La Lettre
Energy Geotechnics
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terrasol
setec

Alstom power plants

A long-lasting partnership

Centrale HEP Plomin, Croatia

Since 2006 and a first expert assessment report on problems on a power plant site in Argentina, ALSTOM POWER SYSTEMS has regularly called upon TERRASOL for 'soil risk' management on its projects.

ALSTOM POWER SYSTEMS is one of the major players in the energy sector, and one of its specialities is the delivery of power plants on the basis of turnkey or EPC (Engineering, Procurement and Construction) contracts. Its areas of interest encompass thermal plants (gas, oil, coal), biomass plants (often supplementing another fuel) and solar plants (using heat transfer fluid).

After several projects, it soon became clear that the specific nature of the phases with which ALSTOM has to comply necessitated the development by TERRASOL of specific working methods and task sequencing, in order to optimise its response with respect to the requirements of the projects.

The primary need is management of the soil risk, starting from the call for tenders phase, so that ALSTOM can negotiate with its client either the estimated cost of accepting this risk, or the transfer of the risk to the client. Thus a large proportion of the geotechnical investigations has to be conducted and analysed before the signature of the contract. This is essential in order to determine as accurately as possible not only the cost of the geotechnical structures but also the impact on the works schedule, which may be substantial (soil consolidation, phasing).

A specific sequencing of the geotechnical engineering tasks has therefore been developed:

- Analysis of available data (often limited) and initial feasibility study focusing on the general principles of geotechnical structures (types of foundations that can be considered, soil consolidation/reinforcement issues, dewatering, etc),
- Drafting of the first version of the Soil Baseline Assumptions report, the baseline document of the call for tenders phase which defines the assumptions made by ALSTOM for its costing and which may become contractual,
- Preparation of the first version of the Soil Risk Analysis report, in order to get insight into the identified risks of slippage,
- Preparation of the specifications for the additional soil testing intended to obtain data that is lacking and/or for which the risk analysis has revealed a high level of inaccuracy,
- Preparation of the specifications for the execution of the main geotechnical works (piles, soil reinforcement, consolidation) to be included by ALSTOM in its call for tenders to contractors,
- On-site supervision of additional investigations,
- Interpretative report on the additional investigations for a reliable and safe design of all the geotechnical structures.

It should be noted that the tasks involved here are carried out while ALSTOM is still negotiating with its client and has consequently not yet been awarded the contract to build the plant. Of course, if ALSTOM is awarded the contract, the geotechnical studies continue during the construction phase.

The duration of these tasks is often extended over a long period: it is common for the call for tenders phase to last for two years.

Since 2006, more than 45 contracts have been completed for ALSTOM POWER SYSTEMS in Europe (France, United Kingdom, Croatia, Netherlands, Belgium), in Asia (Vietnam, Malaysia, Thailand, Indonesia), in Africa (Algeria, Tunisia, Morocco, South Africa), in the Middle East (Iraq, Israel, Saudi Arabia) and in Latin America (Brazil, Argentina).

Lastly, to facilitate risk analysis, TERRASOL and ALSTOM POWER SYSTEMS have jointly developed a "logic tree" providing a simple way of not only identifying potential areas of residual risk according to the available data, but also targeting investigations to be carried out in order to assess the impact of this risk more precisely.

J. Drivet

Editorial

Energy engineering in the broadest sense brings together a multitude of skills, among which geotechnics may seem marginal.

This is not the case at all, as TERRASOL demonstrates every day through its contribution to a variety of projects (hydroelectric power, oil & gas, wind turbines, thermal power plants, nuclear power, etc), in all regions of the world.

Projects related to hydroelectric power give rise to serious geological and geotechnical issues because of the types of structures they involve (dams, tunnels), and TERRASOL has been working on such projects practically since it was founded, thanks to its competencies in underground structures and slope stability.

Large storage tanks are another of our preferred areas of work, because of the pertinence of our approaches in soil-structure interaction.

