

Line 14 South of the Grand Paris Express: geotechnical works in the spotlight!



TERRASOL is currently working on Lines 14 South and 15 (within the Project Management teams), as well as on Lines 16 and 18 (Geotechnical Assistance to Owner) of the "Grand Paris Express" project.

The South extension of Line 14 will connect the capital with Orly airport. Built entirely underground, this section is composed of tunnels 14 km long, 6 stations and 12 shafts, including one of exceptional size, at 66 m depth. The tight deadlines (the commissioning for this section is scheduled for the Paris Olympics 2024) and the works' scale required to divide the project into 4 sections with 4 different contractors consortia, as well as to anticipate 3 tunnel boring machines. Two of them have already been christened "Claire" (for Claire Mérouze, the first woman to fly a Rafale at the age of 25) and "Koumba" (a reference to Koumba Larroque, a wrestling champion).

One of the main technical complexities of this project is raised by the excavation of the tunnel for section 2 under the former coarse limestone quarries (CG) and the gypsum masses and marls (MFL). To secure the works in such an urban area, it was decided to inject grout in all the quarries and decompressions of the ground above the tunnel over a width ranging from 20 to 30 m (defined during the design phase). These injection works, especially given the dense urban environment, constitute a major challenge, which requires to minimise any nuisance for residents despite the parallel activity of several sites under construction.

The TERRASOL team is currently working within the Project Management consortium SETEC / SYSTRA on both the Visa mission

(control of the detailed design) and on the geotechnical works follow-up (after having ensured the study phases). At this stage, the geotechnical follow-up is mainly focused on the quarries backfilling works, on the diaphragm walls execution and on the earthworks for the stations and ancillary structures.

The presence of underground quarries in the Paris subsoil imposes difficult geotechnical conditions: the presence of voids/decompressions in the soils and of poorly compacted filling material in the quarries generate instability mechanisms as from the grouting phase for the drilling works:

- Local and rapid mechanism: 2 sinkholes were set up at the end of 2018 in the Kremlin-Bicêtre sector, where quarries are identified on several levels, and are known to be in poor condition and very unstable. The quarries are located at shallow depth, in the CG layer, under a cover made of Marls and Stones, sometimes decompressed.
- Slow and extensive mechanism in the district of Marcel Sembat: this neighbourhood of Kremlin-Bicêtre is located on a slope where the MFL layer comes up to the surface, with CG quarries at deeper levels. Major decompressions and quarries were observed in MFL layer during the study phase.

To the extent that, as planned, these quarries and decompressions are reinforced through grouting works, the progress of the tunnel boring machine should not generate instabilities, but only additional settlements, which have to be taken into account during the vulnerability analysis performed for the buildings concerned.

Editorial

Terrasol continues its solid growth trajectory, both in terms of activity and staff.

These last months have seen a significant increase of the number of our engineers on secondment for various missions. We currently count about ten engineers on construction sites (Project Management – Works phase) on the "Grand Paris Express" project, 2 engineers involved with the works follow-up on the Andra site located in Bure, and 3 engineers working in the United Kingdom within the "Design JV" as part of the High Speed 2 project. Proof, if ever needed, that we have the ability to mobilize our teams on the field and/or abroad, to carry out all types of geotechnical missions! This also means that we have valuable feedback on "site" experience, which will add even more expertise to our future projects.

We are also proud to announce the culmination during this year of two CIFRE PhDs supported by Terrasol. Khadija Nejjar will defend her thesis on the "Behaviour of retaining walls in an exceptional context (application to the station Fort d'Issy-Vanves-Clamart of the Grand Paris Express)" on July 4, 2019. And Jesús Perez Herreros will defend his thesis in autumn 2019: "Seismic behaviour of deep foundations: towards the introduction of a frequency aspect in the macro-element tool". Both join the Terrasol teams.

Finally, I am pleased to present Slake, our new tool for the quantitative analysis of liquefaction hazard. This software is the latest addition to the Terrasol suite for geotechnical calculation, and provides optimized features scientifically speaking as well as in terms of user-friendliness.

Wishing all our readers a wonderful summer!

V. Bernhardt

There are many additional constraints: limitation of the rights-of-way, presence of sensitive neighbouring structures, identification of additional operated areas or of unclassified ongoing sinkhole mechanisms (not listed on the IGC maps), etc.

At the beginning of May 2019, approximately 50% of the quarry injection works were completed.

