La Lettre
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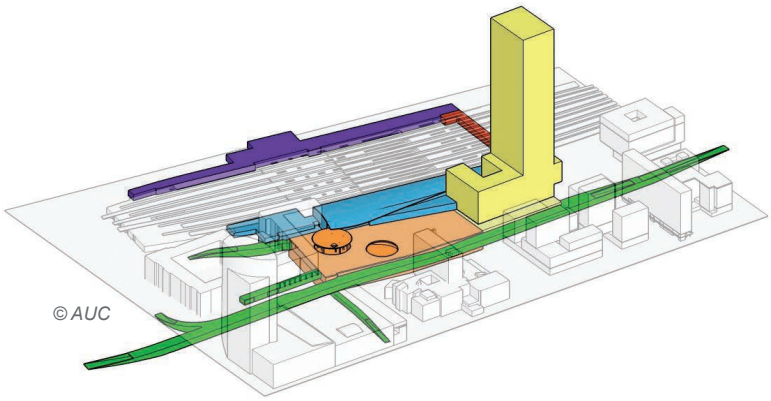
The geotechnical works of the Lyon Part-Dieu project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Since its creation in the sixties, the Part-Dieu district in Lyon has experienced perpetual change and is now the 2nd French tertiary centre. It has reached its limits in terms of operation and capacity to accept new businesses. The fundamental review initiated in 2010 by the Lyon Metropole has led to the definition of a global and ambitious urban project, the Lyon Part-Dieu project, which aims to reorganise the infrastructures of the railway station and the "Pôle d'Echanges Multimodal" (PEM) (Multimodal connection hub), especially at the Place Béraudier.

From a geological viewpoint, the plain of Lyon, where the project is located, is made up of about 20 metres of alluvium overlying tertiary formations present in the form of sandy and sandstone molasses.

Terrasol was entrusted with various geotechnical design assignments for this project.

We are working within the SETEC - EGIS - SUD ARCHITECTES consortium for the PEM infrastructures, which are broken down into two distinct objects:

- The lower parking area ("Parking Place Basse" - PPB) under the Place Béraudier (shown in orange, client VINCI IMMOBILIER).


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On a footprint of approximately 13.000 m² (80 m x 160 m), a volume of 4 underground levels will allow a lower "Place Basse" level to be superimposed, providing access to the subway and the new adjoining property complex located immediately to the south, and will incorporate a taxi rank, a public bicycle station, shops, a short-term parking area and a long-term parking area with at least 1000 spaces. The PPB is an underground structure with a minimum depth of 16 m relative to the upper area. It is located almost entirely in the Rhone groundwater, the table of which is normally about 3 m below the level of the train station. There are many interface subjects, with a structure located in the immediate vicinity of preserved existing buildings, railway lines that are still in operation, the existing Vivier Merle tunnel (TVM) and the tower project (offices and hotel), which will be built during the excavations for the car park.

The works will be executed with protection provided by diaphragm walls anchored in the molasses layer to provide hydraulic embedment when the water table is temporarily drawn down during the construction phase. The excavation works for the parking area will be carried out "top-down", underneath the PPB cover slab. Alternative solutions are currently under study to manage long-term uplift (micropiles / barrettes coupled or not to a ribbed slab).

- Infrastructure connections (shown in green, client SPL LYON PART-DIEU): layout of the Bonnel street exit, creation of a temporary metro access.

Within the consortium led by DOMINIQUE PERRAULT ARCHITECTE, we were also contracted for the To-Lyon project (shown in yellow, project owner VINCI IMMOBILIER), consisting of an 8-storey hotel bordering the upper PPB area on the south side, and a high-rise office tower (170 m) overlooking the Avenue Pompidou and several shops. The project includes a diaphragm wall that is shared with the TVM extension to the south. Another diaphragm wall separates the PPB from the single basement level of the adjacent hotel and office tower. The main geotechnical stakes are related to the tower foundations and the interface subjects related to the retaining structures.

Lastly, in the consortium led by AREP, we are working on the Béraudier arcade (shown in blue, client SNCF GARE & CONNEXION), which is part of the overall station redevelopment project, and which consists of metal framework superstructures resting on pile foundations.

C. Bernuy and C. De La Salle

Editorial

High added-value geotechnical engineering: that is what TERRASOL provides every day for its clients and partners.

This added value can take several forms: accounting for geotechnical risks and securing projects, but also optimisation of the most complex projects, whether in terms of costs (studies and/or works), delivery times or taking account of environmental constraints.

