La Lettre

n°22 June 2013

Uncertainties and risk analysis in geotechnical engineering

Edito

In contrast to the end of 2012, which was marked by a slight slowing of our activities following the postponement or delaying of certain projects, the first half of 2013 has been particularly active for all our teams:

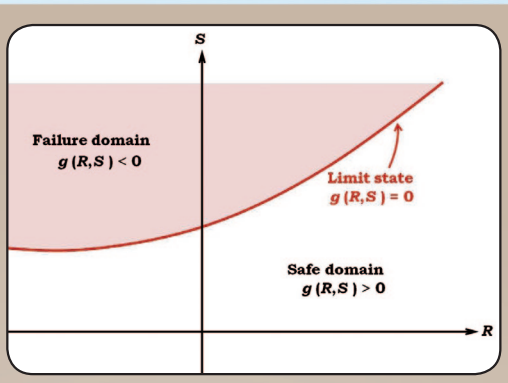
- On the commercial level, we are very busy with current invitations to tender, be it for geotechnical management of major projects in an integrated team with the other companies in the Setec Group, such as the first sections of the Grand Paris Express or the underground storage of radioactive waste for Andra (Cigeo project), or for assistance to construction companies on major projects such as the Rennes metro or the next phase of Saint-Martin-La-Porte adit for the Lyon-Turin HSL project;
- Activity is also particularly intense on ongoing projects, with the end of the preliminary project phase for the extension of the Eole line between Saint-Lazare and La Défense and the geotechnical studies for the extension of Paris metro line 14, various assignments on French High Speed Railway lines (East European, Rhin-Rhône, Bretagne-Pays de Loire, South Europe Atlantic, Nîmes-Montpellier bypass, Provence-Alpes-Côte d'Azur), the Shah Deniz oil tanks in Azerbaijan, and various hydroelectric development projects. It should be noted that complex modelling, with multiple 3D finite element approaches, is used more and more frequently and provides significant assistance to account for soil-structure interaction when these tools are well mastered;
- Software activity in the first half of the year focused on the finalisation of the latest Talren upgrade (version 5), the marketing of which is currently starting in France, and the continued integration of the Eurocodes in our software as and when the corresponding French application standards are validated;
- Lastly, in the "Research and Development" field, we are in particular continuing our action initiated a few years ago to develop risk analysis methods in the geotechnical field, once again in line with the Eurocodes, in order to be able to complement our studies with reliability-based approaches.

All of this of course requires a lot of recruitment, and our staff will soon reach the number of 60, all of us available to assist you in the geotechnical engineering of your increasingly complex projects.

I would also like to use this editorial to inform you that we will be well represented at the next International Conference on Soil Mechanics and Geotechnical Engineering from the 2nd to the 6th of September 2013 at the «Palais des Congrès» in Paris, with active participation in the Conference Organising Committee, scientific lectures and an exhibition stand: come and join us there !

A. Guilloux

Taking uncertainties into account is a constant concern in geotechnical engineering. Everyone involved in the profession seeks to reduce these uncertainties and their effects, by proposing for example:



- Actions aimed at reducing uncertainties concerning geotechnical data and anticipating more effectively the means to react to these uncertainties. These include for example two recent evolutions relating to standards: the publishing by French Tunneling Association of recommendation GT32 on the characterisation of uncertainties and geological, hydrogeological and geotechnical risks, and the current updating of French Standard NF P 94-500 which defines the geotechnical missions and minimum geotechnical investigations to be carried out in the frame of each project. Terrasol took part in the working groups in both these cases;
- Actions enabling these uncertainties to be taken into account more effectively in the structures design; this is the issue which we have chosen to develop here, in connection with the Eurocodes in particular.

Examples of damages on standard works

Since 2009, Terrasol has undertaken research and development work focusing on risk analysis techniques and their applications in the design of geotechnical structures. This is in answer firstly to high demand from project owners faced with ageing infrastructures and a relatively undeveloped body of technical expertise in this area in France, and secondly to requests from construction companies for optimisation of projects in increasingly complex contexts, such as concessions for example.

These techniques are based on a probabilistic approach derived from the reliability theory and are used to define the safety level with respect to a failure mechanism given in the form of a probability of failure or collapse of the structure.

