works phase confirmed from the very beginning the extremely random geology of these dolomites and of the overlaying altered layer.

A. Bergère

Dakar Regional Express Railway (TER)

Senegal



The construction of the Dakar regional express railway line is part of the Senegal economic development plan. Its two main functions are to provide services for the Dakar suburbs, replacing the existing “Petit Train de Banlieue” (PTB), and a connection with Blaise Diagne International Airport (AIBD).

The Dakar TER project is divided into two phases. Phase 1 covers the development and widening of the existing infrastructure between Dakar and Diamniadio stations (36 km), and phase 2 covers the construction of a new line between Diamniadio station and the AIBD airport (19 km).

EIFFAGE entrusted the SETEC group with the project studies and with technical assistance during the works phase. Within the SETEC project teams, TERRASOL is responsible for the geotechnical analysis of the foundations of the structures along the whole of the alignment. Around a hundred structures are concerned: road bridges, railway bridges and footbridges.

The geology varies greatly along the alignment. In general, the project can be divided into three distinct geological sectors:

- Sector 1: 21 km at the Dakar end, comprising dune sands between 15 and 40 m thick;
- Sector 2: around 20 km in the middle part, with marly and marly-limestone layers, overlain by a clayey layer;
- Sector 3: the last 14 km at the airport end, with sandstones, clays and laterite deposits.

One of the major challenges of the project is its schedule, as the opening of the line is planned for 14 January 2019.

S. Delattre and K. V. Nguyen

Tabellout dam

Algeria

The ALGERIAN NATIONAL DAMS and TRANSFERS AGENCY (ANBT) has awarded to the GEIE/RAZEL/CMC/RAVENA consortium the contract for the Tabbelout dam project construction near the city of Texenna, about 70 km south of the Jijel wilaya (district), in Algeria.

The project as a whole comprises the construction of a roller-compacted concrete (RCC) dam 366 m long and 112 m high (reservoir capacity 294 hm3) and a transfer tunnel 4.3 m in diameter (finished diameter 3.5 m) 13 km long, for which a tunnel boring machine (TBM) is being used.

From the start of the works, in March 2010, a number of geotechnical problems have been identified, in particular a landslide on the left bank of the dam, but also extensive degradation of the tunnel lining segments with the development of a collapse, and blocking of the TBM for more than 6 months.

At the request of the consortium, in July 2012 TERRASOL carried out an expert assessment of the landslide of the left bank of the dam, with a full review of the risks of embankment and earthworks instability for the whole of the site.

Given the complexity of the geological context and the insufficiency of geotechnical data, TERRASOL is also providing technical assistance and consultancy services to the consortium on the various geotechnical aspects, including for prediction of the behaviour of the massif during the tunnel excavation, and in particular the behaviour of the Numidian clays and the zones of toppling suspected of being the source of the problems encountered.

M. Yahia-Aissa and A. Guilloux

Ashegoda Wind Farm Project

Ethiopia

Photo credit: Ashegoda Wind Farm Project – VERGNET

Under an EPC contract, VERGNET has built the “Ashegoda Wind Farm” in Ethiopia, with a total installed power of 120 MW generated by 84 wind turbines.

TERRASOL was contracted by VERGNET to carry out the geotechnical studies for the foundations of the wind turbines, including the design of the anchoring micropiles for the guy wires of the GEV HP turbines, which are subjected to cyclically varying tensile loads.

Specifically for these micropiles, TERRASOL developed a design approach based on the cyclic stability diagram concept. The approach consists in plotting a stability domain of the cyclic loads in a plane defined by their mean component on the abscissa and their cyclic component on the ordinate. This domain, defined using the properties of the micropile and the soil, is then compared with the cyclic loads to which the foundation is subjected.

TERRASOL also defined and supervised the on-site geotechnical soil-testing campaign, supervised and analysed the tensile tests on the micropiles, and followed-up the construction of the foundations of the wind turbines.

The first 30 wind turbines of the South zone were commissioned in December 2011 and the 54 turbines of the North zone in 2013.

B. Madinier

Djermaya photovoltaic plant

Chad

Chad is a country where the climatic conditions are particularly favourable for the operation of solar power plants.

At the request of the COMPAGNIE DES ÉNERGIES NOUVELLES and a consortium of developers, TERRASOL has conducted a preliminary geotechnical study for a solar photovoltaic power plant project at Djermaya (about 30 km north of N’Djamena). SETEC HYDRATEC also worked in parallel on a study of the hydraulic conditions of the project.