TERRASOL has also contributed to the development of calculation methods for wind turbine foundations, studying the resistance of micropiles under cyclic loading.

Lastly, although the construction works account for only about 15% of the cost of thermal power plant projects, the 'soil risk' is a fundamental parameter for project scheduling management, with a major impact in the event of slippage. Here again, TERRASOL's expertise has been sought by the major companies in the field.

We hope that you enjoy reading this "Energy" special issue, which highlights our geotechnical know-how related to the Energy field, so crucial in strategic terms.

J. Drivet

New power station in Toul

France

Credits: @ Siemens

After the one at Pont sur Sambre, POWEO built a new power station in Toul, on the site of a previous air base.

The construction of this 412 MW gas plant (combined cycle) was entrusted to SIEMENS, which called on TERRASOL's expertise to carry out the project's geotechnical design and to follow-up the foundations execution. The size of the project and the geotechnical context required 32 boreholes, 40 CPT tests (with pore pressures measurement), 16 pile load tests (static vertical tests, static horizontal tests and dynamic tests). After analysis of the results, TERRASOL designed the deep foundations (CFA piles) for the various buildings of the project and followed-up the execution (by SPIE FONDATIONS) of more than 9,100 m of piles, representing some 2,400 m^3 of concrete. TERRASOL also helped SIEMENS' project team with the constructional aspects of the various geotechnical structures (excavations, retaining walls, stability of the anti-noise protection, structure of the pavements, etc). Before its commissioning in june 2013, up to 500 persons worked on this major construction site.

J. Drivet

Vridi Energy Production Plant – CIPREL IV

Abidjan, Ivory Coast

The thermal power plant operated by the Compagnie Ivoirienne de Production d'Electricité (CIPREL) is located to the south-east of Abidjan, in the region of the Vridi Canal which links Ebrié Lagoon to the Atlantic Ocean. CEGELEC was chosen by CIPREL for the turnkey construction of a fourth-unit extension of the existing plant, enabling the production capacity to be increased by an additional 111 MW.

Credits: CEGELEC

At the request of SETEC ENERGY SOLUTIONS, which provides CEGELEC with technical assistance for aspects related to civil engineering, TERRASOL was called upon for the (G2) project geotechnical studies. TERRASOL intervened first of all with the definition of the geotechnical campaign and a mission to follow-up this campaign in June and August 2012. The soil-testing campaign was marked by the setting up of Cross-Hole tests, the conducting of which was a major first in Ivory Coast. Analysis of the tests enabled the risk of liquefaction due to the turbine vibration phenomenon to be ruled out.

In a second phase, TERRASOL designed the foundations of the various structures (turbine, steel structure, chimney, buildings, etc) adapting the techniques used on a case-by-case basis in accordance with the loading levels and strict differential settlement criteria (shallow raft foundations, micropiles, raft foundation combined with shells executed by cutting, etc).

C. Bernuy

Jijel and Biskra power plants

Algeria

Credits: HYUNDAI

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.

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

Replacement of Malgovert penstocks

Bourg-Saint-Maurice, France

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.

Credits: ©EDF - Pascal Tournaire

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

EDF water development project in Gavet

Isere, France

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 and Y. Bagagli

Tabellout dam

Texenna, Algeria

The Algerian National Dams and Transfers Agency (ANBT) has awarded to the GEIE/RAZEL/CMC/RAVENA consortium the contract for the Tabbelout dam project construction near the city of Texenna, about 70 km south of the Jijel wilaya (district), in Algeria.

The project as a whole comprises the construction of a roller-compacted concrete (RCC) dam 366 m long and 112 m high (reservoir capacity 294 hm3) and a transfer tunnel 4.3 m in diameter (finished diameter 3.5 m) 13 km long, for which a tunnel boring machine (TBM) is being used.

From the start of the works, in March 2010, a number of geotechnical problems have been identified, in particular a landslide on the left bank of the dam, but also extensive degradation of the tunnel lining segments with the development of a collapse, and blocking of the TBM for more than 6 months.