Thus, in this approach, the geotechnical properties are random variables described by a probability distribution with a mean value and a standard deviation. Compared to conventional design by a deterministic or semi-probabilistic approach, the use of reliability engineering techniques enables to ensure a structure is safe when the geotechnical properties present significant scatter, or to optimise its design when the scatter is limited.

This work resulted in the development of a risk analysis tool based on the approximate method known as the "Response Surface Method" (RSM) which has proved to be effective in its applications on geotechnical structures. This tool will be progressively implemented in Terrasol's calculation software in the form of a "reliability engineering design" wizard. This wizard will evaluate the probability of exceeding a limit state predefined by the user (bearing capacity, sliding, settlement, thrust, etc). The probabilities thus obtained are to be compared with the target probability values defined by Eurocode 0 for ultimate or service limit states. The method which has been developed is also intended to clarify the application of the Eurocodes when numerical methods such as the finite element method or the finite difference method are used for the structures design.

F. Cuira & B. Simon

Replacement of Malgovert penstocks

Bourg-Saint-Maurice, Savoy

The Malgovert installation is an essential link in the Haute Isère hydroelectric basin (three-quarters of the installed power, i.e. 300 MW available within minutes), and an important tool for management of the electrical network. It consists of a 15 km supply tunnel leading to two penstock lines with a length of 1500 m and an altitude difference of 750 m located on a hillside subject to slow deep movements.

The penstock replacement works were entrusted to SPIE-BATIGNOLLES, with TERRASOL as its geotechnical engineering consultant. The works require the availability of mobile cranes and the displacement of very heavy sheet metal parts to the penstocks position. Located in a slope with an average gradient of 30°, the earthworks for the site roads and platforms are tricky and require the design of numerous structures of various types: soil-nailed walls, riprap gravity walls, reinforced fills, rock-shed screens, etc.

In addition, the project is located in the mountains and on the site of an old installation. Therefore "surprises" are common - rapid variations in geology, presence of old or abandoned structures (retaining structures, foundations, tunnels, cableways, etc) – and sometimes lead to archaeological issues. The project therefore requires very close follow-up during the works and continuous design adjustment with respect to real conditions of this complex site.

F. Binet

3D modelling of geotechnical structures

Finite element calculations

More and more often, large-scale projects require complex stress-strain modelling for a better understanding of soil-structure interaction.

For a number of years, TERRASOL has been carrying out 3D finite element modelling for structures as varied as retaining structures (the Odeon Tower in Monaco), foundations of complex buildings (the Louis Vuitton Foundation for Creation, the new High Court in Paris), underground works (the extension of Paris metro line 14), foundations of civil engineering structures (the Third Bosphorus Bridge), etc.

Let's consider 2 recent cases:

- The new High Court in Paris in the Batignolles area (a 160 m high building, see opposite): the aim of the 3D modelling was to understand the behaviour and interaction of the deep foundations of the three building cores with the complex Paris geology. This model made it possible to better estimate the settlements and the load transfer within the piled-raft foundation system.
- The dismantling chamber for the metro line 14 TBM : this underground excavation is located below old buildings in the 8th Paris district. The 3D model was to prove that the compact shape of the structure and the chosen construction methods helped to limit settlements.

Through these numerous cases, we have developed our know-how, and determined the limits of such modelling. We are thereby able to propose relevant 3D approaches in accordance with specific issues and design progress of each project.

A. Beaussier, P. Reiffsteck & A. Martin

Credit: 2010-in progress - Paris Courthouse
Renzo Piano Building Workshop, architects - Render by L'Autre Image

Third Bosphorus Bridge

Istanbul, Turkey

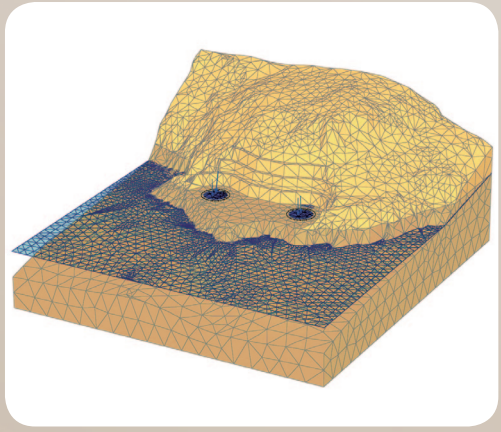
The Third Bosphorus Bridge is a cable-stayed suspension bridge with a single span of 1400 m linking the European and Asian shores of Istanbul (Turkey). Built by the Turkish-Italian consortium Içtas-Astaldi, its design was assigned to T-Ingénierie in collaboration with Michel Virlojeux. TERRASOL is currently carrying out the checking of the foundations design for SETEC TPI (Independent Checker for the project). As the first phase of this work focuses on design analysis, TERRASOL has also provided its advices for project optimisation, with the stability checking of the rock foundations, using 3D finite element calculations.

