

A new launch complex for Ariane 6 in Kourou, Guyana



The Ariane 6 project aims to develop a new launch unit, with the main objective of providing low-cost independent access to space for Europe. The Ariane 6 programme was undertaken following the conclusions of the European Space Agency Ministerial Council meeting on December 2, 2014. The Ground Segment development programme is managed by the CENTRE NATIONAL D'ÉTUDES SPATIALES (CNES), based in Toulouse. The ECLAIR 6 consortium, with EIFFAGE GENIE CIVIL as lead contractor, is responsible for the construction of the infrastructure of the new launch complex (ELA4). The declaration of the Ariane 6 programme includes a schedule with a first launch end of 2020.

In this demanding context in terms of scheduling and cost control, EIFFAGE GENIE CIVIL entrusted TERRASOL with the geotechnical detailed design of the structures.

The new launch unit is located at the Guyana Space Centre, in Kourou. The space centre is on the former coastal plain of Guyana, and the ELA4 site itself is in a savannah zone. The former coastal plain consists of marine deposits of the Coswine series (sands and variegated clays), sandy deposits and silty deposits with lateral variation of facies, resulting from Quaternary sea level changes. These recent deposits overlay granitic material, encountered in the form of multicoloured and often micaeous rock breakdown products, over

the ancient bedrock made of plutonic or grainy metamorphic rocks, showing surface weathering to a depth of around ten centimetres.

Despite a subhorizontal spatial distribution of the top of the granular disintegration, the ancient bedrock presents abrupt level variations on the scale of the site. This high level of heterogeneity is the source of one of the main geotechnical hazards of the project; the additional investigations during construction phase focused on reducing this uncertainty. The length of the piles under the various structures (launcher assembly building, water tower, mobile gantry crane, etc) will thus be adjusted during construction.

And the recent unconsolidated formations raise the main geotechnical issues for the shallow foundations.

Although the site is not located in a seismic area, the thrust of the launcher on lift-off requires a verification (non critical) of the foundations under dynamic loading.

Lastly, the flame trenches under the future Ariane 6 launchpad will be equipped with foundations to a depth of 30 m below groundlevel. Their construction involves the opening of a large "mixed" excavation, with intermediate berms, down to the bedrock, where the excavation is continued by blasting. A watertight barrier, consisting of a bentonite-cement mixture, is executed

Editorial

The second half of 2016 has been particularly busy for the TERRASOL teams, which have responded to many requests. These have included work on flagship projects such as the new launch complex for Ariane 6 in French Guyana and the CERN LHC project, as well as other projects in new or fast-growing sectors such as offshore wind turbine foundations and management/reuse of excavated material.

And of course the "Grand Paris" project in its broadest sense continues to mobilise us to a great extent: while we are still working on design stages for some of the work packages, the construction phase has started on Fort d'Issy/Vanves/Clamart station, and our involvement in these works phases is going to grow substantially in the coming months and years, with reinforcement of our teams in consequence.

Among our successes in 2016, the development of our training activity should be noted. The widening scope, from software-centered topics to geotechnical modelling in the broader sense, was confirmed, and there was increasing international roll-out of our courses, particularly in Africa (Morocco, Algeria, Senegal, etc.). More than ever, transmission of our know-how is a major component of our job, and many Terrasol engineers contribute to these sessions.

With our best wishes for a 2017 full of new challenges!

V. Bernhardt

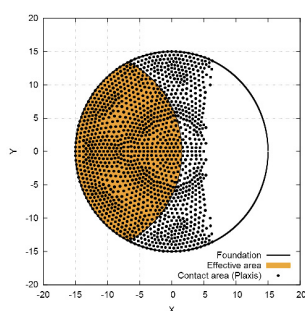
using a clamshell grab and extended by rock grouting in order to ensure dry conditions for the earthworks.

This project is an exciting opportunity for TERRASOL in the field of the space industry. The logistic conditions in French Guyana and the demanding constraints in terms of construction schedule optimisation will be the main challenges for TERRASOL to face in the coming months.

