

## Water gallery at Dunkirk LNG terminal

As part of the Dunkirk LNG terminal works (the Contracting Authority of which is Dunkerque LNG EDF group), TERRASOL first designed the foundations of the three 190 000 m<sup>3</sup> capacity LNG tanks for the group ENTREPOSE PROJETS - BOUYGUES TP. TERRASOL was then entrusted with the design and monitoring of the hydraulic gallery excavation, executed by consortium BRS (CSM BESSAC – RAZEL-BEC – SOLÉTANCHE-BACHY), and which is intended to recover 5 to 10 % from the warm waters of the Gravelines nuclear power plant to heat the liquefied gas.

The gallery access shaft, 16 m in diameter and 50 m deep, was excavated inside a diaphragm wall (65 m deep). The tunnel, 5 km long and 3.8 m in exterior diameter (3 m in interior diameter), was excavated with an earth pressure balance (EPB) tunnel boring machine (TBM). Its complete alignment is located in the Flanders clays, a very homogeneous over-consolidated layer. Progress was satisfactory until the TBM suffered damage on April 29, 2014, when it was still under the outer harbour. The problem was a failure in the link (dowels) between the gear box and the TBM cutting wheel, making it impossible to continue excavating without repair. Moreover, the repair works had to be done from the front

of the TBM (ahead of the cutting wheel). The consortium chose to proceed by excavating a bypass tunnel about 25 metres long using conventional method, starting from the back of the TBM skirt and joining the front part, with creation of a disassembly chamber ahead of the cutting wheel.

TERRASOL was in charge of the supervision of geotechnical works for the bypass tunnel on behalf of COFIVA (Assistant to Contracting Authority Dunkerque LNG). The contractor worked in an extremely confined space, taking all necessary precautions to ensure the safety of the staff and the feasibility of the repairs: excavation in 5 phases, installation of steel arches every 40 to 80 cm, shotcrete, sheet piling cap, beams, pillars, wooden shielding, grouting. The tunnel and chamber reinforcement techniques used evolved day-by-day according to site conditions.

After a six-month interruption only (part of this delay was made up subsequently), the TBM resumed its excavation towards the Gravelines plant, a sensitive site where the TBM was not allowed to generate surface settlement of more than 1 cm. Before reaching the plant, a backfill section was used to analyse surface settlements over nearly 500 m, in order to validate the TBM parameters as it progressed and to calibrate the 3D excavation model. The pressure at the TBM face was increased progressively from 0 to 3 bars over the test section in order to determine a settlement/confinement relationship covering a large range of pressures. The analyses showed that our numerical approach was capable of representing the soil response to the tunnel excavation accurately. The settlement development is influenced by the confinement pressure, and the settlement generated behind the face is related mainly to the volume of mortar injected around the skirt.

The excavation works were completed by March 2015, and the instrumentation equipment installed by the consortium on the power plant site and monitored jointly by BRS and TERRASOL showed that surface settlements generated by the TBM did not exceed 6 mm.

The last step was to connect the tunnel to the 12 siphons of the release basins of the nuclear power plant, previously driven down to tunnel depth. This extremely delicate connection

## Edito

The first half of 2015 has confirmed our substantial involvement in transport infrastructure projects in France :

- Whether as part of Setec project management teams: Grand Paris network (Line 15 South-West and Line 14 South), and High Speed Railways (Nîmes-Montpellier bypass and New Line Provence Côte d'Azur), for example;
- Or directly for our outside clients: Rennes Metro, assistance to contracting authority for 2 sections of the Grand Paris project, various contracts for Paris metro operator and French railways company, etc.

In parallel, we are continuing our activities in all geotechnical sectors: assistance to contracting authority within Setec teams on the Seine North Europe Canal project, participation in various tower, building and civil engineering structure projects.

At the same time, our activity abroad has ranged from structures in the energy sector (Plomin power plant in Croatia, for example) to major towers (such as the emblematic Entisar Tower in Dubai), as well as infrastructure projects.

All of these services are based on calculation/modelling methods and tools under continuous development. Current projects include the development of a new calculation engine for K-Réa calculation software, and the integration of sensitivity and reliability calculations into Talren software. These tools enable us to guarantee optimised solutions to our clients for their projects (in terms of technical choices, costs, but also of design and construction completion times).

Wishing you a beautiful summer,

V. Bernhardt

method was defined by the consortium and required special equipment (rail-mounted core drilling machine with a diameter of 0.6 m) as well as small section earthworks within a confined space 1.3 m in diameter. TERRASOL worked on behalf of COFIVA to validate the connection principles and monitor on-site operations.

The gallery is scheduled to be filled with water in August 2015.