And this added value is to a large extent based on the high level of qualification of our teams, close attention to the needs of our clients, excellent responsiveness and Terrasol's continuous scientific investment, which enable us to propose innovating design methods and tools.

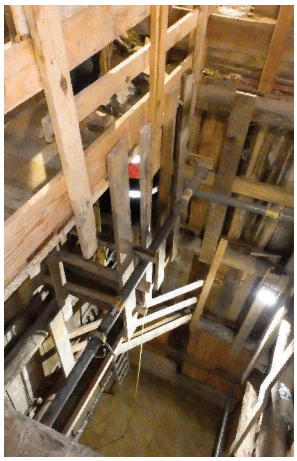
In this issue of the Terrasol Newsletter you will find a variety of examples of projects on which we have worked recently, taking you on a trip from Paris to Colombia and to the Middle East.

Wishing you a great summer,

V. Bernhardt

Restructuring of old buildings

Paris, France



TERRASOL is currently working on several old buildings in Paris, two of which are undergoing major restructuring works and are presented here:

- "La Poste du Louvre", a building made up of metal structures characteristic of the 19th century industrial architecture: the project in progress consists of creating a second basement level. In this context, underpinning works using alternating lined shafts are carried out under thick dressed-stone facades and cast-iron columns that are sensitive to settlement (photo opposite).

- A reinforced concrete building on the Necker Hospital site: an increase in live loads is expected on the slabs of the last basement level. This project requires grouting of partially-filled underground quarries in the Paris coarse limestone.

TERRASOL is monitoring the progress of these two projects on behalf of their respective owners, POSTE IMMO for the first project, and PARIS DESCARTES UNIVERSITY / EPAURIF for the second one.

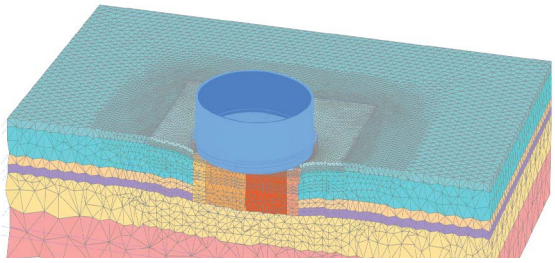
We are conducting site visits on a weekly basis to regularly inspect the works carried out and to validate the methodological adaptations related to the site's constraints.

M. Brun and J. De Cacqueray

LNG tanks on special foundations

Kuwait

To secure its imports and exports of Liquefied Natural Gas (LNG), the KUWAIT NATIONAL PETROLEUM COMPANY (KNPC) has launched the construction of a giant terminal on the Al-Zour site. The project, which must be completed in 2020, consists of building a regasification plant (USD 1.39bn) and 8 storage tanks with an individual capacity of 225,000 m^3 (USD 1.52bn), all located on a platform reclaimed entirely from the sea. This major "Design & Build" contract was won by HYUNDAI ENGINEERING & CONSTRUCTION, which entrusted the design to the Korean firm KOGAS TECH, specialized in engineering and maintenance of onshore and offshore gas facilities.



After consulting several international geotechnical engineering companies, KOGAS TECH entrusted TERRASOL with the design of the tanks foundations. These eight pre-stressed concrete structures, with a diameter of 90 m and height of 45 m, must in particular be able to withstand strong seismic accelerations with a return period of 2475 years.

HYUNDAI ENGINEERING & CONSTRUCTION has selected a Disconnected Pile Raft foundation system. TERRASOL's wealth of expertise and experience in this field (analytical design approach, technical management of the ASIRI project, and previous collaborations with HYUNDAI) proved decisive for this project.

TERRASOL provided static justification for the inclusions and distribution layer, and also determined the seismic response of the site using SHAKE program, which enabled the dynamic impedances of the foundation system to be defined (using SASSI program) with the right degradation functions for the shear moduli. On this occasion, we called for Alain Pecker's expertise to calibrate seismic design spectra.

J. Drivet, C. Bernuy and N. Frattini

Bogota – Girardot motorway

Colombia

In association with the Colombian geotechnical consultancy company JEOPROBE, TERRASOL was contracted by the concession-holder VIA 40 EXPRESS (formed by VINCI and CONCONCRETO) to carry out a geotechnical assessment of the stability of the slopes along the motorway between Bogota and Girardot.

This motorway is one of the busiest routes in Colombia and connects Bogota to the Pacific ports. It is planned to be renewed and widened.

