

Terrasol creates an expertise unit dedicated to seismic and dynamic engineering



Over the last few years, TERRASOL's activity has experienced strong growth in seismic and dynamic engineering, responding to an increasing demand from owners and contractors to improve design reliability of structures with respect to seismic and vibration risks.

An example is the KNPC project in Al Zour-Kuwait (picture hereabove), for which TERRASOL was entrusted with the seismic design of the foundations for 8 LNG tanks each 90m in diameter. This project is special due to the choice of a foundation system consisting of rigid inclusions to isolate the structure from the seismic loading transferred by the supporting soil.

TERRASOL also worked recently on the EPR project of Hinkley Point (UK) with SETEC NUCLÉAIRE to optimize the justification of the seismic stability of some of the project's facilities through non-linear dynamic analyses. Let's also refer to TERRASOL's recent assignment for GROUP RENAULT to qualify and validate the dynamic and vibratory performance of the foundations for a driverless vehicle simulator.

Aware of the growing complexity of studies in this field, and of the importance of building on what we have learned from our projects, we created a few months ago a TERRASOL unit dedicated to "Dynamics engineering", aiming at offering our clients relevant and robust

solutions covering the following issues:

- 1D / 2D dynamic and seismic site responses;
- Accounting for the effects of soil-structure interaction in the justification of structures under seismic and vibratory loads;
- Modelling of the response of structures and foundations under complex dynamic loading (impacts, wind, waves, etc.);
- Considering non-linearity issues in the justification of structures under high dynamic loads (extreme earthquakes, shocks and impacts, etc.).

These services are provided notably thanks to our teams' in-depth expertise of several specialized calculation tools such as SASSI/MISS-3D, Plaxis Dynamics 2D/3D, Flac 2D/3D, or Code_Aster. It should be also noted that the actions carried out within our Dynamics Unit are supported by several recognised experts from TERRASOL, and from other companies in the SETEC GROUP, as well as by external consultants such as Françoise Ropers and Alain Pecker.

Finally, Terrasol's Dynamics Unit also aims to continue and value our scientific development works carried out over recent years in soil-structure interaction (SSI) in seismic conditions: for example, we co-supervised a CIFRE doctoral project on the dynamic behaviour of pile groups, and we carry out an assignment for EDF on the development of a dynamic macro-element in Code_Aster to simulate non-linear material behaviour at the

Editorial

The TERRASOL team further expanded in 2019 and is now structured to take our geotechnical engineering development even closer to our customers and partners. This concerns major projects (Grand Paris Express, High-Speed 2 / UK, nuclear waste landfill in Bure, etc.), geotechnical services on all types of structures in France and abroad, as well as new geotechnical applications or innovative scientific developments, with for example, the start of a new CIFRE PhD in early 2020. In partnership with the Navier Laboratory, this thesis will focus on reducing soil behaviour uncertainties when using tunnel boring machines by continuously analysing the collected data (with application to 2 sections of the Grand Paris Express).

Furthermore, we recently completed and marketed our new Slake software (liquefaction risk analysis), and we are notably preparing the release of version 4 of our Foxta software.

Finally, our training offer in design and modelling of geotechnical structures continues to grow, both geographically and through the topics proposed.

So, 2020 promises to be another busy year with exciting new challenges for our teams!

We wish you a very happy New Year 2020!

V. Bernhardt

soil-foundation interface. These actions have stimulated the development of specialized engineering tools such as Fondsis (non-linear SSI under seismic conditions) and Slake (liquefaction risk analysis). Both these tools allow for instance a deeper insight into the concept of structural seismic stability by overcoming the conceptual limitations of pseudo-static justification formalisms and by quantifying the seismic limit state in terms of displacements. These developments are ongoing today with the launch of a new thesis dealing with the development of a macro-element for structures based on rigid inclusions, as part of the ASIRI+ National Research Project.

J. Pérez Herreros and F. Cuira

Numerous bridge projects in Abidjan

Abidjan, Ivory Coast

Abidjan, the capital of the Ivory Coast, is built along a series of islands, peninsulas and lagoons. Therefore, all infrastructure projects in this city must cross different seaways, requiring engineering structures that sometimes span considerable distances. The geological and geotechnical conditions of the different sites are particularly complex: thick layers (sometimes more than 30 m) of compressible and soft soils (silts), low density sandy alluvium the behaviour of which often falls short of expectations, and a very deep substratum (more than 80 m).