A. Bergère, E. Geay and P. De Oliveira

Restoration of the "Hôtel de la Marine"

Paris, France



Photo credit: @DR

TERRASOL is currently working on the restoration-redevelopment of the Hôtel de la Marine, within the Project Management team led by CABINET 2BDM ARCHITECTES, and on behalf of the Center of National Monuments (Centre des Monuments Nationaux). This 18th century building is located along Place de la Concorde in Paris.

One of the objectives of the current project is the opening of the monument to the public and the creation of offices in the upper floors. In this context, the structural changes and some local weaknesses led to design the reinforcement of part of the existing foundations.

Several techniques have been selected in coordination with the engineering firm EQUILIBRE STRUCTURES: expansive resin injections, micropiles, alternated lined shafts.

In addition, we carried out a bearing capacity diagnosis for the courtyards in order to indicate to the Owner the vehicles that can circulate in each zone. The consideration of both geophysical and geotechnical investigations made it possible to have a general overview of the soils close to the surface, and to locate certain weak zones and buried structures (networks, ...). TERRASOL now provides supervision of the detailed design and geotechnical works. To achieve this, we carry out regular site visits to ensure the control of the works carried out.

M. Brun and S. Messikh

New towers in Casablanca

Morocco

For a number of years now, TERRASOL has been largely involved alongside SETEC MOROCCO in the geotechnical design and works follow-up of several projects of towers and high-rise buildings in Casablanca: CFC Tower, BCP Tower, Attijari Tower, RMC project.

These assignments concern the different successive construction stages of the towers. We have been called on notably in the context of the excavations and preliminary earthworks in sensitive urban environments: it is necessary to design / study reinforcement techniques that are appropriate considering the rocky nature of the ground (rock fracturing, presence of water, etc.).

Our missions also include the design of the foundation system for these towers in terms of bearing capacity and stiffness, taking into account the soil-structure interaction for combinations of static and seismic actions, as well as different aspects regarding drainage and sanitation.

Also, by monitoring the execution of these different projects we learn valuable lessons regarding the real behaviour of the structures. The experience thus accumulated by TERRASOL and SETEC MOROCCO on these different projects should allow to propose in the future construction methods with optimized costs while guaranteeing optimal reliability and robustness.

S. Burlon and T. El Malki



Banda Azúl hydroelectric project

Bolivia



Located in the foothills of the Eastern Cordillera separating the Amazonian plain from the Andean highlands, the Bolivian province of Chaparé (Cochabamba department) has a high hydroelectric potential that Bolivia is developing in order to cope with the increasing energy needs of the country.

As part of the Banda Azúl project, developed by ENDE CORANI (Bolivian electricity company), SETEC GROUP (SETEC ENERGIE ENVIRONNEMENT and TERRASOL) is working on behalf of AFD (French Development Agency), the co-financier of the project, for an expert mission on sediment management and geological / geotechnical topics.

Following a field mission performed on site in December 2018 and on the basis of the geotechnical surveys already carried out, TERRASOL is in charge of the geotechnical design review of every structure of this project.

These structures include: a concrete gravity dam with a retaining capacity of fifty meters, a seven-kilometer water conveyance tunnel, underground wells and decompression chimneys, an engine room, a one-kilometer sediment diversion tunnel, as well as a dozen weirs to control the sediments.

A. Beaussier

Extension of Tribhuvan Airport in Kathmandu

Nepal

Kathmandu, the capital and gateway to Nepal, is a destination renowned for its cultural and natural heritage. The city's airport is therefore a major element of the country's development. Its modernization and capacity reinforcement were entrusted to ADPi's Project Manager.

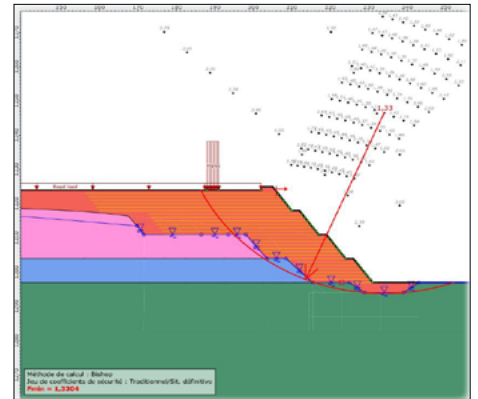
The infrastructure is set on a hill, and the tarmacs and taxiways project faces a double challenge: considerable altitude variations and limited expansion possibilities (the city surrounds the airport).

ADPi entrusted TERRASOL with the design of the retaining structures, which presents many geotechnical issues: a very high embankment (up to 28 m height); strong seismic hazard (earthquake of magnitude 7.9 on April 25, 2015); site located in the valley bottom on liquefiable soils; and a platform sensitive to displacements.