At the request of the consortium, in July 2012 TERRASOL carried out an expert assessment of the landslide of the left bank of the dam, with a full review of the risks of embankment and earthworks instability for the whole of the site.

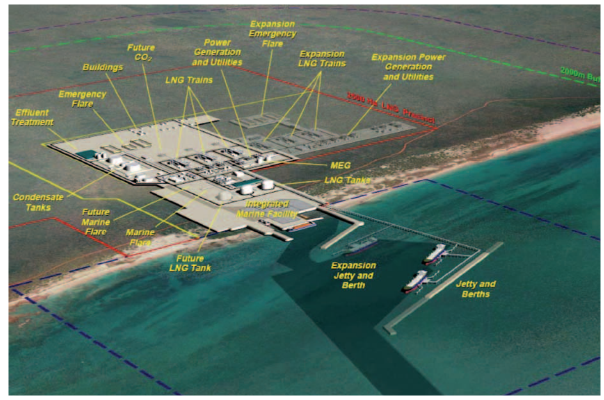
Given the complexity of the geological context and the insufficiency of geotechnical data, TERRASOL is also providing technical assistance and consultancy services to the consortium on the various geotechnical aspects, including for prediction of the behaviour of the massif during the tunnel excavation, and in particular the behaviour of the Numidian clays and the zones of toppling suspected of being the source of the problems encountered.

M. Yahia-Aissa and A. Guilloux

LNG plant at Browse

Australia

The project consists of the construction of a natural gas liquefaction plant on the Dampier peninsula in the region of Kimberley (Western Australia). TERRASOL provided geotechnical assistance for SAIPEM which was producing a competitive FEED (Front End Engineering Design) for WOODSIDE.



Credits: Woodside

In the maritime zone, 3 geophysical testing campaigns and 5 geotechnical testing campaigns were conducted between 2010 and 2012, comprising a hundred or so boreholes and more than a thousand laboratory tests. TERRASOL's geotechnical analysis enabled to identify several geotechnical profiles, define the geotechnical calculation parameters and assess the risk of liquefaction of the site's soils.

Because of the presence of loose sands on the sea bed, particular attention was paid to the analysis of pore pressures in these sands under the caisson-type main breakwater. Time-dependent dynamic finite element calculations were performed using the PLAXIS 2D software to examine the behaviour of the main dike under thousand-year return seismic and swell loads.

The earthquakes were modelled by application of the accelerograms at the base of the model; the values of the swell loads of the thousand-year return storm applied to the caissons were derived from a physical model in a basin. The sandy soils were modelled initially using a "standard" soil behaviour law (HSM) and then, once the cyclic shear tests were available, by an advanced behaviour law (UBC Sand) capable of simulating the accumulation of pore pressures and cyclic plastic deformations in the loose sands. The results of these studies confirmed the need for specific tests and studies to analyze the cyclic behaviour of the soils.

K.V. Nguyen, A. Bergère, A. Guilloux

Development of an oil field

Amazon, Peru

The "Block 67" oil field project will be developed in North-Eastern Peru, in the heart of the Amazonian Forest between the Andes and the Guiana Shield. The operation involves a limited number of platforms so as to minimise environmental impact. The extracted fluids will be collected and processed in a production plant before being exported.

The initial phase of the project consists in the development of just a single field, named Piraña. It includes two well platforms and a production plant, as well as the creation of a terminal on the Curaray River for the loading and unloading of fluids (for transportation to Manaus, where they will then be exported via a pipeline).

TERRASOL was called upon for the provision of G2 geotechnical services to DORIS ENGINEERING, which had been contracted by PERENCO PETROLEUM LIMITED to perform the engineering work for the oil field's initial development phase. TERRASOL's mission included:

- Drafting specifications for earthworks / backfilling, roads, car parks, basins, ditches and additional geotechnical surveys;
- Producing design reports relating to the foundations of the platforms and the production plant, to the retaining walls required along the Curaray river, as well as to the drainage system (design subcontracted to HYDRATEC).