TERRASOL's expertise is regularly called upon by diverse parties in the construction industry (contracting authorities, project managers, contractors, etc.) for the design and/or construction supervision of deep foundations for the most symbolic structures in Abidjan:

- Cocody bridge ("5th bridge"): assistance to CRBC for the analysis of the pile tests during the construction phase,
- Banco bridge ("4th bridge"): geotechnical expertise within the Project Management consortium consisting of SETEC TPI, SETEC COTE D'IVOIRE, SETEC INTERNATIONAL, TERRABO and STUDI,
- Henri Konan-Bédié Bridge (or Riviera - Marcory bridge, or "3rd bridge"): assistance to BOUYGUES TP for the foundations design,
- Félix Houphouët Boigny bridge ("2nd bridge"): geotechnical expertise, for the SETEC TPI / SETEC COTE D'IVOIRE / SGI / IETF Project Management consortium
- Jacquville bridge: expertise on the foundation piles of the structure on behalf of the owner.

Furthermore, TERRASOL is also involved in development projects such as the project in Cocody Bay or the Indénié roundabout. Hence, with its in-depth experience, TERRASOL is a benchmark engineering company for complex geotechnical projects in Abidjan.

J. Drivet



Reconstruction of the Jungheinrich company headquarters

Vélizy-Villacoublay, France

JUNGHEINRICH, a world leader in the intralogistics sector (handling equipment, storage systems and services) has been operating in France for 55 years and is now planning to rebuild the headquarters of its French branch in Vélizy-Villacoublay, in the Paris region. The project, covering a surface area of approximately 7,200 m², involves demolishing the existing headquarters and building six-floor and three-floor office buildings, as well as a car park with two underground levels.

TERRASOL was commissioned by JUNGHEINRICH and their architect to carry out geotechnical assignments "G2 AVP", "G2 PRO/DCE" (preliminary and project design geotechnical studies) and G4 (geotechnical construction follow-up).

TERRASOL utilized its strong experience of the local geotechnical background (for example, nearby project of the Vélizy shopping centre) to provide support to the Owner.

We were involved early on from the design studies in 2016, and went on until the works started in 2018. We defined suitable and cost-effective solutions for the foundations and retaining structures (shallow foundations and staged walls). The first building was built in 2019; the entire project will be inaugurated in 2020.

K.V. Nguyen



Multiple geotechnical assignments on quarries projects

France



TERRASOL is responding to a growing number of demands from quarries operators. The range of customers includes: GSM, EQIOM, PLACOPLÂTRE, KNAUF, etc. From a technical viewpoint, the type of demands varies greatly:

- Studies on development projects (extensions, construction of industrial facilities),
- Studies on specific points of the authorisation file (impact on neighbouring structures),
- Expertises after an operating incident (landslides/rockslides),
- Diagnosis of sites with a view to their abandonment or remediation (long-term stability, inert waste storage).

For example, we recently worked for the quarry manager EQIOM on searching for inert waste storage sites, particularly intended for waste from the Grand Paris Express works. One of the sites studied consisted of old underground quarries, for which filling would offer two advantages: inert waste can be stored without any environmental

impact, and an abandoned site can be secured permanently without remediation. TERRASOL provided a feasibility diagnosis for the project by inspecting the galleries to assess the site's geotechnical hazards and to consider any residual hazards at the end of the filling operations.

Another example: the road aggregate producer CARRIERES DU STINKAL entrusted TERRASOL in the framework of geotechnical surveys to assess the conditions for a quarry extension. Quarry observations, followed by the analysis of a soil-testing campaign programme combining geophysical testing and profiling, enabled us to identify and locate a fault that limited the extension of the deposit.

The main common point of these diverse services is the pragmatism of the questions asked, as the companies were clearly aware of the constraints imposed by the geological situation of the sites.

F. Binet

Amman bypass

Amman, Jordan

The Amman Development Corridor project involves building an expressway located 10 to 25 km from the capital to connect the airport in the south to the Jerash Highway in the north, via the Dead Sea Road and adjacent towns. The project aims to free up urban traffic, reduce pollution, facilitate the transfer of goods and promote economic development of the regions that are served.

