

A new dyke at the Port of Brest



Photo credit: Panoramic Bretagne / Région Bretagne.

As part of the development of the Brest Harbour carried out by the Brittany Region, several companies of the SETEC GROUP (TERRASOL, SETEC INTERNATIONAL, SETEC HYDRATEC and SETEC IN VIVO) have been assisting BOUYGUES TP RF for the construction of a 860 meters long dyke-embankment, from the tendering and negotiation phase up until the current execution phase. The dyke will close up on the new wharf, which is under construction, allowing the creation of a future 14 ha polder (in addition to the existing 30 ha polder under development), designed for the Renewable Marine Energy sector. The new polder will be backfilled using materials from the dredging of both the main access channel to the harbour and the wharves' trenches of the terminals (500.000 m³ from the dredging of the trench of the new terminal's wharf). In total, there are 12 contracts for maritime and onshore works, managed between 2015 and 2020, that will allow not only the adaptation of the Brest Harbour to the new maritime transport standards, but also to promote its economic growth, and, by opening up to new industries, to diversify its activity.

The dyke being built consists of a series of circular sheetpile enclosures (AS-500) called "gabionades" (26 gabions and 25 festoons), covered on the sea-side by a riprap embankment. This alternative solution proposed by the contractor has replaced the embankment dam initially planned during the design phase.

The construction of the dyke is in progress and is carried out by onshore means using a temporary jetty (140 m) with supply and storage through

maritime means. The vibrosinking of the sheetpiles (20 to 33 m) is performed using a double-level circular sheetpile driving guide placed on metal tubes previously driven down to the bedrock. After the gabionade backfilling, the layers of the armour embankment are implemented.

The geology of the Brest Harbour area consists of recent alluvial formations with muddy facies of about ten meters thick characterized by a high compressibility, and of a shaly bedrock. The construction solution adopted allows to maintain the muds in place by installing a network of vertical drains (415 km) on the height of the sediments layer, in order to accelerate the consolidation and to anticipate the primary and secondary settlements of the global structure.

The studies carried out by TERRASOL allowed to justify the dyke's design by checking the gabionade's stability, its structural integrity and the riprap embankment stability; all of this taking into account the interaction between both parts of the structure. The gabionade is subjected to the active earth pressures, to the tides (differential of 5 m), to the swell, and to operating loads.

The structure verification takes into account the various shear failure mechanisms that can develop in terms of external stability (sliding, bearing capacity and eccentricity) and of internal stability (vertical shear failure, internal soil failure - Brinch-Hansen type, sheetpiles tensile failure and declutching of the locks). These checks are carried out with analytical models using Talren and K-Réa softwares, which are developed by TERRASOL. It should be noted that an area with a deeper

Editorial

Given our high level of activity over the past 2 years, the launch of the Eole and the Grand Paris Express works phases, and taking into account the positive prospects for 2019, we have decided to strengthen significantly our team in both Paris and Lyon, thus increasing our workforce to more than 75 employees at the beginning of 2019.

In addition to our current projects in France, we are particularly active in the United Kingdom, in Sub-Saharan Africa, in the Middle East, and in Colombia (where we work in collaboration with SETEC GÓMEZ CAJIAO): many different regions where we develop our engineering and expertise services, directly or through the Setec group.

Our current activity covers a wide variety of construction projects, from underground structures and transport infrastructure, to large civil engineering structures, high-rise buildings, and harbour works, including soil-structure interaction and seismic design.

We are also planning to further develop our training sessions dedicated to geotechnical modelling and design, resulting in a new 2019 training catalogue that will include sessions in France and abroad.

The whole Terrasol team wishes you a very happy New Year 2019!

V. Bernhardt

bedrock level required additional 3D finite element modelling.

This analysis also made it possible to define the drains mesh associated with intermediate backfilling and consolidation phases, allowing for an increase of the short-term (undrained) mud layers strength as well as for the structure's consolidation in the long term.

The teams in charge of the studies and the construction worked in a continuous flow of communication in order to reach a schedule complying with the partial and overall deadlines of the project.

The engineers of TERRASOL are proud to have contributed with their experience to this major project, one of the few projects of this scale in the field of French civil port works.

