TERRASOL

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Edito

In the last « Ground and foundation » special issue of the "Travaux" magazine, in June 2010, I described a few challenges geotechnicians are increasingly facing, requiring permanent innovation. The projects evoked in this Letter show how **TERRASOL** plays its part perfectly in this context.

I among other cited:

- Control of risks and notably of deformations caused by works, as well as the use of the interactive design: compensation grouting used in the Toulon project, for the first time in France, is an application pushed to the extreme;
- Soil reinforcement, a geotechnical answer to sustainable development requirements; the reinforcement of the foundations of the "château de Versailles" by Jet Grouting to implement an underground technical gallery is a perfect illustration;
- Numerical modelling and its proper use: examples such as particularly complex 3D finite elements model for the Tour Odéon project in Monaco, or the fine approach of the non-linear constitutive laws, based on specific tests, with a real-scale feedback for the LNG tanks in Dunkerque, show how these tools can be used to find relevant responses to various problems;
- The consideration of standardisation increasingly present, notably with Eurocodes, of which the French national application standards for the different types of geotechnical structures are for some already published and being developed for the others. **TERRASOL** participates proactively in this preparation, and our software team is already preparing the upgrade of the tools to accompany these standards.

This is how **TERRASOL**, in a difficult economic context, continues driving its development, with a staff of almost 50 people, and with a permanent goal of performance, innovation and quality in our services. I believe it is the best way to consider a year 2011 during which we shall pursue these goals.

A. GUILLOUX
Chief Executive Officer

Toulon: compensation grouting for the second tube of the underground crossing

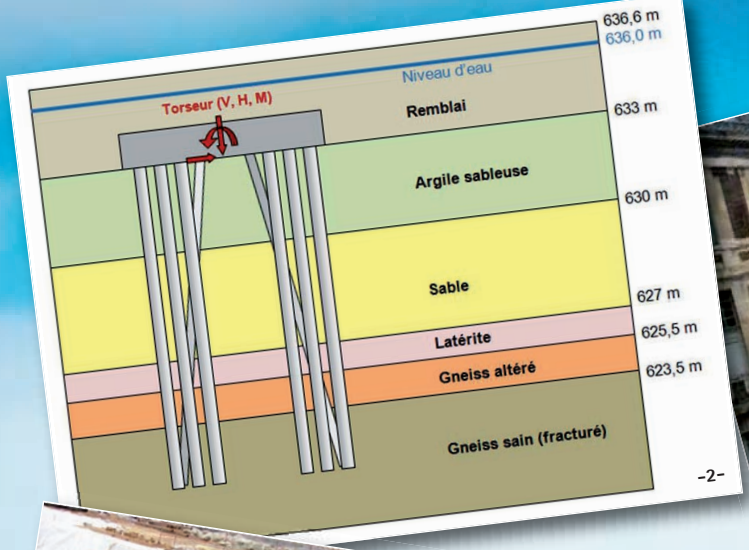
From the initiation of the studies of the second tube project of the Toulon underground crossing, the passage under the Esplanade and Scheherazade buildings in the Marchand sector, in the central part of the tunnel, was identified as being particularly difficult.
Indeed, these two 8-floor buildings had already undergone the digging of the first tube, and soil testing showed the presence of soil with particularly mediocre quality (soft clay pockets issued from dissolved gypsum).
A very rigid support with face reinforcement by jet grouting columns had been considered, using compensation grouting as an option in case of excessive deformations at groundlevel.
From the beginning of the excavation strating from the intermediate attack of the Marchand shaft, the Esplanade building responded significantly with cracks in the finishings of the buildings, in spite of a still relatively low level of surface deformation. The building's structure turned out to be much more sensitive than foreseen. Excavation was stopped due to the anticipation of deformations very close to the limit of the acceptable thresholds after passage of the tunnel. After considering the possibility of reinforcing the building's structure, it was finally decided to use compensation grouting to stabilize the building.