The World Bank has commissioned the SETEC Group to provide technical assistance in a Value Engineering approach on phase 2 located to the west. A site visit and a critical analysis of the existing studies were followed by the assessment of (technical and financial) solutions leading to project optimizations in order to consolidate the tender documents.

TERRASOL was responsible for analyzing the geotechnical design studies for the 6 tunnels and the 14 viaducts structures planned over a 50-km long distance. The tunnels are twin-tubes with an excavated surface area of 100m² per tube, and a cover thickness that can exceed 100 m. They will be excavated using the traditional method with occasional use of explosives. The lengths of the viaducts crossing the wadis will vary up to as much as 500 m, with 50-m high pillars. Two foundation systems are proposed: shallow foundations or deep caissons.

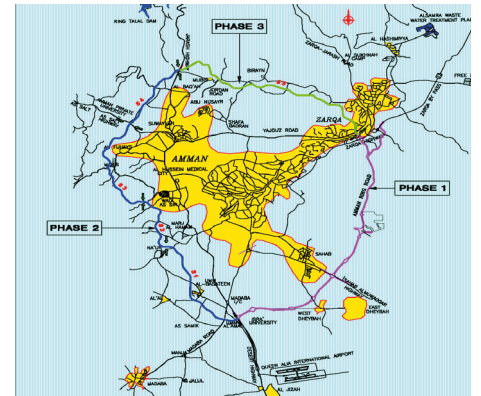


Photo credit: Engicon

The assumptions, calculation methods and design choices were reviewed by taking the local geological environment into consideration. Alternatives to the project were then studied to reduce the number of required structures and consequently, the overall budget.

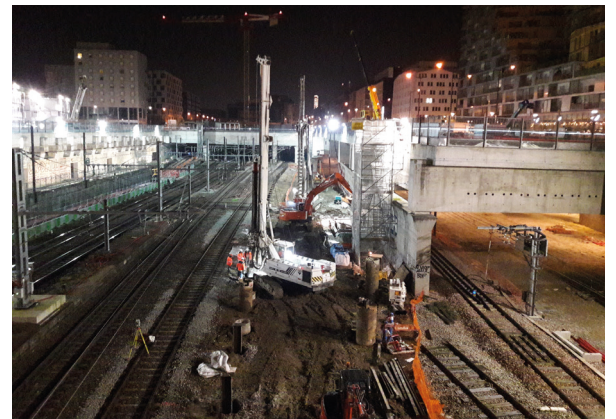
A. Abboud and J. Targhaoui

The covering of an existing railway platform in Paris

France

The covering of the railway platform between Austerlitz station and the Boulevard des Maréchaux in South-East Paris was initiated in the 1990s under the project name "ATM" (Austerlitz Tolbiac Masséna). The construction of the M10VP block involves building 10 cover-slabs (nearly 9,300 m²), which are intended to accommodate single-storey to thirteen-storey buildings, landscaped areas, roads and a rail bridge on the "Small Ring" line.

In a specific geological context (the coarse limestone "slab" is progressively thinning and changing towards the east, on top of Ypresian plastic clays), the conditions under which the works were carried out strongly influenced the design, given the compelling requirements to limit the impact on rail traffic, the accesses and the space taken up by the construction site. These constraints justified using a deep foundation system with rows of narrowly spaced barrettes. The solution combined the construction of new barrettes and the re-use of existing ones. In addition to the barrettes, with local grout injections at the tip, the geotechnical works include temporary soldier-pile walls designed to support the railway tracks during the construction of the reinforced concrete footings, as well as a temporary slab supported by micropiles to allow the heavy drilling equipment to operate in very tight worksite spaces.



The Project Manager SNCF RESEAU DGII entrusted TERRASOL with a global technical assistance assignment: "G2-AVP/PRO" (design), "G2-DCE/ACT" (tender phase), "G4-VISA" (critical analysis and validation of the detailed design), and "G4-DET" assignment (technical assistance during the geotechnical works).