A. Abboud and C. Borely

Follow-up of works on Line 15 South-West of the "Grand Paris Express"

Paris, France



Within the SETEC project management teams, ten TERRASOL engineers are presently involved in the site monitoring of the Grand Paris Express project, four of which are working on the follow-up of the packages T3B (Fort d'Issy Vanves-Clamart "FIVC" Station) and T3C (5 stations, 8 km of tunnel and 8 ancillary structures) of Line 15, South-West part.

In addition to the "Visa" assignment (control of the detailed design) regarding the geotechnical aspects, TERRASOL ensures the control and follow-up of the construction works carried out by the CAP consortium on this outstanding project: the impressive excavation of the circular shaft of the "IGR" station, currently at 30 m of depth; the successful execution of diaphragm walls under the train line RER B in the area of Cachan; the first tunnel boring machine is being assembled at the Robespierre shaft at Bagneux; and the first time a VSM (Vertical Shaft Machine) is used in France in this autumn of 2018.

Regarding the FIVC station, TERRASOL initiated a CIFRE PhD when the works started, in order to develop a better understanding of the deep excavations' behaviour. This was achieved by reinforcing the classical monitoring equipment with advanced devices such as fiber optics and pressure cells. The results analysis is underway; they will be reflected in a paper developed in partnership with Soletanche Bachy programmed to be published at the ECSMGE Conference in Reykjavik in September 2019.

G. Chapron

Reconstruction of the Chirajara Bridge

Colombia

Following the collapse of the Chirajara cable-stayed bridge in Colombia on January 25, 2018, a call for tenders was issued for its reconstruction. TERRASOL assisted the consortium of contractors led by EIFFAGE GENIE CIVIL on the foundation design of the new structure. The foundations were particularly decisive since the two piers under construction were each based on a single shaft with a diameter of 8 m and depth of 32/42 m, and it was of interest to reuse them for the new bridge.

Following a detailed analysis of the expertise reports (focusing on a structural explanation of the collapse), of the condition of the foundations after the disaster, of the additional stability analyses produced by the BIEP, and a site visit, we were able to conclude that the existing foundations were fit to be reused, especially considering that the new project generates lower solicitations on the foundations than the initial design. In any case, some vigilance points have to be carefully monitored during works, particularly regarding slope stability, given that the slopes were heavily damaged during the accident and the demolition works.



Photo credit: Setec TPI

The consortium EIFFAGE GENIE CIVIL / PUENTES Y TORONES, to which the contract was awarded, has renewed its trust in TERRASOL, entrusting us with the geotechnical studies and the follow-up during the works phase, in collaboration with our colleagues of SETEC GÓMEZ CAJIAO, while SETEC TPI is in charge of the structural studies.

A. Guilloux and J. Marlinge

Turin–Lyon railway link

France / Italy

The S2IP consortium lead by SETEC TPI and including SYSTRA, ITALFERR and PINI SWISS ENGINEERS won the call for tenders for the project management of the CO6 and CO7 Operational Worksites, as part of the european "TELT" project (Turin-Lyon railway link). These sites correspond to the excavation of the central part of the base tunnel between PM 6 + 760 and PM 29 + 900 (ie 23 km). They also include the extension of the excavations carried out as part of the "SMP4" exploratory works: this involves the connection of the Saint-Martin-la-Porte and La Praz access tunnels to the South tube.

TERRASOL is involved mainly to study the topic of the deferred behaviour (squeezing) of the carbonaceous shales at the crossing of the Briançonnais coal grounds. In this context, we were led to analyse the large volume of data collected throughout the excavation works of the exploratory galleries in the coal grounds. After a first phase of appropriation of the works already carried out, and after a detailed analysis of the collected data (geology, in-situ measurements, monitoring, ...), we were able to approach analytically the soil behaviour along the base tunnel. In a second phase, the mechanical and deferred behaviour of the massif could be adjusted thanks to 2D and 3D numerical studies performed as back-analysis using FLAC software. The numerical model thus obtained made it possible to approach satisfactorily the massif behaviour observed during the excavation of the SMP4 gallery as well as to justify the temporary support and final lining (for 120 years).



The main challenges during this study were the very tight deadlines (< 5 months), the important amount of data collected over more than 10 years, and the intrinsic complexity of the project. The monitoring measurements (convergences, convergences' speeds, extrusions...) could be globally calibrated with the same behaviour law thanks to the back-analysis.