A. Bergère, H. Le Bissonnais,  
A. Despierres and S. Perrot-Minot



Credit: Dunkerque LNG – Happy Day

# Renewal of the Nantes - Saint-Gilles railway lines

France

As part of the French railway system upgrade plan, SETEC group was mandated by RFF (French Railway Infrastructure Manager) as Project Manager for the studies and the works for the complete renewal of the railway tracks between Sainte-Pazanne and Pornic and between Sainte-Pazanne and Saint-Gilles-Croix-de-Vie, a total length of 84 km. These works, intended to enable improvements including an increase in operating speeds, necessitated the replacement of the decks of a viaduct and six standard civil engineering structures built in the 1910s.

TERRASOL was involved from the preliminary design phase for the definition and design of the reinforcements to be implemented to ensure that the external stability of the abutments complies with current regulations under the future loading, which includes the new deck, the increase in operating speed and changes in train loads. Given the uncertainties on the abutment geometries, the following solutions were selected:

- Abutment reinforcement by soil nailing, enabling the checking of the geometrical assumptions and an easy adjustment of reinforcements during works,
- Vertical micropiles taking up the additional vertical loads, supplementing nailing for structures with inadequate load-bearing capacity,
- Anchoring of the fixed support of the structure by inclined micropiles, taking up the horizontal loads generated by the deck.

During the works phase, TERRASOL continued its involvement, with the checking of the detailed design and the monitoring of the works on site, including reinforced monitoring during the preparatory works in order to validate the anchors installation methods prior to the works, for which time constraints were very demanding.

A. Beaussier and A. Bachelier



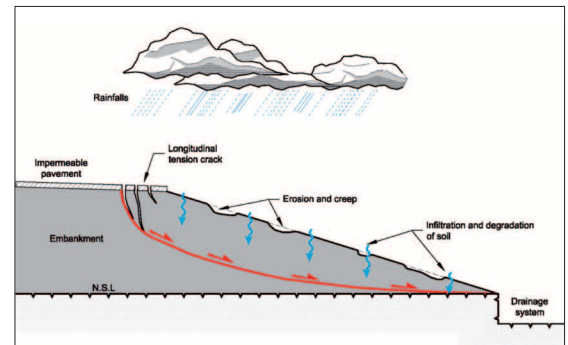
# New Islamabad International Airport

Pakistan

ADPI is the General Project Manager for the construction of the New Islamabad International Airport for the CAA (Civil Aviation Authority). The site of the new airport is located in a context of pre-Himalayan plain, with soils of sedimentary origin. The specificity of the project is the construction of a very high embankment under extremely variable weather conditions: summer temperatures regularly exceed 35 °C and there are large rainfalls at the same time. The wettest season of the year is from June to September, with heavy rains and storms.

In this particular context, the construction of a high embankment necessitates specific precautions, and TERRASOL, at the request of ADPI, has conducted an expert geotechnical assessment of the behaviour and the construction conditions of the embankments.

U.S. Okayay



# Our involvement on the “Grand Paris Express”

France

TERRASOL has a substantial involvement in the Greater Paris project, through various on-going contracts:

- Within the Project Management by SETEC teams of the Pont de Sèvres - Villejuif Louis Aragon section (Line 15 South-West), we are presently finalising the design and tender documents package, in order to issue the first calls for tenders to contractors before the end of 2015. Within the same Project Management contract, we are also monitoring the construction works for the exploratory shaft and tunnel at Arcueil-Cachan station, which are intended to test the feasibility of jet grouting columns in the plastic clays and the excavation in these highly-deformable rocks (see picture).
- Since the beginning of 2015 we have also been providing geotechnical assistance to the Contracting Authority (Société du Grand Paris), i.e. geotechnical second checking, on sections T1 (Line 16 East) and T5a (Lines 16/17) for the second soil testing phase, which will lead in to the construction phase.
- In the first half of 2015, the ELIOS consortium (SETEC/SYSTRA) was awarded the Project Management contract (studies and works) for the Olympiades-Orly section (Line 14 South). For this section with substantial geotechnical constraints, in particular due to the presence of coarse limestone quarries on the tunnel alignment, TERRASOL is responsible for all the geotechnical syntheses, and is involved more particularly on the first tunnel section between Paris and Villejuif.
- Lastly, also worth noting is the detailed design we are carrying out for the exploratory shaft and gallery in the Saint-Maur plastic clays on section T2 of Line 15 between Noisy and Villejuif.

H. Le Bissonnais, J. Marlinge and G. Chapron





# Jijel and Biskra power plants

Algeria

In 2013, the « Société Algérienne de Production de l'Électricité » (SPE), a SONELGAZ Group subsidiary, launched a project to build six combined-cycle power plants, with installed power ratings of 1200 to 1600 MW. The plants are part of its 2013/2017 development plan, with a total investment of about \$4 billion USD. Contracts for two of the plants were awarded to the South-Korean consortium HYUNDAI ENGINEERING & CONSTRUCTION / DAEWOO INTERNATIONAL, at Oumache (Biskra province) and Bellara (Jijel province), each with a capacity of 1400 MW.