M. Hocdé and F. Cuira

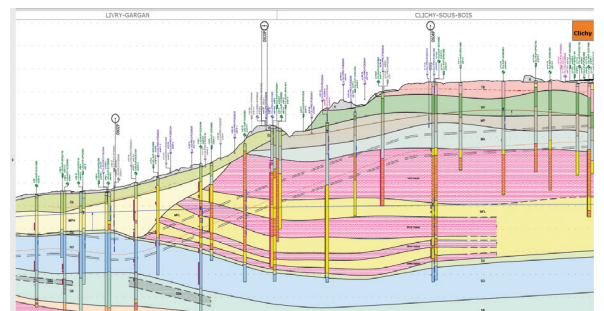
Grand Paris Express - Geotechnical Assistance to the Owner

France

As part of the Grand Paris Express project, the assignments involving geological and geotechnical assistance to the Contracting Authority for the SOCIÉTÉ DU GRAND PARIS are taking on an exceptional scope, which is expressed not only in terms of the volume of data to be examined, but also in terms of the volume of services, guidance and discussions between the Contracting Authority and their assistance provider. TERRASOL provides geotechnical Assistance to Owner on future lines 16 and 18 of this outstanding project.

In this context, our actions are multiple and evolve as the project progresses:

- In the preliminary phase: accounting for the Project Manager's requests concerning geological, geotechnical and hydrogeological data. TERRASOL defines the soil testing programmes (or checks the programmes proposed by the Project Manager), follows up the campaigns, and validates the data and their availability.
- In the design phase: second-look assignment on the project's key structures or designs. The aim of our assignment is to consolidate choices by producing "double-blind" designs, to assess the differences in methods to exhaustively review the hazards, and to optimize the structures.
- In the works phase: sharing the technical vision of the project with the Project Manager, together with feedback on site hazards or adaptation proposals. Our role is to step back from the site's constraints and provide a "horizontal" vision that complements the viewpoints of the other parties involved in the project.



On projects at the scale of the Grand Paris Express, these are long-term assignments. The 2 lines on which TERRASOL is mobilized as a geotechnical assistant to owner move forward in phases: Line 16 is in the construction phase for the first works package, whereas Line 18 is currently in the design phase. These projects will go on for several years.

C. Babin and F. Binet



Slake

Slake, our new tool dedicated to quantitative analysis of the soil liquefaction hazard under seismic loading, is officially marketed and now available. It joins our catalogue of software products, initially by proposing strict application of the "NCEER" direct semi-empirical method (Youd and Idriss, 2001), based on using SPT/CPT in-situ tests. At the same time, the calculation of safety factors is coupled with an assessment of induced effects, notably post-liquefaction settlements, based on implementing Ishihara and Yoshimine (1992) curves with an option to check the integration steps of volumetric strains.

Analysis results can be displayed graphically and in table form, the content of which can be exported to facilitate post-processing operations. Several individual analyses can also be superimposed within the same project using the comparison function. The graphical display module that provides contour line maps of different calculation results (minimum safety factor, post-liquefaction settlements, cumulative liquefiable thicknesses, LPI, etc.) gives a spatial perspective of the hazard without restricting the analysis to the notion of a safety coefficient calculated locally.

A demo version is now available on our website and enables you to discover and operate the interface, get an overview of the available features and of the output printing options. Technical and user manuals for the software are also available online.

Slake is intended to accommodate the content of the new generation of Eurocode 8 as soon as it is published, as well as of the AFPS Liquefaction sub-working group recommendations (produced in parallel with the PS2020), to the drafting of which TERRASOL contributes actively.

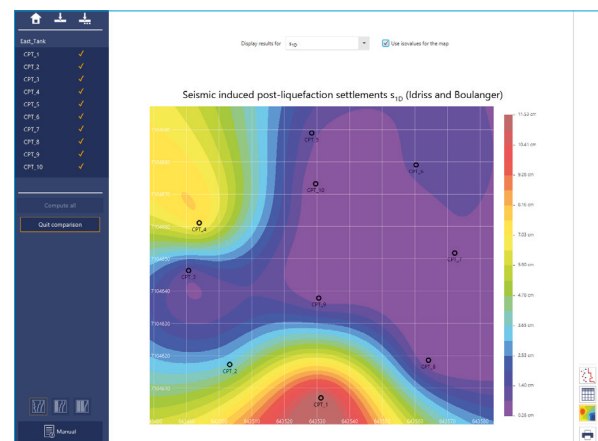
Please do not hesitate to contact us for more information, or to register for the first training session dedicated to Slake.