The major part of the work was carried out in direct interaction with the project team of DORIS ENGINEERING, for an optimised design process.

A. Bergère

Protection of a gas pipeline from erosion

Yemen

Transporting gas from the Marib' deposits in the middle of the country to Bahlaf on the coast of the Gulf of Aden, a YEMEN LNG "pipe" runs across almost 320 kilometres of sandy, stony and occasionally very mountainous deserts.

A 5 km section, permitting the passage from a high plateau reaching up to an altitude of 1,700 m to a plain lying 800 m below, is subject to hard geotechnical conditions: surrounded by high dolomitic cliffs that occasionally see massive rockfalls and located in a barely stable slope, this section also crosses over a series of oueds that, during the monsoon season, erode everything lying in their path.

Following an expertise assignment carried out in 2010 concerning the damages linked to this torrential erosion, TERRASOL was once again called on by TOTAL in March 2012, this time to send a TERRASOL engineer on site for a one month period. His mission concerned:

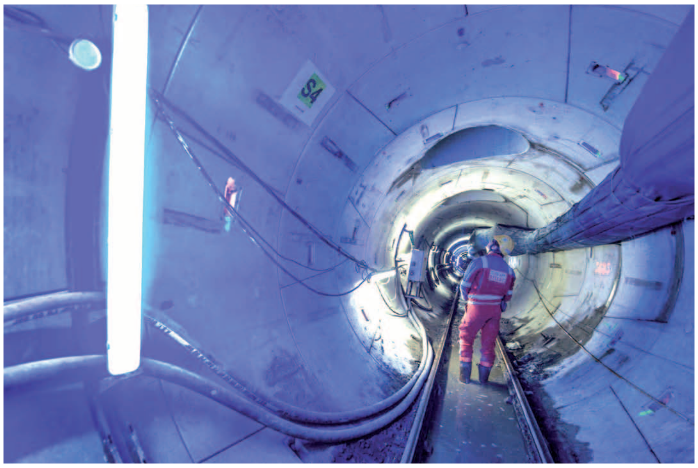
- Supervision of works on a gabion and rockfill hydraulic structure.
- An expert assessment of all the redevelopment works carried out to date.

A. Beaussier

Water gallery at Dunkirk LNG terminal

France

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^3 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.



Credits: Dunkerque LNG – Happy Day

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 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

Coastal reinforcement in Cape Lopez

Gabon

Cape Lopez is the point of Mandji island, Gabon, extending the furthest into the Atlantic Ocean. It consists of mainly-sandy delta deposits, underlain by a very dense layer located at a depth of more than twenty metres. The main ocean currents flow around the cape from West to East, carrying sediments eroded from the West coast towards the East coast. When they enter Princes' Bay, the currents are protected by the cape and slow down. Very fine sands, of very uniform grain size, are then deposited along the East coast, resulting in its growth.

Credits: Total Gabon

Submarine landslides of varying magnitudes (up to several million cubic metres) occur frequently on the East coast. The slides take place along very gentle slopes (less than 5°). A possible explanation of these recurrent landslides is that the relative densities of the local sands are lower than the critical densities. This makes them very sensitive to the generation of excess pore pressures, which may be refered to as "lateral spreading" phenomenon. Under the action of growth or of any other load generating excess pore pressures, the sands lose their shear strength and flow.

In this context, TERRASOL has worked with TOTAL SA and TOTAL GABON to reinforce the East coast, where erosion by recurring landslides is threatening the oil terminal located on Cape Lopez.

C. Babin, K.V. N'Guyen and M. Blanchet

Shah Deniz phase 2

Azerbaijan

Credits: ENTREPOSE Projets

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 m3 per year, with two additional auxiliary gas processing trains. It requires the construction of seven hydrocarbon product storage tanks.