For the geotechnical structures design, TERRASOL used the results of a soil survey campaign including SPTs, core drilling, and laboratory testing. The geotechnical synthesis made it possible to define, for each site, the geotechnical models and the liquefaction potential according to the NCEER method (with our new software SLAKE).

The design of the reinforced embankments was carried out with Talren, and the platform settlements were evaluated with Tasseldo module (Foxta software). Finally, settlements due to creep in the long term (taking into account the reinforcement elements) were estimated using a PLAXIS 2D model.

F. Binet



Towards new structural and geotechnical Eurocodes

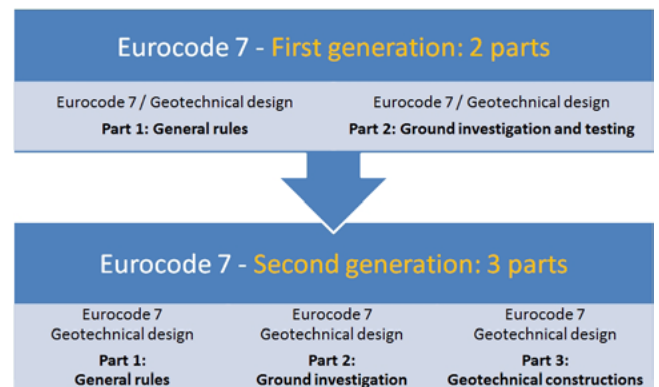
Standardisation actions

TERRASOL has always been greatly involved in research and development activities, as well as in standardisation actions. As part of the implementation of the second generation of Eurocodes, TERRASOL is currently participating in the works of the latest project team in charge of the final version of the three new parts of Eurocode 7, which are to be finalized by April 2021. The vote of this new Eurocode 7 (and of the other Eurocodes) should take place in 2022, and the new version should be applicable in 2024.

The new Eurocode 7 will deal with additional topics: simplification of safety formats, management of studies reliability, effects of water, dynamic and cyclic loading, rock mechanics, etc. The aim is to provide a European standard for geotechnical design that is easily applicable in Europe, but also and most importantly beyond Europe, by promoting the different aspects of European engineering. The idea is to take advantage of the main European know-how to optimize geotechnical structures and make European engineering truly competitive.

In France, it will then be necessary to update the various national application standards of Eurocode 7, and where appropriate, propose new standards detailing the complementary topics addressed.

S. Burlon



A first waste recovery plant in Sharjah

United Arab Emirates

The Emirate of Sharjah created in 2007 a municipal waste management company - BEE'AH (a public-private partnership) - which chose CNIM to design and build the first waste-to-energy plant of the United Arab Emirates. The plant will ultimately convert 300,000 tons of waste per year into 30 MW. The electricity produced will be sent out to Sharjah (except for the part used for the specific needs of the plant).

TERRASOL works on behalf of CNIM, and as a subcontractor of SETEC ENERGIE ENVIRONNEMENT, firstly carrying out a geotechnical diagnosis mission, which made it possible to propose optimizations of the structures foundations.

TERRASOL then participated in the detailed design of this project. This includes the geotechnical design of the foundations of the power plant's major structures (boiler, turbine foundation, waste storage area) and the study of the interactions between the structures supported by deep foundations and those built on rafts (deformation estimation, taking into account the effects of the negative skin friction on the piles).

TERRASOL also provides on-site technical supervision at the beginning of the deep foundation works in May 2019.



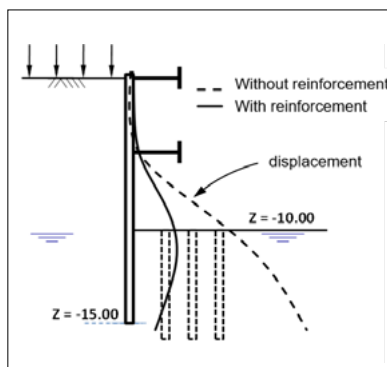
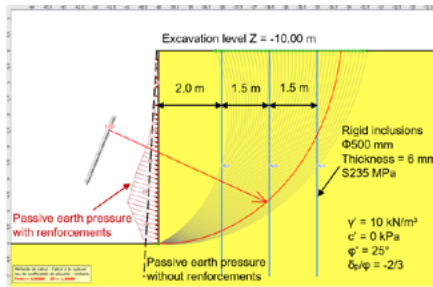
Photo credit: Bee'ah

C. Bernuy and J.Drivet

Combined contributions of Talren and K-Réa

The case of a sheet pile wall embedded in a silty soil reinforced by rigid inclusions illustrates the contribution of a combined use of Talren and K-Réa.