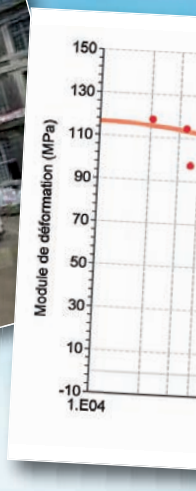
This method consists in injecting small quantities of grout to lift the building and compensate for settlements generated by tunnel excavation. These injections were performed from 3 layers of 20 subhorizontal drillings equipped with tubes-à-manchette, making up 5300 injection points. A large-size measurement system, made of topographic measurements from automated theodolites, electro-level chains, borehole extensometers and tiltmeters, allowed for continuous check of absolute and differential settlements, with a sub-millimeter accuracy.
A first phase before resuming excavation consisted in pre-lifting the building by 12 to 15 mm, in order to "catch up" the initial settlements already acquired. This phase also allowed to calibrate the system and validate the volumes of grout to inject by manchette.
Excavation could then resume, by activating the compensation device. With daily injections of about 2000 to 3000 liters, settlement were fully controlled, with an accuracy of about 1 mm.

A « first » in France, allowing to consider using the method in other delicate projects.

H. Le Bissonnais

Compensation grouting under building / Marchand zone





Cable-stayed bridges

Equatorial Guinea

TERRASOL was entrusted with foundation studies within the design-construction project of two triple span cable-stayed bridges over the river Wele at the entrance of Oyala, in central Equatorial Guinea. Bridge no.1 is located upstream, about 1 km away from bridge no.2. Both bridges are identical, except for vertical leveling.

The local geological context is:

- alluviums of the river Wele on the surface, with mediocre mechanical characteristics,
- layer resulting from in situ alteration of the crystalline substrate (lateritic profile),
- granitic or gneissic substratum with an upper part of alteration reaching sand consistency.

The conditions of access to the site, as well as low availability of laboratories and boring machines in the country result in a difficult soil testing campaign. Evaluating the soil mechanical characteristics is delicate because of the disparity of values measured, requiring a range-based approach for design calculations.
The design of the foundations of the two structures in this lateritic geological context led to designing 44 micropiles of 10 to 15 m long for each pylon and abutment foundation, anchored by 4 m minimum in the gneissic substratum. These micropiles work mainly through friction in the rock, as the contribution of upper layers remains low. About ten micropiles are tilted by 15° to take up horizontal loads.

A. Bergère

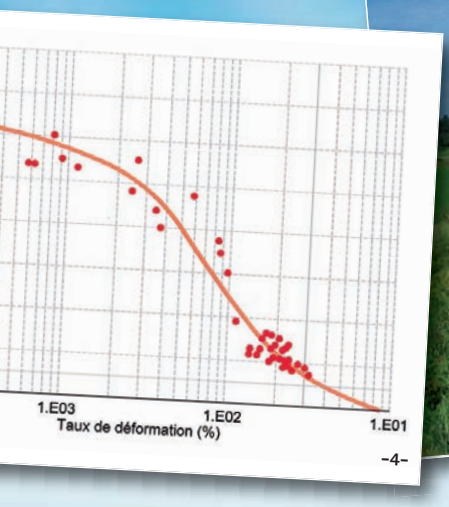
Technical gallery

Château de Versailles

The "Château de Versailles", a classified historical monument, is one of the most visited sites in France. It is a complex building, composed of 5 to 11 levels, with many architectural reconstructions initiated in the middle of the XVIIth century by Louis XIV, and finished in the early XIXth century upon the initiative of Louis Philippe. Within a network renovation and securing program, it was decided to build a large section underground technical gallery. The gallery is located partially below the Grand Commun building and western Pavillon of the South Ministers wing.
TERRASOL, associated with SETEC Bâtiment, intervened within a type G12 and G2 design contract for the definition of the main geotechnical works for underpinning and retaining structures. The first step of our mission consisted in defining the geotechnical surveys suited to the structure in order to specify the levels of existing foundations, which led to execute shielded shafts, sometimes several meters deep. Variability of geometrical constraints led us to choose and associate, in the "project" phase, two different techniques to build the structure. These consisted in traditional underpinning works together with jet grouting columns to transfer the foundation loads in depth, but also make up locally the support of the gallery abutments.
The foundations underpinning with jet grouting columns turned out to be perfectly suited, in association with preliminary load tests, and the implementation of deformations monitoring controlled by the injection system. The narrow site access also imposed the use of small size machines to produce columns not exceeding 10 m long.