The 100 ha site is a rough square with 1 kilometre side, partially located in a flood-prone area. The project is planned to comprise 200,000 solar panels (72-cell each) totalling 60 MW installed power. It will use the single-axis solar tracker technology.

After a site visit, the TERRASOL assignment consisted in defining and following up a geotechnical investigation programme. The programme was implemented by a Chad firm (LAGEMOT), which TERRASOL placed in direct contact with the plant operator consortium.

The geotechnical study enabled to define the foundation conditions for the steerable panels (driven piles), the earthworks conditions (fill re-use, compacting, general levelling) and the site hydraulics/drainage principles.

J. Drivet

Coastal reinforcement in Cape Lopez

Gabon

Photo credit: Total Gabon

Cape Lopez is the point of Mandji island, Gabon, extending the furthest into the Atlantic Ocean. It consists of mainly-sandy delta deposits, underlain by a very dense layer located at a depth of more than twenty metres. The main ocean currents flow around the cape from West to East, carrying sediments eroded from the West coast towards the East coast. When they enter Princes' Bay, the currents are protected by the cape and slow down. Very fine sands, of very uniform grain size, are then deposited along the East coast, resulting in its growth.

Submarine landslides of varying magnitudes (up to several million cubic metres) occur frequently on the East coast. The slides take place along very gentle slopes (less than 5°).

A possible explanation of these recurrent landslides is that the relative densities of the local sands are lower than the critical densities. This makes them very sensitive to the generation of excess pore pressures, which may be refered to as "lateral spreading" phenomenon.

Under the action of growth or of any other load generating excess pore pressures, the sands lose their shear strength and flow.

In this context, TERRASOL has worked with TOTAL SA and TOTAL GABON to reinforce the East coast, where erosion by recurring landslides is threatening the oil terminal located on Cape Lopez.

C. Babin, K.V. Nguyen and M. Blanchet

Vridi Energy Production Plant – CIPREL IV

Ivory Coast

The thermal power plant operated by the COMPAGNIE IVOIRIENNE de PRODUCTION d'ÉLECTRICITÉ (CIPREL) is located to the south-east of Abidjan, in the region of the Vridi Canal which links Ebrié Lagoon to the Atlantic Ocean. CEGELEC was chosen by CIPREL for the turnkey construction of a fourth-unit extension of the existing plant, enabling the production capacity to be increased by an additional 111 MW.

Photo credit: CEGELEC

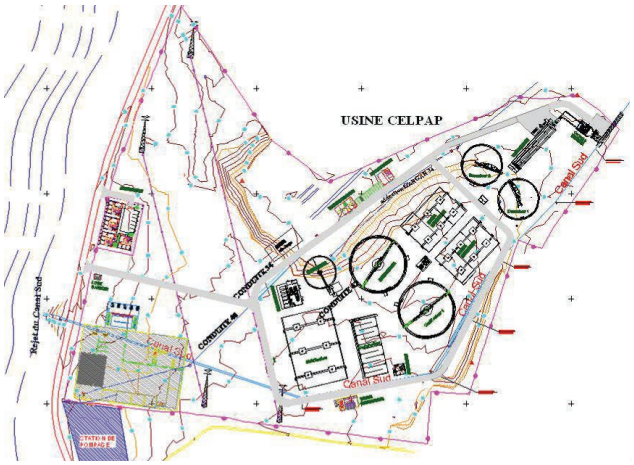
At the request of SETEC ENERGY SOLUTIONS, which provides CEGELEC with technical assistance for aspects related to civil engineering, TERRASOL was called upon for the (G2) project geotechnical studies. TERRASOL intervened first of all with the definition of the geotechnical campaign and a mission to follow-up this campaign in June and August 2012. The soil-testing campaign was marked by the setting up of Cross-Hole tests, the conducting of which was a major first in Ivory Coast. Analysis of the tests enabled the risk of liquefaction due to the turbine vibration phenomenon to be ruled out.

In a second phase, TERRASOL designed the foundations of the various structures (turbine, steel structure, chimney, buildings, etc) adapting the techniques used on a case-by-case basis in accordance with the loading levels and strict differential settlement criteria (shallow raft foundations, micropiles, raft foundation combined with shells executed by cutting, etc).