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

Oil & Gas complex in Das Island

Abu Dhabi, United Arab Emirates

ADNOC is one of the largest national oil companies and one of the most advanced in terms of seismic analysis and recovery optimisation techniques applied to its oil fields, both onshore and offshore. Its subsidiary Abu Dhabi Gas (ADGAS), specialising in the processing, marketing and distribution of LPG and LNG, has contracted CEGELEC OIL AND GAS for the construction of an eighth turbine (36 MW, Frame 6 type) on Das Island, which is located in the Persian Gulf about 110 km from the Emirate of Abu Dhabi.

In the framework of civil engineering studies, CEGELEC contracted TERRASOL for the geotechnical detailed design.

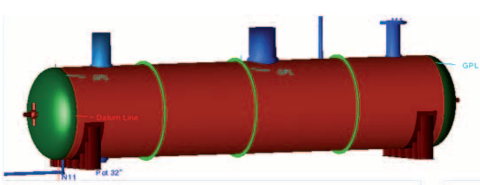
TERRASOL first worked on the definition and supervision of the on-site geotechnical investigations, in strict compliance with offshore safety and risk management procedures. We then designed the foundations of the various elements of the power plant (turbine, structural steelwork, chimney, buildings, etc), paying particular attention to the behaviour of the deep foundations under dynamic loading.

C. Bernuy

Credits: CEGELEC

STIR Bizerte

Tunisia



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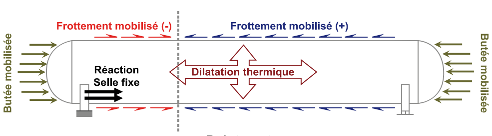


TERRASOL recently assisted the Italian company TANKO SPA, which builds 'cigar' tanks - an innovative concept for storing LPG – in the framework of a project in Bizerte, Tunisia.

Intended for the Société Tunisienne des Industries de Raffinage (STIR), these cylinders buried in a compact backfill are subject to temperature changes. TERRASOL's task: calculate and optimise the thermal loads exerted on the tanks at the fixed support points (slab on piles) taking into account the tank / backfill / foundation block interaction mechanisms. Without involving numerical processing in three dimensions, these interactions could be investigated in a satisfactory manner using the Thermopie program (developed by TERRASOL originally for the design of geothermal foundations), using as input parameters:

- The result of a PLAXIS 2D model for a cross-section of the tank, intended to assess the normal stress state around the tank (and consequently the lateral friction mobilisable longitudinally);
- The result of a Groupie+ model (FOXTA software) used to quantify the lateral response function at the top of the foundation block.

F. Cuira and B. Simon

Ashegoda Wind Farm Project

Ethiopia

Under an EPC contract, VERGNET has built the “Ashegoda Wind Farm” in Ethiopia, with a total installed power of 120 MW generated by 84 wind turbines.

TERRASOL was contracted by VERGNET to carry out the geotechnical studies for the foundations of the wind turbines, including the design of the anchoring micropiles for the guy wires of the GEV HP turbines, which are subjected to cyclically varying tensile loads.

Specifically for these micropiles, TERRASOL developed a design approach based on the cyclic stability diagram concept. The approach consists in plotting a stability domain of the cyclic loads in a plane defined by their mean component on the abscissa and their cyclic component on the ordinate. This domain, defined using the properties of the micropile and the soil, is then compared with the cyclic loads to which the foundation is subjected.

TERRASOL also defined and supervised the on-site geotechnical soil-testing campaign, supervised and analysed the tensile tests on the micropiles, and followed-up the construction of the foundations of the wind turbines.