In a first step, using the kinematic approach of the yield design method, Talren enables to establish the diagram of limiting passive earth pressure taking into account the interaction with the inclusions (assimilated to nails working in bending/shearing).



The figure here-above illustrates the increase of the limiting passive pressure compared to the case of an unreinforced soil.

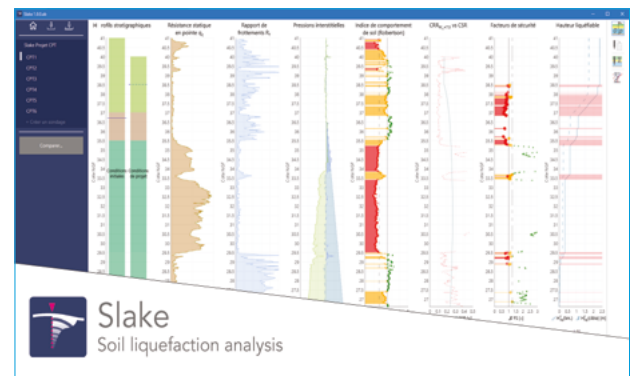
In a 2nd phase, the passive earth pressure diagram obtained can be imported into K-Réa in order to analyse the local equilibrium of the wall in terms of forces and displacements, taking into account the additional resistance provided by the inclusions.

Slake: your new "liquefaction tool"

Slake is the latest TERRASOL software: it is dedicated to the quantitative analysis of the liquefaction hazard of soils under seismic loading by applying the direct semi-empirical method known as "NCEER" (Youd and Idriss, 2001). This user-friendly tool can also be used to carry out sensitivity analyses on all critical parameters by managing "scenarios" that are associated with the analysis of a borehole or a group of boreholes.

In addition, an assessment of seismic-induced settlements is presented using the semi-empirical Zhang and Brachman method (2002). This indicator, which will soon be extended to further options stemming from future developments, enables a spatial analysis and paves the way to multi-criteria analyses that do not limit liquefaction studies to just safety factors.

The beta-test phase is coming to an end and Slake will be on the market this summer. Do not hesitate to contact us for further information!



M. Huerta

Recent publications and presentations

- "Ligne 15 Sud : Retex de la gare Fort-d'Issy-Vanves-Clamart" (**K. Nejjar**) – CFMS Scientific and Technical Session / Major infrastructures projects in Paris, March 2019
- Shallow chalk quarry stability using an original shear strength reduction approach (F. Rafeh, H. Mroueh et **S. Burlon**) – Computers and Geotechnics 112, April 2019
- "Etude expérimentale en centrifugeuse du comportement d'un groupe de pieux sous séisme" (**J. Perez Herreros**) – CFMS Scientific and Technical Session / Young Members Group, Paris, April 2019
- "Exemples de problèmes posés dans la justification des ouvrages mêlant géotechnique et parasismique" (**F. Cuira**) – CFMS Scientific and Technical Session / Young Members Group, Paris, April 2019
- "Kourou, centre spatial guyannais : nouvel ensemble de lancement pour Ariane 6" (**C. Babin, F. Binet et M. Hocdé**) – Solscope Mag n°12, April 2019
- Editorial Revue Travaux - Soils and Foundations (**V. Bernhardt**) - Revue Travaux n°950, April/May 2019
- A macroelement for dynamic soil-structure interaction analysis of pile-group foundations (**J. Perez-Herreros, F. Cuira, S. Escoffier et P. Kotronis**) - 7th International Conference on Earthquake Geotechnical Engineering, Rome, June 2019

World Tunnel Congress (WTC) 2019, Naples, May 2019

- South extension of the metro Line 14 in Paris – focus on Limestone quarries grouting (**A. Bergère, M. Coblard, JP. Janin, F. Lanquette et PL. Le Tolguenec**)
- Arcueil-Cachan, Grand Paris Express Metro Station (S. Telhawi, L. de Saint-Palais, **G. Chapron, JP. Vaysse, B. Mouguel et J. Royer**)
- Performance and modelling of Fort-d'Issy-Vanves-Clamart metro station: a 32 m deep excavation of the Grand Paris project (**K. Nejjar, D. Dias, F. Cuira, H. Le Bissonnais et G. Chapron**)
- 3D numerical back-analysis on an experimental conventional tunnel in Paris Sanoisian "Green" Clay (**JP. Janin, A. Beaussier et H. Le Bissonnais**)



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