C. Babin and M. Hocdé

Offshore wind turbines

France



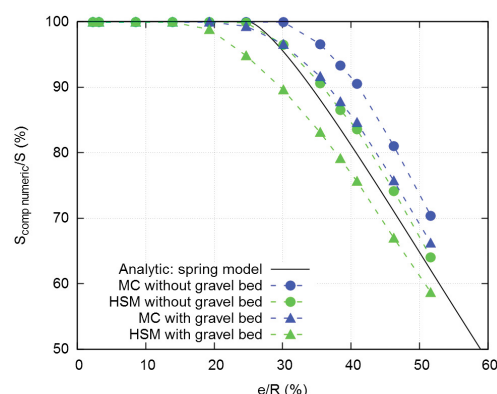
TERRASOL has conducted an in-depth study for EDF-EN on the behaviour of the gravity foundations for offshore wind turbines. The aim of the study was to characterise the disbond, stiffness and stability of gravity foundations, considering various combinations of loads, stratigraphies and foundation geometries (circular or annular with various internal diameters).

Several calculation approaches were applied: analytical, semi-analytical using Foxta, and numerical with finite elements using Plaxis. The influence of the constitutive models used in the finite-element calculations was also studied. The results obtained were compared with the

existing recommendations on the topic (DNV, GLW guideline, Eurocodes, research papers, etc).

The parametric study highlighted the relevance of the analytical approaches compared with over-simplified finite-element numerical approaches. However, when the site stratigraphy is not suitable for application of the analytical methods from the literature, simplified numerical or semi-analytical methods are nevertheless of interest for setting the calculation models.

J.F. Bruchon and F. Cuira



Underpasses under the A16 motorway

Calais, France

TERRASOL has been contracted by RTE (French transmission system operator) for various stages of studies and works follow-up concerning two underpasses under the A16 motorway near Calais.

Each passage is intended to accommodate 4 to 6 high-voltage cables and 2 to 4 series of telecom cables running under the motorway. The technical, operational and financial feasibility of various trenchless working methods has been examined: directional drilling, microtunnelling, auger driving (single-flight or guided) and driving. For the two sites under study, appropriate additional geotechnical investigations were necessary in order to refine the choice of methods and reduce the uncertainties. The geotechnical conditions were of primary importance in the selection of the most relevant execution method.

Risk analyses were performed and used to estimate the residual risks associated with each solution and to enable reliable comparison between them.

We then defined the technical characteristics of the selected methods and used finite-element calculations (Plaxis) to estimate the settlements induced by the works under the motorway. The equipment and site facilities were also considered, along with a financial estimate and a schedule for each method. Lastly, TERRASOL is supporting RTE for the next phases: "DCE" (tendering document package), contract award, and works follow-up.



Microtunneling machine breakthrough

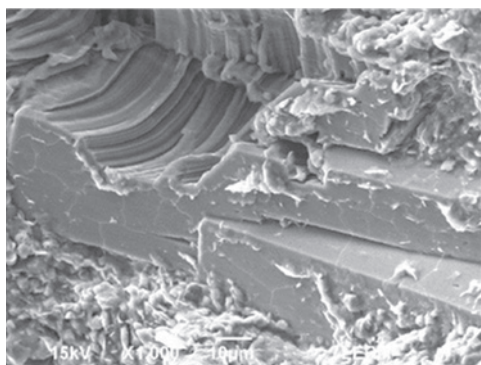
Photo credit: Entreprise Valentin

P. Bemani

Reuse of excavated materials of the "Grand Paris Express"

Paris, France

The SOCIÉTÉ DU GRAND PARIS entrusted TERRASOL, as part of its services of geotechnical assistance to owner for sections T1 and T5a of the "Grand Paris Express", with a specific consultancy assignment: it consists in identifying and characterising, from the design phase, the options for reuse of the materials that will be produced by the excavation of the approximately 30 km of tunnel of these sections of the project.



Details of the large calcium sulfate crystals (scanning electron microscopy)
Photo credit: LERM 2016.

The tunnels are to be bored in the particular context of the formations North of Paris (mainly marls and gypsum beds, Saint-Ouen marly limestone and Beauchamp clayey sands), which are heterogeneous with a high gypsum content. The definition of the properties of the materials, whether physical (grain size distribution for instance), chemical or mineralogical (sulphates content and speciation) determine the techno-economic feasibility of potential reuse.