P. Chalivat

-1- Oyala cable-stayed bridges: foundations
-2- Oyala cable-stayed bridges: foundation principle
-3- Château de Versailles
-4- Dunkerque gaz terminal: constitutive law $E=f(\varepsilon)$ for Flanders clay
-5- The Petit Rhône: earth dike
-6- Odéon Project: César 3D FEM model
-7- Odéon Project: first excavation



Methane Terminal

Dunkerque

Within the methane terminal project in the outer harbor of Dunkerque, **TERRASOL** was entrusted by Bouygues with the design of foundations of 3 LNG reservoirs. These structures are implanted in a stratigraphic context characterized by very thick (90 m) Flanders clay, a geological formation that may generate considerable settlements and impact the structures behavior.
A major part of the work performed for this project consisted in building a reliable geotechnical model of the behavior of the Flanders clay.

This setting was performed using two parallel approaches.

- on the one hand, we used finite element calculations (Plaxis) to build a numerical model able to reproduce the evolution of settlements measured over 20 years at the Gravelines nuclear power plant, located next to the project site.
- on the other hand, we led a detailed analysis of the geotechnical data available on site, combined with a synthesis of the existing bibliography on the Flanders clay. By comparing the results of oedometric tests, triaxial tests with bender element and cross-hole measurements, we were able to highlight compressibility variations with the deformation rate in Flanders clay.

Convergence of both approaches (back analysis with numerical modeling and law E=f(ε) derived from the tests) was established by simulating the behavior of a LNG reservoir with each set of parameters, the distribution of deformations and settlements obtained being comparable. These converging results were decisive in establishing the reliability of settlement values below the project reservoirs.

M. Reboul

Earth dikes

The "Petit Rhône"

Within the framework of the flood section of the Rhône program, the SYMADREM ("SYndicat Mixte interrégional d'Aménagement du Delta du Rhône et de la Mer") entrusted the **TERRASOL** – HYDRATEC pool with examining 18 kilometers of earth dikes on the left bank of the Petit Rhône, downstream the city of Arles. This area includes a section resistant to overflow.
This contract for preliminary survey and design consists in examining and designing adjustments of the dike to protect the delta from the floods of the Petit Rhône. The last flood, which occurred in 2003, impacted over 12,000 persons and caused over 700 M€ damage. The possible adjustments are reinforcements and limited geometrical modification of the dikes. The preliminary survey (diagnostic) is based on a bibliographic analysis, inspection visits (as per the dike SIRS method), as well as geophysical and geotechnical surveys.

The objective was ultimately to define:

- a risk level per homogeneous dike segment,
- the new position of the dike limit.

The preliminary design is intended to:

- model the geomechanical behavior and underground flow,
- design the proposed structures,
- design the dissipation basins and discharge carriers linked with overflow behavior.

The preliminary survey and design are currently ending. The limited geometrical modification of the dikes is being validated by the SYMADREM.

J. Sénemaud

The Odéon Project

Monaco

The Odéon tower project in Monaco is exceptional, both by its height, 160 m, the tallest building in Monaco, and the depth of excavation required, planned to reach about 70 m maximum:

- 30 m temporary support: anchored "micro" soldier-pile wall then soldier-pile wall to create a horizontal platform at the superstructures base level,
- then 40 m diaphragm walls for the infrastructures, in top/down construction.