In the context of the construction works, HYUNDAI E & C contracted TERRASOL to produce the geotechnical studies for both projects in order to define the most suitable foundation technique for all the equipment of the future plants.

TERRASOL defined and then supervised the soil testing campaign, which was contracted to a local company (GEOLAB). On examination of the initial results from boreholes on the Bellara site, TERRASOL, in consultation with HYUNDAI E & C, moved the project to the south, away from a highly compressible area.



Credit: HYUNDAI

Still on the Bellara site, TERRASOL subsequently identified a residual risk of lenticular zones of soft soil under the turbine foundations, potentially leading to differential settlements expected to be unacceptable for the structure. To remove this uncertainty, TERRASOL proposed an additional soil testing campaign using destructive boreholes with parameters logging.

On completion of all the soil testing, TERRASOL was able to finalise the interpretation of the geotechnical data, define the stratigraphic models and the geotechnical assumptions, and then specify the most suitable foundation technique, with preliminary design of the foundations according to the current baselines for both projects. Lastly, TERRASOL was responsible for technical assistance to the contractor during these foundation works.

M. Yahia-Aissa and C. Babin

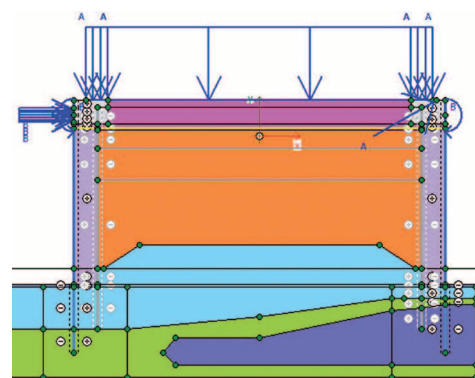
# Dakar harbour

Senegal

TERRASOL has been working for many years on port and offshore infrastructure projects on behalf of EIFFAGE SÉNÉGAL and its subcontractors, upgrading and expanding the Port Autonome de Dakar.

The local geology is specific, with alternating very compact limestone levels and softer marly levels, within which decompressed areas and clayey lenses with weak properties may also be found. TERRASOL recently contributed its geotechnical expertise to the following projects:

- Analysis of additional soil testing and updating of the foundations design for container terminal TAC1 (700 m alongside quay, foundation on 12 to 13 m deep piles);
- Geotechnical detailed design for the renovation of the foundations of an oil wharf (pier 9) by construction of a double sheet-pile wall (length 260 m, width 30 m) driven 2 m outside the existing structure, embedded in the marly limestone substratum, and anchored at the top (see picture);
- Assistance during the call for tenders for the extension of pier 8 (length about 300 m).



C. Bernuy

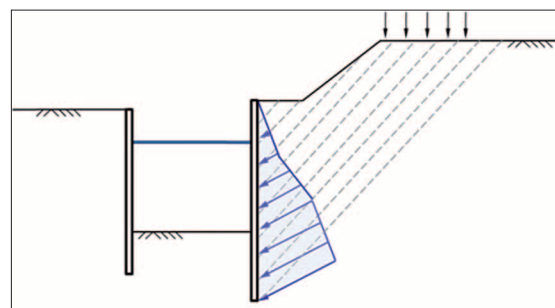
# K-Réa software

Current developments and new features

We have recently developed a new calculation engine for the K-Réa software, scheduled for integration into the commercially-available version of K-Réa in early-autumn 2015. Based on an all-matrix formulation, the new engine considerably extends the options offered by the K-Réa software for the design of retaining walls.

The new key features include:

- Automated processing of bank and berm effects using the kinematic approach with the yield design method (see picture),
- Direct processing without iterations of double-wall projects, without limitation of the number of linking anchors,
- Generalisation of initial conditions, including the possibility to define a loading history preceding the construction of the retaining wall,
- Upgrading of the anchoring conditions: local or surface anchors with capping of the anchoring reaction (elastic-plastic behaviour), generalisation of "creep" and "prestress" actions to all anchor types including linking anchors,
- Automated processing of combinations of loads applied onto the wall and the soil (necessary for harbour projects, for instance),
- Hydraulic gradient: possibility of defining a profile point by point (z, u) on each side of the wall,
- Ultimate limit state design: integration of approaches 1 and 3 of Eurocode 7 (in addition to approach 2 already included in the current version), stability analysis of the anchoring block (Kranz) extended to double-wall projects, automatic checking of the stability of the bottom of the excavation.