TERRASOL has called upon the SETEC subsidiary specialising in materials (LERM) to contribute to the three parts of this assignment: assessment of the possibilities of reuse (definition of the natures, states and volumes of material depending on the structure of the tunnel faces and the excavation techniques, identification of potential reuse processes); definition, supervision and execution of specific additional surveys (sampling, management of material sorting tests according to specifically-defined protocols, analysis of the mineralogical composition of the formations); and lastly drafting of test protocols for fast characterisation of the materials, applicable on site.

J. Marlinge and H. Le Bissonnais

Rabat river cliff

Morocco



As part of the works to reinforce the river cliff in Rabat, the consortium formed by the consultants TERRASOL and INGEAB was commissioned by the owner RABAT RÉGION AMÉNAGEMENT (RRA) to conduct a study of phase 1 of the cliff reinforcement.

With an average height of 20 m, the cliff fits into a lithological framework formed by gravelly clays in the uppermost part underlain by a sandstone slab supported by a friable calcarenite (shell sandstone sand) subject to pronounced erosion.

Situated alongside the mouth of the Bouregreg river, the cliff presents several signs of instability, including a network of cracks forming unstable wedges and metre-scale undercuts of the sandstone slab.

Because of the owner's requirement for maximum preservation of the historical charm of the cliff and consequent avoidance of systematic use of shotcrete for its reinforcement, the selected treatment consisted in building a soil-nailed wall to reinforce the loose and uppermost part of the cliff, using shotcrete the same colour as the cliff, then reinforcement by nails 8 to 12 m long associated with a plastic-coated galvanised mesh laid to secure the cracked rock blocks and the potentially unstable wedges. It should be noted that the reinforcement and grid-laying operations necessitated acrobatic works and lightweight drilling equipment for work on the cliff face.

Regular site visits were conducted by TERRASOL's Moroccan representative. They covered the follow-up of the remedial operations, the follow-up and validation of the nails pull-out tests, and technical advices on specific adjustments.

T. El Malki and F. Binet

Brest cable car: a first in France

Brest, France

The first urban cable car in France has been linking the two banks of the Penfeld river in Brest for the last few weeks. It connects the Siam and Les Capucins districts and fits perfectly into a port and industry environment.

The BOUYGUES / BMF / HALET VILLETTE ARCHITECTES / SETEC consortium won the construction contract for this cable car system in 2014. Within the framework of this consortium, TERRASOL was assigned through SETEC to conduct the foundations studies.

The cable car travels a length of 420 m, reaching a height of 65 m in an urban context, i.e. a sensitive environment. One of the issues raised by the project concerned the absorption of the tensile forces (several hundred tons) transmitted to the supports during cable car operation: a system of anchoring by pre-stressed tie-rods was used to anchor one of the supports firmly into the Brest gneiss, a highly metamorphized rock of magmatic origin. The upper station and the pylon below are anchored using micropiles cleverly placed to reduce interfering efforts. Lastly, the studies considered the seismic context in the framework of this structure which is ranked in the importance category I.



TERRASOL was involved in all the phases of this pioneering project, which was inaugurated in mid-November 2016.

U. S. Okyay

Training and teaching

France and abroad



The TERRASOL teams have always invested substantial time and effort in training in the broadest sense: transmission of knowledge, whether to future engineers or to working engineers, is one of our priorities. TERRASOL staff contribute to the initial training of geotechnical engineers within several engineering schools: Ecole des Ponts ParisTech, Mastère AFTES, ENSG, Polytech'Grenoble, EOST, CHEC, Institut Lasalle Beauvais, CNAM, ESITC, ESTP and others.

Several of our experts are also involved in continuing education with organizations such as PFC and ESITC. These contributions cover very extensive areas, such as the effects of water within soils, numerical modelling in geotechnical engineering, or seismic design of structures.

Lastly, TERRASOL is approved by French authorities as a training organization, and year-by-year is expanding its own range of inter- and intra-company training courses, both geographically, with more and more sessions organised abroad and particularly in Africa; and in terms of topics, with training on numerical modelling of geotechnical structures or the application of the Eurocodes, for example, going well beyond the aspects related to the use of the software itself.

And the results have been successful, since in 2016 we trained more than 300 engineers in 30 sessions.

F. Cuira and M. Huerta

Software department



Foxta v3

A number of developments eagerly awaited by our users are now in the pipeline for the upcoming version v4 of our foundations design software. This new upgrade will include:

- a new module for calculations of semi-deep foundations;
- generation of interaction diagrams and extension of the "alternative solutions" feature to all Foxta modules;
- generation of triangular meshes in Tasplaq, enabling for locally-refined results while optimising computing times;
- taking footing deformation into account in Groupie+;
- processing in Taspie+ of a finite number of inclusions (taking edge effects into account) and ability to simulate thermal effects (geothermal foundations).