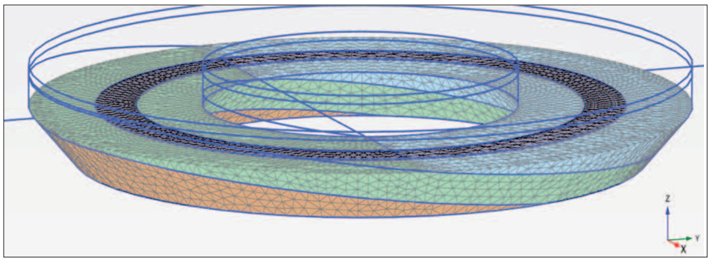
The first 30 wind turbines of the South zone were commissioned in December 2011 and the 54 turbines of the North zone in 2013.

B. Madinier

Credits: Ashegoda Wind Farm Project - VERGNET

EPR UK at Hinkley Point

United Kingdom



In the context of the construction of the British EPRs (Evolutionary Power Reactors), TERRASOL has been entrusted with the design of the prestressing gallery under the plant at Hinkley Point. The prestressing gallery is used for tensioning the cables of the EPR’s inner containment wall. With no structural link to the slab, the prestressing gallery takes the form of a ring 26 m in diameter with a rectangular cross-section (height 3.5 metres). A ring of mass concrete is built around the gallery in order to limit the impact of the loads transmitted by the plant slab. The complexity of the geological context (general dip of the strata towards the north, anisotropy of the deformation moduli) lead to prepare three-dimensional numerical modelling using PLAXIS software (400,000 elements). A specially-developed routine in Visual Basic is intended to make the distribution of pressures (of static and/or seismic origin) under the slab produced by the structure model compatible with the PLAXIS model.

The model was then used as a tool to justify the structural strength of the gallery, optimise the geometry of the mass concrete around it, and define the optimal contact conditions to be guaranteed between the mass concrete and the gallery.

E. Cazes and F. Cuira

Chooz laboratory

Ardennes, France

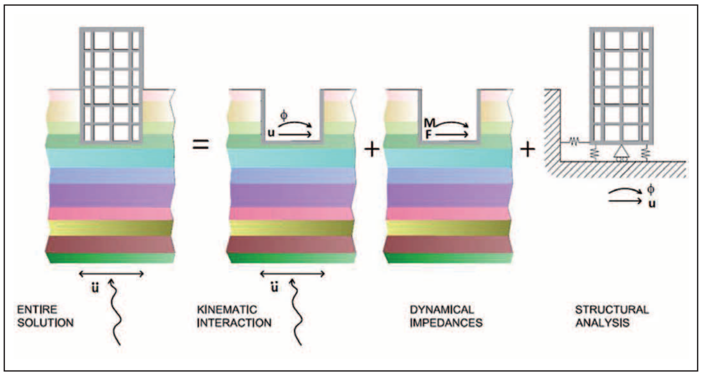
Within the scope of the “Double Chooz” scientific experiment aiming to study the behaviour of neutrinos, the GUINTOLI - SOLETANCHE BACHY TUNNELS group of contractors is currently building an underground laboratory on the site of the Chooz nuclear power plant in the Ardennes region of France on behalf of CEA and CNRS, with project management by EDF. The detailed design was awarded to the TERRASOL (contract leader) – SETEC TPI group.

TERRASOL carried out the design of supporting structures for the laboratory access (trench – 90 m long, and access tunnel – 20 m² section, 145 m long), for the underground cavern (95 m² section, 30 m length) and for its vertical shaft required for the experiment (13 m excavation depth, 9.5 m diameter). The studies for the works, excavated in shale/sandstone materials, combined a structural approach (analysis of the stability of blocks cut out by bedrock fracturation) and finite element calculations in an equivalent elasto-plastic environment (estimation of deformations and stresses using 2D and 3D modelling).

J. Marlinge

Credits: Cédric Helsly for Soletanche Bachy

Energy projects and seismic design



Until recently, earthquakes were taken into account in the design of geotechnical structures mainly through simplified pseudo-static models enabling to join up with common design practices. Today, the introduction of the Eurocodes and the recent awareness of the issues related to the seismic risk lead to favour computer models which are capable of realistic processing of the dynamic behaviour of the soil interacting with the structure that it supports. The development of these models, which demand a fresh and enlightened view by the engineer, is nevertheless hampered by a geotechnical corpus which is not familiar with seismic aspects and which by a wide margin prefers semi-empirical design based on the pressuremeter test data.