C. Bernuy

Mostaganem treatment plant

Algeria



As part of the project of the Mostaganem urban wastewater treatment plant in Algeria (capacity 130,000 population equivalent) TERRASOL conducted for BUTEC a geotechnical preliminary design study of the project area (La Salamandre – Mostaganem) to define the foundations system required for the future structures, and also to clarify the construction specifications to take into account, in particular for the site's circulation areas and parking facilities.

Following the definition of the specific survey programme, TERRASOL supervised the geotechnical testing campaign (executed by a local contractor), analysed the data, and drew up the study report.

In close cooperation with the BUTEC structural engineers, TERRASOL proposed a recalculation of the structures levels and specific measures to limit the risk of under-pressures in the event of a rise in the water table.

TERRASOL also assisted BUTEC during the earthworks to ensure conformity of site observations with predictions and to provide the additional clarifications requested by the project owner, in particular with regard to problems of liquefaction of the bearing layers in the case of seismic loading, and to the potential risk of water table rise in the project area.

M. Yahia-Aissa

Rabat river cliff

Morocco

As part of the works to reinforce the river cliff in Rabat, the consortium formed by the consultants TERRASOL and INGEAB was commissioned by the owner RABAT RÉGION AMÉNAGEMENT (RRA) to conduct a study of phase 1 of the cliff reinforcement.

With an average height of 20 m, the cliff fits into a lithological framework formed by gravelly clays in the uppermost part underlain by a sandstone slab supported by a friable calcarenite (shell sandstone sand) subject to pronounced erosion.

Situated alongside the mouth of the Bouregreg river, the cliff presents several signs of instability, including a network of cracks forming unstable wedges and metre-scale undercuts of the sandstone slab.

Because of the owner's requirement for maximum preservation of the historical charm of the cliff and consequent avoidance of systematic use of shotcrete for its reinforcement, the selected treatment consisted in building a soil-nailed wall to reinforce the loose and uppermost part of the cliff, using shotcrete the same colour as the cliff, then reinforcement by nails 8 to 12 m long associated with a plastic-coated galvanised mesh laid to secure the cracked rock blocks and the potentially unstable wedges. It should be noted that the reinforcement and grid-laying operations necessitated acrobatic works and lightweight drilling equipment for work on the cliff face.

Regular site visits were conducted by TERRASOL's Moroccan representative. They covered the follow-up of the remedial operations, the follow-up and validation of the nails pull-out tests, and technical advices on specific adjustments.

T. El Malki and F. Binet

Securing the village of Korbous

Tunisia

The village of Korbous on the shores of the bay of Tunis, wedged between the Mediterranean sea and the cliffs of Cap Bon, is famous for its hot springs and its landscapes. Blocks of rock have been known to fall from the sandstone cliffs that overlook the village, but the development of tourism convinced the provincial authority of the need to secure the site.

TERRASOL signed-off on studies (trajectometric studies, design of anchors, etc.) in order to optimise the project, and contributed to the follow-up of the works execution (anchors pull-out tests, conformity of works execution to the supplier's specifications):

- passive solutions (class 9 dynamic screens) in sectors where there is room to put them into effect, suspended grid;
- active solutions (anchors, buttresses, plated meshes, wrapping, etc.) for cliff sectors directly overlooking buildings or streets, and for blocks exceeding the capacities of the dynamic screens.

The layout of the site (proximity of the cliff, variability of the issues at stake and of block volumes), the influence of broad splitting of fall trajectories and the occupancy of the site (rock shelters) have resulted in the selection of a wide diversity of technical solutions.

F. Binet

Moroccan motorways – Geotechnical expertises

Morocco

In mid-2011, AUTOROUTES DU MAROC (ADM) entrusted TERRASOL with a standing offer agreement over a period of several years for geotechnical expertises on the Moroccan motorway network. The agreement (renewed in 2015) also includes structural and hydraulic expertises, entrusted to MAROC SETEC.

We thus carry out regular missions on site, mainly on sections which are in service, concerning aspects as varied as:

- Embankments which have been unstable for around ten years, or showing worsening cracking after only a few months of operation;
- Rocky cutting slopes with problems of protection against falling blocks or wider instabilities;
- Cutting slopes in loose soils, often evolving clays and marls, on heights up to one hundred metres;
- Problems on underpasses or viaduct abutments;
- Pavement cracking.

These operations cover the whole national motorway network, from North to South (Tangiers, Rabat – Fès – Oujda, Marrakech – Agadir, etc) and provide an opportunity to apply our know-how on the various aspects of motorways infrastructure damage and repair works.