J.P. Janin and T. Rossi

Testimonio II Project

Monaco

In 2016, TERRASOL started its studies regarding both the retaining structures of the Testimonio II project - a 25-floor tower with 13 parking levels - and its impact on the nearby structures. The Owner of this project is SAM TESTIMONIO II (represented by MARZOCCO group and VINCI IMMOBILIER). The architects of the project are ALEXANDRE GIRALDI and ARQUITECTONICA, and the works are executed by SATRI and VINCI CONSTRUCTION. VINCI CONSTRUCTION MONACO entrusted TERRASOL with the geotechnical studies during the execution phase.

The project is located in Monaco in a steep hillside composed mainly of screes overlying the marly bedrock in which are anchored the retaining walls and the barrettes that support the structure. The project footprint is constrained and the new tower is surrounded by sensitive structures. To date, TERRASOL has built three 3D finite element models (using PLAXIS 3D software), in order to study successively:

- compliance with deformation thresholds of nearby structures as part of the initial solution: lightweight embankment in the Aval Florida area;
- impact of the first alternative solution (vertical soil-nailing wall) in the Aval Florida area;
- impact of the removal of the counter-wall from the "armrests".

Due to the project's complex geometry and its location at the foot of the hillside, a strong 3D effect leads to vertical shear stresses in the armrests. It has therefore been necessary to consider sliding between the side panels using interfaces between the volume elements representing the wall. These models, which are exceptionally large (more than a million nodes), required several months of work, powerful computers, and the anticipated use of the 2018 version of PLAXIS 3D software to make the system's numeric resolution possible.

A. Bergère and P. De Oliveira

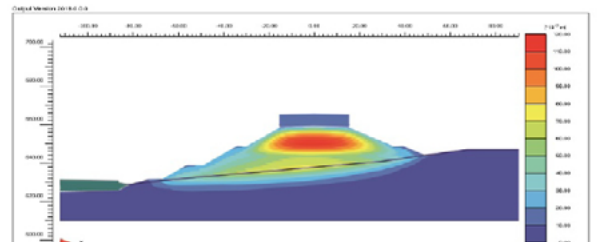


Photo credit: Kairos/Réalis

Optimized design of high embankments for the RN88 road

Baraqueville, France

With a length of 14.3 km, the Baraqueville bypass (Aveyron) requires the construction of five "high-rise" embankments (as defined in the guide of Road Earthworks, "Guide des Terrassements Routiers"). This type of embankments, with a height greater than 10/15 m, do not only present challenges related with berms stability, settlements and punching. It is crucial to also consider the internal deformations governed by the hydric evolutions within these unsaturated materials. Indeed, the deformations of the embankment related to the variations of the hydric states are not specific to large embankments; but for these, the energy used for compaction is lower than the loading effect of the overlying layers in the final situation, meaning that the amplitudes of these deformations can be significant ("initial loading" situation).



Conventionally, safety with respect to this limit state is achieved by using, at the base of the high embankments, either non-evolving and waterproof materials (severely missing in the bypass' excavated materials) or materials reinforced with binders.

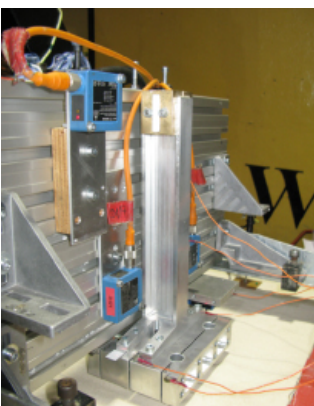
TERRASOL, as part of the geotechnical diagnostic and design assignment entrusted by DREAL OCCITANIE, assisted the South-West Interdepartmental Roads Department on the design of these embankments, which includes:

- The definition of the area that requires implementation specifications, based on laboratory mechanical tests;
- The definition of possible optimized treatment solutions for the bottom part of the embankment.

A. Beaussier

Seismic response of shallow and deep foundations

Development of macro elements



TERRASOL continues to create original computing tools, this time focusing on the development of macro elements to deepen the notion of seismic stability with an estimation of irreversible post-earthquake displacements. The goal is to quantify realistically the inertial efforts transmitted by the upper structure to its foundations. By considering irreversible displacements, even if minimal, it is possible to decrease significantly these efforts compared to calculations that consider a linear elastic behaviour.