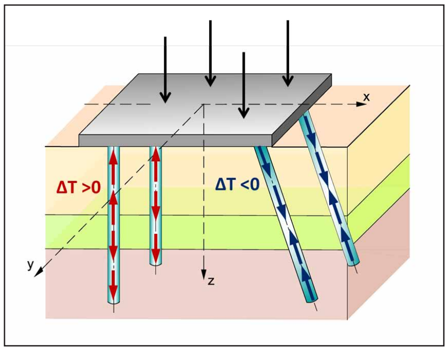
In this context, and thanks to the multidisciplinary training of its team, TERRASOL has developed advanced practice in design of earthquake-resistant structures. This requires effective control of soil-structure interaction effects going well beyond the radical simplification consisting in assuming the structure to be perfectly embedded at its base, a simplification sometimes leading to excessively unrealistic results. In practice, this interaction may be analysed by representing the soil response using dynamic impedance functions (expressing the soil stiffness and damping according to the natural frequency content of the load) and, strictly speaking, by considering the seismic movement affected by the presence of the structure (kinematic interaction). This type of analysis, which can be performed easily using a SASSI or similar model, is regularly used for design of new or existing earthquake-resistant industrial facilities, in particular for EDF and AREVA.

Another aspect of seismic design is the question of seismic stability. This can only be approached realistically if it is related with the concept of irreversible displacements. The drafting of Eurocode 8 was an opportunity to point out this fundamental link by defining the seismic limit state as “the state corresponding to the appearance of irreversible (or permanent) displacements of unacceptable amplitude”. Such post-earthquake displacements may result from two phenomena:

- Temporary loss of shear strength resistance during seismic action through a ‘conventional’ failure mechanism by sliding (load bearing, reversal, overall instability, etc). In this case, the assessment of irreversible displacements can be based on a simplified Newmark method, which may be enhanced by accounting for soil-structure interaction effects. As an example, we carried out for ANDRA a study on a radioactive waste cover fill.
- Mechanism of strength ‘deterioration’ of the native soils, such as liquefaction of loose sands. The associated irreversible displacements can be analysed, supplementing a ‘conventional’ analysis of the liquefaction risk based on the estimation of the safety available between the applied seismic load and the load causing soil liquefaction. An application example is provided by the post-Fukushima studies carried out for EDF, aiming at estimating post-liquefaction settlement resulting from a re-assessed earthquake below the LNG tanks of the Dunkirk terminal.

F. Cuira

Thermopie+ program: design of energy piles



The use of energy piles is growing substantially in France and abroad. Deep energy pile foundations are equipped with heat pumps and are used as energy sources for buildings heating and cooling. The piles are thus exposed to temperature variations causing settlement or uplift as well as extra loads in the structure. The design of energy piles requires understanding of the effects of thermo-mechanical interactions between the structure, the piles and the surrounding ground.

To accompany the growth in application of this technique, TERRASOL has developed Thermopie+, a new calculation program for modelling soil-pile-structure interaction for a group of energy piles. The model estimates the loads and the displacements generated by a thermo-mechanical loading cycle. The modelling principle consists in approaching the axial behaviour of the piles by a generalised t-z model, introducing the thermal effects and the unloading/reloading effects into the original definition of the skin friction and tip resistance mobilisation functions. The pile heads are then linked by a non-diagonal stiffness matrix representing the response of the structure (a kind of ‘macro-element’ for the structure).

This model has been used recently in a number of applications, including the Sept-Sorts water treatment plant project in France. These applications have shown that the use of a stiffness matrix to represent the response of the structure leads to much more realistic results than would be obtained by representing the structure response by a fixed support condition or by separate springs at each pile head.

The Thermopie+ program will eventually be incorporated into the Foxta v3 software suite.

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