F. Cuira

# Software Section



Talren v5.1.1



Foxta v3.2.1



Stratcad v1.4



K-Rea v3.1.2



Plaxis2D 2015.01

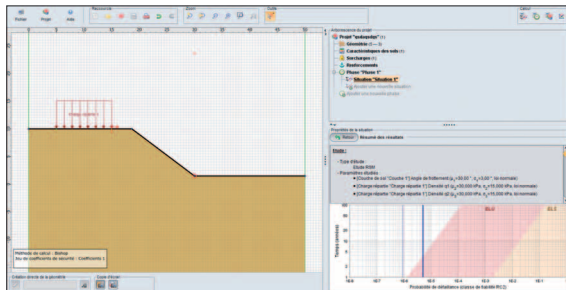


Plaxis 3D AE

## Talren v5

Since 2009 TERRASOL scientists have been undertaking research and development work on risk analysis techniques and their applications to the design of geotechnical structures. Practical results from this work will be integrated into a forthcoming update of the Talren v5 software enabling reliability calculations according to the RSM (Response Surface Methodology) method and, more generally, sensitivity analyses.

In addition, a wizard allowing for direct calculations of earth pressure diagrams in cases when the Kerisel and Absi tables are not applicable is being developed. It is intended to facilitate the analysis of retaining walls in the case of complex stratigraphy.



Talren v5 - RSM - Failure probability

## Plaxis 3D

A new version of the 3D software was released in May 2015. This new version 3D AE includes many improvements and offers new features, including a tunnel wizard for the design of complex geometries.

M. Huerta

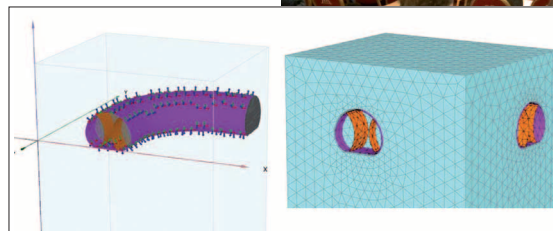
## Conferences

- TERRASOL took part in the African Regional Conference on Soil Mechanics and Geotechnical Engineering from April 27 to 30, 2015 in Hammamet, Tunisia: a good opportunity to meet our colleagues on the continent, alongside the Terrasol Tunisia team and our Algerian and Moroccan software partners.
- This summer we shall take part in the International Seminar "Numerical Analysis in Geotechnics" in Hanoi, Vietnam.
- We shall also be attending the European Regional Conference for Soil Mechanics and Geotechnical Engineering from September 13 to 17, 2015 in Edinburgh, Scotland.

## Training sessions 2015

From October 13 to 14	TERRASOL office (Paris)	Session K-Réa v4
From November 3 to 6	La Défense (Paris)	Session Plaxis 2D

African Regional Conference, Tunisia - April 2015



Plaxis 3D AE

# Recent publications and presentations

- « Solution de remblai de grande hauteur renforcé par géotextile – Lot Centre de l'Autoroute Est-Ouest algérienne (section Labartache – Lakhdaria) » (**M. Yahia-Aissa**, **P. Brossier**, L. Zhuo and S. Tabti) – Algerian Conference on Geosynthetics, January 2015
- « Renforcement des sols par clouage – Principes de stabilité interne et de dimensionnement » (**A. Guilloix** and **F. Cuira**) – Colloque sur les techniques de clouage des parois, Société Belge de Géologie de l'Ingénieur et de Mécanique des Roches, Namur (Belgium), March 2015
- Dynamic finite element analysis of the seismic behavior of a breakwater (**KV. Nguyen**, **A. Guilloix** and **J. De Cacqueray**) – CIGOS Paris, May 2015
- « Etude géotechnique d'un ouvrage d'art de la LGV SEA Tours-Bordeaux » (**KV. Nguyen**, PL. Loriferne, F. Mathonière) – CIGOS Paris, May 2015
- « La géotechnique pour la conception et la réalisation des dallages » (**B. Simon** and Luis Carpinteiro) – Information day « Dallages en béton pour l'industrie », Toulon, 21 May 2015
- Rotation failure of diaphragm walls justification – Case of particular geometric interaction (**A.M. Alzate**) – Plaxis European Users Meeting, Gescher (Germany), 28 - 29 May 2015
- International Workshop - Maritime & Port Engineering, ESITC Caen, June 2015 - **Cécile Babin** and **Bruno Simon** contributed to this workshop which was attended by students from many different nationalities, in the framework of a curriculum common to their universities and to ESITC. Their presentations focused on the stability of marine slopes, and on the use of Talren software.
- A damage-plasticity model for cohesive fractures (A. Pouya and **P. Bemani**) – International Journal of Rock Mechanics & Mining Sciences 73, 2015



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