Within this project, performed by a Vinci Construction France – Solétanche Bachy pool, **TERRASOL** was entrusted with geotechnical consultancy on the soil testing, foundations ... but also and mostly with the implementation of a 3D finite elements model to analyze notably the influence of the excavations on the surrounding buildings.
Built-up with the CESAR-LCPC software, this model is particularly "heavy", including close to 700 000 elements, with explicit modeling of 366 pre-stressed anchors (adjustable in length), 48 micropiles, 22 piles, and over 500 ml diaphragm walls and barrettes, as well as the structural elements of the underground levels, to which 57 computation phases must be added, with excavations per passes, activation of supporting elements, and gradual application of the tower's load ! Computing the entire model takes 36 hours.

A challenge for modelling engineers, taken up successfully thanks to the perseverance of our team !

A. Guilloux

Software Departement

You need a software demo ?

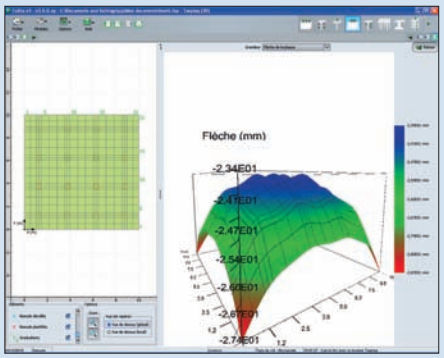
If you feel our software could be useful to you, but you would first like to learn more about them, please contact us so that we can come up with the best solution for you: demonstration/evaluation versions, live demonstrations, visioconferences, etc.
There are plenty of possible ways to organize demos, either with **TERRASOL** or through one of our worldwide agents !

TALREN course in Istanbul

TERRASOL, together with our agent for Turkey GEOGRUP Insaat, will organize a TALREN course in Istanbul in spring 2011.
Please contact Geogrup for more information about this course: info@geogrup.com.tr

Foxta v3

We are presently working on a new version of our Foxta program: Foxta v3.

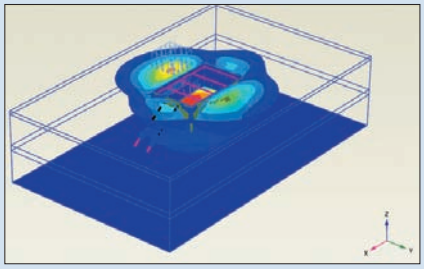


This program is intended for foundations design: shallow foundations, deep foundations, piled-raft foundations, stiff inclusions, pile groups, etc.
The new version will include a fully new and up-to-date user interface and some new calculation features.
The French version is due to be released in 2011, and the English version will be released shortly afterwards.

UP-TO-DATE VERSIONS

- Talren 4 v2.0.3
- Foxta v2.0.2
- K-Rea v2.4.0
- Tunren v1.05
- Straticad v1.2

PLAXIS products and training



TERRASOL has been the PLAXIS agent for France and French-speaking countries for a long time, and is thus happy to promote PLAXIS new products released recently: PLAXIS 2D 2010 and PLAXIS 3D 2010.

Like every year, a PLAXIS 2D French-speaking training session was held in Paris in November 2010. 30 participants attended this course.

Recent publications

- Retours d'expériences sur grands tunnels en roche tendre (**A. Guilloux**, **S. Curtil** and **H. Le Bissonnais**) – CIGOS-2010 – Paris, November 2010
- La fondation Louis Vuitton pour la Création : modélisations géotechniques croisées 2D et 3D et confrontation avec les auscultations (**A. Beaussier**, **A. Guilloux** and J. Verschuere) – CIGOS-2010 – Paris, November 2010
- Tassements sous un IGH fondé sur radier (**C. Lefèvre** and **B. Simon**) – CIGOS-2010 – Paris, November 2010
- Remblais de grandes hauteurs renforcés par géotextiles (R. Arab, **M. Yahia-Aissa**, Z. Djidjeli and S. Tabti) – CFMIG – Tunis, December 2010

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