Training

Our catalogue is getting larger and now includes a new type of sessions directed towards the geotechnical design of structures. Our next training sessions are as follows :

- Accounting for the effects of soil-structure interaction when designing shallow and deep foundations, March 25th and 26th 2020, in Paris
- Slake software, March 27th 2020, in Lyon
- Practical design of retaining walls in urban or maritime environments, March 30th and 31st 2020, in Paris
- Foxta v3 software, April 1st and 2nd 2020, in Paris

Our 2020 training catalogue is available on our website. Please feel free to take a look, or contact us to organize in-company training sessions to match your requirements.



M. Hocdé and O. Gilles

Recent publications and presentations

XVII ECSMGE 2019, Reykjavik, September 2019

- Accounting for nonlinear behavior of ground for the prediction of settlements due to deep excavations (**K. Nejjar**, R. Witasse, D. Dias, **F. Cuira** and **S. Burlon**)
- Performance and modelling of a deep excavation in the context of the Grand Paris project (**K. Nejjar**, A. Boffa, D. Dias, **F. Cuira**, P. Vidil, **H. Le Bissonnais** and **G. Chapron**)
- Centrifuge modelling of a pile group foundation in a multilayered soil under sinusoidal and seismic loadings (**J. Pérez-Herreros**, **F. Cuira**, S. Escoffier and P. Kotronis)
- Accounting for plastic strain mechanism in calculations of deep excavations (H. EL Arja, E. Bourgeois and **S. Burlon**)
- Comparison of different approaches of pile design in chalk adopted in France and UK (M. Doghman, H. Mroueh and **S. Burlon**)
- "S" shaped curves for shallow foundations design using pressuremeter test results (**N. El Khotri**, **M.T. Hoang**, **F. Cuira** and **S. Burlon**)
- Synthetic charts for the thermo-mechanical behaviour of thermoactive piles (J. Habert, H. Mroueh and **S. Burlon**)

10th National Symposium AFPS, Strasbourg, September 2019

- "Interaction dynamique sol-structure d'un groupe de pieux avec l'approche macroélément" (**J. Pérez-Herreros**, P. Kotronis, S. Escoffier and **F. Cuira**)
- "Etude expérimentale en centrifugeuse du comportement d'un groupe de pieux sous séisme" (**J. Pérez-Herreros**, S. Escoffier, P. Kotronis and **F. Cuira**)
- "Une approche simplifiée d'interaction sol-structure non linéaire pour la justification des fondations sous charge sismique" (**F. Cuira** and **S. Burlon**)
- "Prise en compte des efforts d'inertie dans le sol dans l'étude sismique des fondations superficielles" (**Y. Abboud**, **S. Burlon** and **F. Cuira**)

Additional publications

- "Propositions d'approche probabiliste dans un logiciel de calcul de stabilité" (**A. Bergère**, **H. Pillard**, X. Guo, D. Dias, P. Tachker, O. Bory and J.J. Fry) – "Colloque CFBR - Justification des barrages : état de l'art et perspectives", Chambéry, November 2019
- "Quand le numérique s'invite en géotechnique" (**V. Bernhardt**) – Solscope Mag, November 2019



Scan this QR code with your smartphone

Head Office

Immeuble Central Seine
42-52 quai de la Râpée
75583 Paris Cedex 12
France

Tel: +33 (0)1 82 51 52 00
Fax: +33 (0)1 82 51 52 99
Email: terrasol@setec.com

Rhône-Alpes office

Immeuble le Crystallin
191/193 cours Lafayette
69458 Lyon Cedex 06
France

Tel: +33 (0)4 27 85 49 35
Fax: +33 (0)4 27 85 49 36
Email: terrasol@setec.com

Representation in Morocco

Setec Maroc
3, rue Abou Hanifa
Agdal
Rabat-Morocco

Tel: +212 (661) 25 53 89
Fax: +212 (529) 03 64 00
Email: tarik.elmalki@setec.com

Terrasol Tunisia

2, rue Mustapha Abdesslem
El Menzeh
2037 Tunis
Tunisia

Tel: +276 71 23 63 14
Fax: +256 71 75 32 88
Email: info@terrasol.com.tn