The alignment of the 147-km long motorway climbs from Girardot through the eastern Cordillera of Colombia up to the capital located at 2600 metres above sea level. It crosses mountainous terrain with active tectonics and presents many risks of slope instability, landslides and rock falls. Erosion problems influenced by the Sumapaz River along the route must also be taken into consideration.

TERRASOL made a one-week field visit in March 2017, followed by a risk analysis assignment on various sites along the motorway. We are also providing support for the concession-holder in selecting reinforcement solutions: in the short term, the aim is to ensure user safety with immediate effect, whereas in the long term, we have to take into account the future widening works when identifying the relevant solutions.

A. Guilloux and A.M. Alzate

The Fort d'Issy-Vanves-Clamart station of the "Grand Paris Express"

France

TERRASOL, together with SETEC TPI, is continuing to follow-up the works on the first station of the "Grand Paris Express" metro network: Fort-d'Issy-Vanves-Clamart. These works began a year ago with the construction of access roads and site facilities.

The "box" is partially located underneath the tracks of the Transilien (urban train) line N: therefore, the diaphragm wall retaining structures are executed in several phases. The parts outside the track areas were completed at the end of last year. The beginning of the year saw the impressive craning of the parts for the new footbridge to access the platforms of the current station, the installation of 8 auxiliary decks to temporarily support the railway tracks, as well as the underpinning excavation works (project owner is SNCF). The HORIZON consortium (BOUYGUES / SOLETANCHE BACHY) is currently executing the remaining 100 m of diaphragm walls with restricted clearance (6 m), using suitable machines (grab and "hydrofraise").

Objective: be able to shift the slab covering the station onto the height extensions of the retaining walls over the forthcoming weekend of August 15, during the temporary 100-hour traffic interruption scheduled from the design phase more than 3 years ago.

G. Chapron and H. Le Bissonnais

Upgrading of the Lakhdaria-Bouira motorway section

Algeria

As part of the upgrading works for a 33-km motorway section between Lakhdaria and Bouira, TERRASOL was contracted by the ETRHB / ALTRO consortium to carry out the project detailed design. It is one of the most difficult sections on the East-West motorway axis, particularly due to the topography and geology along the route. As part of its assignment, TERRASOL managed all technical aspects related to the upgrade, including specific works phasing enabling to maintain the traffic on the motorway.

We worked on road geotechnical issues (wide-ranging damage covering the road surfaces and foundation soils): a preliminary breakdown of the section into homogeneous zones was established based on the damage survey and the various investigations carried out by ETRHB (georadar, evenness measurement, deflectograph and core drilling); then pavement structures were proposed (new / reinforced roadways) based on the residual resistance of each zone.

We also studied the stability of the slopes along the alignment, notably with an exceptional challenge in the section with a 6% gradient between Oued Isser and the Bouira plateau (Djebahia sector): various motion kinetics were analysed from photographic reports, archive files, geotechnical testing, as well as the specific instrumentation monitoring set up during the design phase (topographic targets and inclinometers). Several treatment solutions were then proposed: embedded slab on piles, rigid inclusions, barrier, anchored pile wall, stiffened backfill reinforced with geotextile, consolidation and drainage.

Lastly, at the consortium's request, TERRASOL fulfilled a technical assistance assignment throughout the duration of the works.

M. Yahia-Aissa

Dubai Creek Harbour Tower

United Arab Emirates

This tower in Dubai developed by EMAAR is aimed to be the highest structure in the world, hence its name «The Tower". It was designed by Spanish architect Santiago Calatrava, backed by the Australian engineering design company AURECON. This new monument located in the Dubai Creek Harbour area should be taller than the Burj Khalifa tower. The tower, in the shape of a "Fleur-de-Lys" and resembling a minaret, will host an observation area and will be inaugurated for the international exhibition in 2020. The design of the structure, which takes its inspiration from guyed masts, is a world first: the vertical structure of the tower, which has a constant diameter, is held at a height of 700 m by pre-stressed cables. The other end of these cables are anchored in foundation blocks.

© Calatrava

In the framework of this project, TERRASOL has provided support for SETEC TPI, who participated in the Peer Review for the foundations and the superstructure on behalf of BUREAU VERITAS, who was appointed as Third party Reviewer for the project. Our assignment was to validate the overall behaviour of the foundations by checking the detailed design documents produced by SOLETANCHE BACHY, the contractor in charge of the geotechnical works. In particular, we examined the site investigation report produced by FUGRO, the O-Cell method loading tests, and the studies of the tower foundation barrettes and of the foundations for the cable anchor structures.