An optimised interface will accommodate all these developments during 2017.

K-Réa v4

Our retaining walls design software is evolving towards still better user-friendliness and more features. The latest update includes new wizards awaited by our users, among which: a wizard for circular walls definition, which determines a cylindrical rigidity variable with depth as a function of the vertical execution tolerance; a wizard for taking coefficient β_D into account for U-type sheetpiles; a new wizard for calculating the stiffness of a bracing-footing system.

Talren v5

Our software for stability verification of geotechnical structures is also continuing its evolution, with the opening of ever-broader fields of application, for example through the many options enabled by the yield design method. In addition, the capability of performing sensitivity or reliability calculations, already operational in-house, will be incorporated into the Talren commercial version during 2017.

Congresses

During the second half of the year, TERRASOL has taken part in the "Journées Nationales de Géotechnique et de Géologie de l'Ingénieur" (JNGG) in Nancy, the "5th Congrès Maghrébin en Ingénierie Géotechnique" in Marrakech, and the SITP in Algiers: at each of these events, our attendance took the form of a number of publications and contributions, as well as an exhibition booth.



TERRASOL's booth at SITP, Algiers, Nov. 2016

Training

The second half of 2016 saw continuing intense inter- and intra-company training activity both in France and abroad (see also our article in the inside pages).

The following inter-company training sessions are already scheduled for 2017:

Talren v5	February 2 nd 2017
Plaxis: geotechnics in urban environment	March 9 th and 10 th 2017
K-Réa v4	March 16 th 2017
Plaxis: offshore	April 20 th 2017
Foxta v3	May 17 th and 18 th 2017

Please check our website for the full program of our courses, or contact us directly for an in-house training estimate.

M. Huerta and F. Cuira

Recent publications and presentations

Journées Nationales de Géotechnique et de Géologie de l'Ingénieur, Nancy, July 2016

- "Apports de la méthode cinématique du calcul à la rupture pour la conception des soutènements" (F. Cuira and B. Simon)
- "Apports de l'interaction sol-structure dans la conception des fondations" (F. Cuira and B. Simon)
- "Considérations pratiques autour de modèles numériques de certaines gares du futur Grand Paris" (G. Chapron, K. Nejjar, H. Le Bissonnais and F. Cuira)
- "Fondation d'un IGH en environnement contraint" (E. Cazès, A. Bergère, F. Cuira and B. Simon)
- "Modélisation d'un système d'interaction sol-pieu-structure pour un groupe de pieux géothermiques" (C. Borély, F. Cuira and U.S. Okyay)
- "Analyse et rétro-analyse du comportement des fondations d'un ouvrage d'art de la LGV SEA" (K.V. Nguyen, P.L. Loriferne and F. Mathoniere)
- "Conception et dimensionnement des fondations d'un IGH en milieu karstique – Le futur Palais de Justice de Paris" (A. Beaussier and P. Reiffsteck)

5th Congrès Maghrébin en Ingénierie Géotechnique, Marrakech, October 2016

- "Les glissements de talus sur le réseau autoroutier marocain" (A. Guilloux)
- "Essai pressiométrique et calculs par éléments finis" (F. Cuira and E. Flavigny)
- "Les excavations en milieu urbain, exemple de confortement de deux fouilles urbaines au Maroc" (T. El Malki, J.F. Bruchon and F. Cuira)
- "Application de la méthode observationnelle pour le renforcement de talus de déblais par clouage – Projet d'autoroute Est-Ouest Algérienne" (M. Yahia-Aissa and P. Brossier)

Other

- "TERRASOL : un engagement fort sur le Grand Paris Express" (H. Le Bissonnais, K. Nejjar, F. Cuira and G. Chapron) – Solscope mag. N°6, November 2016
- "Brazzaville – La route de la corniche et le pont du 15 août 1960" (S. Reynaud, A. Zonco, J.B. Detry, J. Drivet) – Travaux journal n°928, November 2016
- "Retour d'expérience de chantiers récents de tunnels" (P. Brossier) – SITP, Algiers, November 2016



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