Constructed in a particularly demanding seismic context, the bridge lays on both shores on a rocky formation composed of andesite and conglomerates. Each end of the bridge is composed of:

- A 15 m deep anchor block;
- A block comprising 2 m deep shear keys enabling anchoring of the cables;
- 4 piers;
- 2 shafts (20 m in diameter and 20 m deep) to anchor the 320 m high pylons.

These pylons will exert considerable forces in the construction phase, under the effect of the wind and during the installation of the deck, and in the final phase, under the effect of deck tipping and seismic actions.

B. Aksoy



Extension of metro line 14

Paris

For more than a year and a half, TERRASOL has been carrying out missions G12 and G2 for the extension of Paris metro line 14 to Mairie de Saint-Ouen, on behalf of SYSTRA Ile de France. This project, constituting the first step in the GRAND PARIS EXPRESS network, is mainly intended to relieve congestion on metro line 13 and assist in the development of large-scale urban development zones located in the 17th Paris district and in the neighbouring cities of Clichy and Saint-Ouen.

This entirely underground extension will be excavated with a Tunnel Boring Machine (TBM) over a distance of 5.8 km (plus approximately 500 m of connection tunnel to the maintenance site) and also includes the construction of four new open-air stations with a depth of 23 to 34 m, and a number of related structures with various functions (safety, ventilation, TBM dismantling structure, etc).
This extension is located in the well-known Paris soil series, ranging from Ludian infra-gypsum marl to Lutetian coarse limestone, with a risk of gypsum dissolution.

TERRASOL's assignment combines follow-up of geotechnical soil-testing and drafting of geotechnical synthesis reports, from the preliminary project phase to the invitation to tender. TERRASOL also works on additional specific issues, such as the 3D modelling of the TBM dismantling structure. The works are scheduled to begin in the first quarter of 2014.

A. Martin

Credit: RATP/STIF

Shah Deniz phase 2

Baku, Azerbaijan

The Shah Deniz phase 2 project is intended to extend the existing Sangachal land-based gas processing and oil production terminal operated largely by BP. The terminal is located on the banks of the Caspian Sea, 50 kilometres south of Baku in Azerbaijan. The new gas and oil refinery will be adjacent to the existing one.
The extension will include in particular a new gas production platform with a capacity of 16,000 billion m^3 per year, with two additional auxiliary gas processing trains. It requires the construction of seven hydrocarbon product storage tanks.


Credit: ENTREPOSE Projets

The particularity of the site lies in the presence of "collapsible" soil with a thickness of 6 to 8 m. This surface layer mainly consists of sand grains bound in a silty-clayey matrix. The composition also includes volcanic compounds. This layer presents the distinctive feature of containing a lot of void and being sensitive to water addition. Wetting this layer causes it to collapse on itself with or without extra load. Conversely, in the natural state, this layer is protected by a crust and presents what could be described as good quality mechanical characteristics.

During the construction and operation of the extension, the protective crust may be damaged and the surface layer may thus get wet. Accidents, which have already occurred in the past on the existing terminal, may also cause wetting of this surface layer. To limit future settlement problems, the storage tanks will therefore be founded on piles reaching the lower layers.

In this special and rare context, ENTREPOSE PROJETS SAS entrusted TERRASOL with the geotechnical part and SETEC TPI with the structural aspects of the detailed design of the storage tank foundations.

C. Babin

EDF water development project in Gavet

Isère

TERRASOL is conducting a global geotechnical expertise assignment for the new Romanche-Gavet water development project in Isère, with the participation of Alain GUILLOUX on the Technical Committee. This development consists of an underground power plant equipped with two production units which will replace the six existing plants on the river Romanche and will allow production capacities to be increased by 10%. The Romanche-Gavet project is the largest water project currently being developed by EDF (French National Electricity Board) in France.