TERRASOL was also involved in determining the geotechnical parameters in relation to the selected behaviour laws, as well as in designing the foundations using soil-structure interaction concepts (numerical models and analytical calculations). To check the tower foundation barrettes loaded beyond 100 MN, a 3D finite element model had to be created, which was used in particular to obtain the foundation stiffness matrices required for the structural calculation review model.

A. Guilloux and A. Abboud

Software department

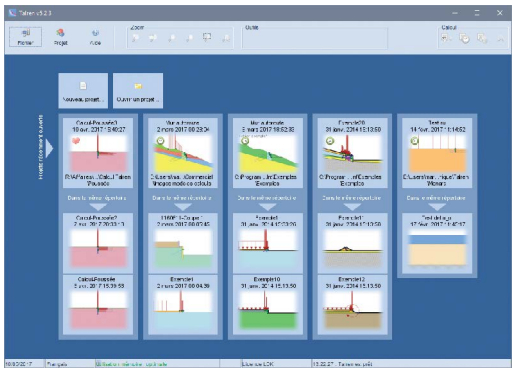
Talren v5.2.3

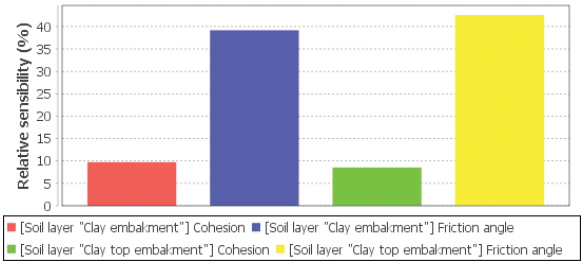
This major new update (free for Talren v5 users) was released during the 1st semester of 2017.

In scientific terms, it provides an important new feature: sensitivity studies on the input parameters of the model in order to quantify their respective contributions to the variability of safety with respect to overall project stability. The user can freely define the input parameters to be targeted and the ranges in which they vary.

In ergonomic terms, this new update offers an even more modern user interface with new data import modules: points, segments, live loads, reinforcements, etc. Compatibility with Excel© remains operational. It can also display thumbnails of recently used projects when the application is started.

Lastly, the user can now define live load or reinforcement «families» that can be used to create/manipulate sets of items with the same properties.





Conferences

Terrasol recently participated in 2 major events:

- The latest Roads, Bridges and Tunnels Fair held May 24-26 in Ankara, Turkey. Geogrup, our agent for Turkey, represented Terrasol during this event.
- Solscope 2017: 14th and 15th June in Lyon

And other events are emerging for the second semester:

- International Conference on Soil Mechanics and Geotechnical Engineering in Seoul, South Korea, from the 17th to 22nd September: we will share a booth with Basis Soft company, our local partner.
- AFTES Conference in Paris, from the 13th to the 16th November: we will be participating within the Setec group delegation.
- Indian Geotechnical Conference, from the 14th to 16th December in India: we will be present alongside our local partner Aimil.

Training

Our inter- and intra-enterprise training activities are always very intense, both in France and abroad.

Talren v5 training at Freyssinet Thailand office (Bangkok, March 2017)

The following inter-enterprise training courses are already shecduled for the end of 2017:

Talren v5	Paris	September 27th 2017
Plaxis Dynamics	Paris	September 28th and 29th 2017
K-Réa v4	Paris	October 12th 2017
Plaxis 2D	Paris	November 2017
Foxta v3	Paris	November 21st and 22nd 2017

M. Huerta

Recent publications and presentations

- *"Rencontre entre les tunneliers du Grand Paris et les carrières du Calcaire Grossier"* (**F. Binet**) – Conference at CFGI, March 30th 2017
- *"Le soutènement périphérique de l'IGH SKY 56 : des études à l'exécution"* (R. Prunel, **A. Beaussier, J. Voiron**) – Solscope Mag n° 7, April 2017
- *"Traitement des effets inertiels dans le calcul des pieux sous séisme"* (**F. Cuira**) – Conference AFPS / CFMS, May 4th 2017
- *"Mise en sécurité de champs de catiches à Lille"* (**F. Binet**) – Conference CFMS, May 4th 2017
- *"Apports de la simulation numérique tridimensionnelle dans les études de tunnels"* (**J-P. Janin**) – Revue Française de Géotechnique, June 2017
- *"Terrasol, l'ingénierie géotechnique à forte valeur ajoutée, entretien avec **Valérie Bernhardt**"* – Travaux Sols&Fondations journal, June 2017
- *"Le défi de l'ingénierie géotechnique face à la généralisation des modèles numériques"* (**F. Cuira**) – Solscope, Lyon, June 2017

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