In the field of seismic calculations for deep foundations, TERRASOL engaged in a CIFRE PhD work in collaboration with IFSTTAR and ECOLE CENTRALE DE NANTES, in order to develop a macro element capable of estimating the dynamic impedance of a group of piles, accounting for the non-linear effects that characterize the pile / soil / structure interaction. This macro element is being calibrated from numerical modeling as well as physical modeling using a centrifuge.

As for seismic calculations of shallow foundations, we carry out a Research and Development assignment on behalf of EDF-TEGG, aiming to implement in Code_Aster a seismic macro-element which represents the behaviour of an extended shallow foundation (raft type). Simultaneously, we just developed an autonomous computing tool, called FONDSIS, based on an extension of the stick model to the case of a non-linear calculation: the upper structure and

the foundation soil are represented by a set of masses, springs and dampers; the soil / structure interface accounts for several combined non linear mechanisms: bearing capacity, sliding and eccentricity.

S. Burlon and F. Cuira

Terrasol software in Colombia

TERRASOL took part in the XVIth Colombian Geotechnical Conference (GCC) in Paipa, alongside our colleagues from SETEC GÓMEZ-CAJIAO. This conference, organized by the Colombian Society for Geotechnical Engineering (SCG) and entitled this year "Infrastructures and Geotechnical Risks", took place from the 7th to the 10th of November 2018.

We had the opportunity to present the software developed by TERRASOL (Foxta, K-Réa and Talren) to a number of Colombian engineers from universities and companies, and we plan to equip several Colombian universities with our software from the 1st semester 2019 onwards.



Presentation of the Terrasol software at the XVIth CCG (Colombia), November 2018

Slake

Terrasol has finished the development of Slake, our new software dedicated to quantitative analysis of liquefaction hazards of soils under seismic loading, through the application of the direct semi-empirical method known as "NCEER" (Youd and Idriss, 2001). Slake will be released to some beta-testers at the beginning of 2019, before being integrated into the TERRASOL software catalog during the first semester of 2019. Feel free to contact us if you wish to be one of our beta testers!

Training

The public training sessions scheduled in Paris for the first semester of 2019 are as follows:

- Talren v5 on April 1, 2019 and October 14, 2019
- K-Réa v4 on April 2, 2019 and October 15, 2019
- Foxta v3 on April 3 and 4, 2019 and on October 16 and 17, 2019
- Plaxis 2D on March 28 and 29, 2019 - June 19 and 20, 2019 and from November 4 to 6, 2019

Contact us if you wish to organize in-house training sessions about geotechnical design and modelling, whether in France or abroad.



Training on foundation design using Foxta v3 for Bauer in Abu Dhabi, November 2018

M. Huerta

Recent publications and presentations

- Kinematic interaction of piles under seismic loading (**J. Perez-Herreros, F. Cuira**, S. Escoffier and P. Kotronis) – ICPMG Conference, London, July 2018
- "Modélisation numérique des ouvrages géotechniques" (E. Bourgeois, **S. Burlon** and **F. Cuira**) – Techniques de l'Ingénieur, July 2018
- "L'impact du numérique sur nos métiers" (M. Lebreton, **G. Chapron**, A. Guillen and S. Riss) – "70 ans du CFMS", Paris, October 2018
- "Le point de vue des praticiens" (JC. Robinet and **H. Le Bissonnais**) – Technical session CFMS / CFMR "Microstructure de sols et des sols argileux – conséquences pour l'ingénieur", October 2018
- Extension L11 – Adaptation of the Mairie des Lilas Station (**JP. Janin**) - The Year in Infrastructure 2018 Conference, London, October 2018
- LNG tanks on rigid inclusions: Kuwait (**C. Bernuy**, B. Hor, S. Kim, M. Song, S-Y. Alqoud) – Innovative Infrastructure Solutions, Springer, November 2018 and GeoMEast 2018 Conference, Cairo, November 2018
- "Fonctionnement des éoliennes offshore : charges, sollicitations, interaction sol-structure" (**F. Ropers**) – Technical session CFMS "Fondations d'éoliennes offshore", Marne-la-Vallée, December 2018
- Modellazione numerica 2D e 3D nel progetto di opere sotterranee per l'estensione della linea 14 Métro di Parigi (**JP. Janin**, O. Gastebled and A. Martin) – Revue Ingenio, 2018
- Book "Calcul des fondations superficielles et profondes" (R. Frank, **F. Cuira** and **S. Burlon**) – Presses des Ponts, December 2018



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