In parallel, TERRASOL is providing hydrogeological and geotechnical assistance during the works of the downstream release structures: a cofferdam was built to enable an excavation of 100 m by 30 m down to a depth of 12 m. TERRASOL was entrusted with the definition and follow-up of the geotechnical soil-testing campaign at the beginning of 2012, and the preparation of the geotechnical assumptions report. TERRASOL then carried out external control of the cofferdam detailed design documents.

In addition, it is necessary to lower the water table below the excavation level in the event of a 10-year flood, and thus to design the relevant pumping solution. TERRASOL carried out a 3D hydraulic modelling to simulate as accurately as possible the real project conditions, i.e. irregular stratigraphy and the presence of a deep confined water level. A parametric sensitivity study (flow and position of pumping wells) enabled us to optimise the pumping system.

C. Bernuy & Y. Bagagli

Software Department

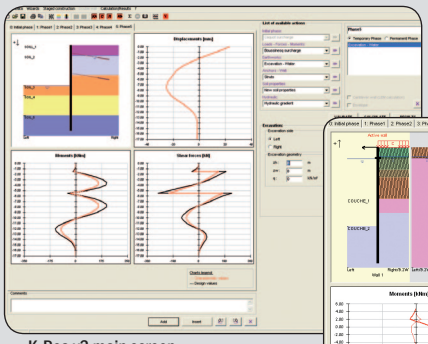
Retaining walls design: K-Rea v3 software

K-Rea v3 is a user-friendly analytical software which enables to check the design of retaining walls using the subgrade reaction calculation method.

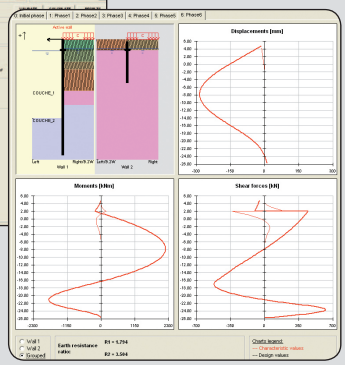
It is available in English language and includes 2 major features in addition to regular SLS calculations:

- LEM and SSIM ULS calculations and checks according to French Standard NF P 94-282 (French application of Eurocode 7 using approach 2): failure on the passive side, balance of vertical forces, and stability of the anchoring block (with simplified Kranz method).
- Calculation of double walls, with 2 possible levels of linking anchors (cofferdams, main wall anchored to a rear wall, etc).

Please check K-Rea page on Terrasol website for a demo video or download of the demo version.



K-Rea v3 main screen



Example of double-wall calculation with K-Rea

18th ICSMGE in Paris!

Terrasol is a Partner sponsor and we will have a stand during the next International Conference on Soil Mechanics and Geotechnical Engineering in Paris (France), September 2 to 6, 2013.
Some of our international agents will also attend this major event.
Join us there !

www.paris2013-icsmge.org

- Talren v5.0
- Straticad v1.4
- Foxta v3.1
- Plaxis2D 2012.00
- K-Rea v3.0
- Plaxis3D 2012.02

Focus on our agent for India

ATES division of AIMIL company became our agent for India in 2010. We already had the opportunity to participate twice with them in IGC (Indian Geotechnical Conference): in 2010 in Mumbai and in 2012 in Delhi (papers presentation and exhibition stand).

AIMIL has several offices through India, and ATES division presently develops a high-level know-how in geotechnical engineering and design.

Feel free to contact them for a software demo: atesdel@aimil.com !
Please check our website for their full coordinates, and for our full agents list.

During IGC 2012 conference

Aman Khullar and the ATES division team, at Aimil's Head Office

Recent publications and presentations

- « LGV Est Européenne – Tunnel de Saverne » (A. Cuccaroni, N. Zehani, A. Lacroix, P. Bouvatier, J. Sousa, **P. Legrand**)– Revue Travaux 894, January/February 2013
- « Calculation of Dynamic Impedances for an embedded structure: Practical concerns, limitations and suggestions » (**F. Cuira, N. Kottaki**) – ICEGE Istanbul, June 2013
- « Traitement anti-liquéfaction sous trois réservoirs GNL à Dunkerque » (M. Lebreton, **B. Simon**, D. Michel) - Revue Travaux 897, June 2013
- « South Toulon tube: numerical back-analysis on in situ measurements » (**JP. Janin**) - Plaxis Bulletin, Spring 2013

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