A. Guilloux

Casablanca Finance City tower

Morocco

In the context of the construction of the Casablanca Finance City tower, BYMARO, the contractor in charge of the works, has contracted TERRASOL:

- to conduct geotechnical detailed studies related to the design of the temporary retaining structures, the drainage system, and the soil-structure interaction aspects,
- for the follow-up of the works.

The project, located on the site of the former Anfa airport (Casablanca), consists of a 25-floor tower with six underground parking levels (down to 20 m deep). The geology consists of loose formations some ten metres thick, underlain by a schist substratum. The phreatic level is expected at 8 m below the groundlevel. The temporary retaining walls consist of:

- a soil-nailed wall for the upper part, its stability checked with Talren calculations,
- a wall with rock bolts for the lower part, its stability checked with block calculations.

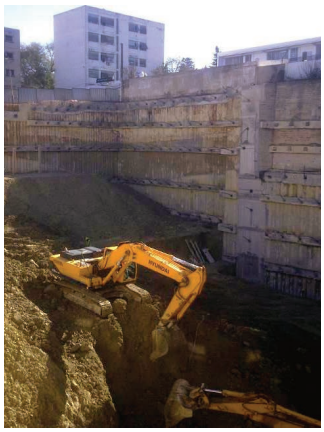
Photo credit: CFC © BYMARO

We also carried out the studies of the tower settlements, and of the control system for water under-pressures. The follow-up of the works on site was carried out by our Morocco-based geotechnician. It included the follow-up of the excavation operations: validation of the soil nails pull-out tests, checks during excavation, fractures survey, advice on project ad-hoc adjustments.

T. El Malki, J-F. Bruchon and J. Marlinge

AGB Bank complex at Château-Neuf

Algeria



As part of the construction of the new headquarters of the AGB Bank complex at Château-Neuf in the Algiers suburbs, TERRASOL carried out, on behalf of SSHI (operation project manager), the conception and design of the retaining wall for the project excavation (one basement level and three parking levels) .

Following the drawing up of a geotechnical synthesis report and the definition of the geotechnical model and assumptions, TERRASOL proceeded with the justification of the retaining wall, consisting of an anchored special soldier-pile wall.

In view of the many adjacent structures, including an underpass approach on the main road, TERRASOL made many adjustments, in particular of the anchor inclinations and lengths.

TERRASOL also examined the stability of the adjacent retaining wall and proposed specific reinforcement by micro-piles.

Lastly, TERRASOL assisted the Project Manager with the production of the tender documents and the technical analysis of the tenders. On this point, TERRASOL confirmed that the alternative system consisting of an anchored secant piles retaining wall, proposed by one of the bidders, was also acceptable; this alternative solution was finally the one selected for the execution of the works.

M. Yahia-Aissa

“Little Manhattan” building

Madagascar

The “Little Manhattan” project consists of the construction of a 21-storey tower in the Ivandry district of Antananarivo, Madagascar. It is a residential building with three parking levels, its architecture inspired by the New-York buildings of the 1950s. The project was initiated by DREAMSLAND and the architects MCA RAHARISON & ASSOCIATES, in partnership with the ASSIST group.

TERRASOL worked on this project in 2014 and 2015, at the request of engineering firm LAGEOTEC, in the context of a geotechnical design assignment covering the design of the deep foundations of the building and the check of the stability of the project.

The following geological layers are encountered under the future structure:

- a surface lateritic layer of sandy brown silt, of variable thickness, with rocky fractured blocks;
- then an altered rock layer 10 to 15 m thick;
- and below, rocks that are sufficiently alteration-resistant to have remained as relief when the erosion surface was formed.

TERRASOL carried out the following steps:

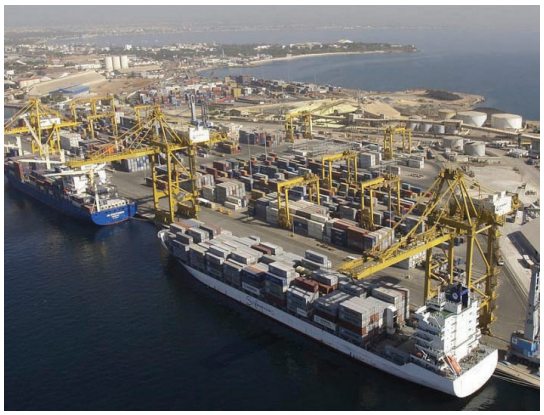
- synthesis of available geotechnical data and determination of the geotechnical parameters;
- pile design using the Foxta software;
- stability calculations using the Talren software;
- recommendation of construction specifications.

H. Le Bissonnais

Dakar Harbour

Senegal

TERRASOL has been working for many years on port and offshore infrastructure projects on behalf of EIFFAGE SÉNÉGAL and its subcontractors, upgrading and expanding the Port Autonome de Dakar.



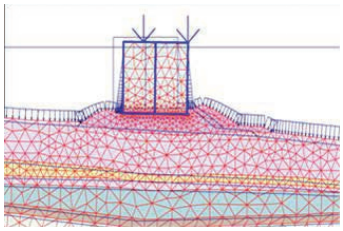
The local geology is specific, with alternating very compact limestone levels and softer marly levels, within which decompressed areas and clayey lenses with weak properties may also be found. TERRASOL recently contributed its geotechnical expertise to the following projects:

- Analysis of additional soil testing and updating of the foundations design for container terminal TAC1 (700 m alongside quay, foundation on 12 to 13 m deep piles);
- Geotechnical detailed design for the renovation of the foundations of an oil wharf (pier 9) by construction of a double sheet-pile wall (length 260 m, width 30 m) driven 2 m outside the existing structure, embedded in the marly limestone substratum, and anchored at the top;
- Assistance during the call for tenders for the extension of pier 8 (length about 300 m).

C. Bernuy

New port of Tangiers

Morocco



The breakwater of New Port of Tangiers is made of reinforced concrete caissons laid on a seabed fill. The foundation soil is made of silty to gravelly sand over a thickness of thirty meters above the substratum.

These temporal calculations were performed with the Plaxis software. The behaviour laws and mechanical properties of these soils were adjusted to the deformation level under seismic solicitations. The geotechnical, dynamic and numerical assumptions required many setting calculations to preserve the quality of the signal during its propagation through the model.

The temporal acceleration signals located at substratum level were built up following a seismotectonic study which allowed to determine the earthquakes that would be the most damageable for the structure. They were generated from analytical processing by deconvolution of comparable real signals. The study highlighted the effects of far and nearby earthquakes, and more particularly the major influence of the frequential content of the signals on the structure's behaviour.

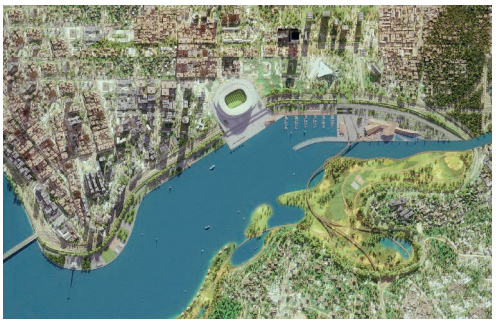
Indeed, although far earthquakes generate a smaller acceleration on the site than nearby earthquakes, their low frequency content is close to the global system's resonance frequency (~ 1 Hz). Therefore, they are more unfavourable in terms of the breakwater stability. The maximum irreversible displacements are 4 cm after the far earthquake, and 12 cm upon the arrival of shear waves. On the other hand, the displacements during a nearby earthquake have low amplitudes and the model illustrates an elastic behaviour.

A. Bergère

Cocody lagoon development

Ivory Coast

Ivory Coast has launched an ambitious project to safeguard and develop the Cocody lagoon, ideally located below the Plateau district in Abidjan, and threatened by mud and sand silting. The developments comprise a first phase of backfilling in the lagoon to create platforms, which will be developed subsequently, and a marina.



Moroccan company SGTM has been contracted to build the backfill platforms in the lagoon, under joint project management by BNETD and CID, and project owner assistance by MARCHICA.

The complex geotechnical context, with large thicknesses of mud and extremely compressible materials, decided SGTM to call upon the services of TERRASOL as geotechnical expert to get optimal understanding of the geotechnical risks. TERRASOL has consequently provided expert assessment as needed on part of the works already completed (phase 1), and then design studies on the part under construction (phase 2).

The main issue of these backfilling works is to predict not only the settlements but also the volume of sand replacing the mud that is pushed ahead of it. The phase 2 geotechnical investigations (programme defined by TERRASOL) are currently in progress, and the design phase itself will start when they are completed.

J. Drivet

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