THE NATIONAL PROJECTS

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The National Project program is a French research program aiming to create new knowledge in the domain of civil engineering and construction by regrouping university researchers, engineering companies and construction companies. Several of them, concerning geotechnical work, are presented here.

Introduction

Full-scale experimentation in civil engineering is a powerful tool to study and understand the behavior of structures and to validate new construction processes. At the beginning of the 1960s, France showed a particular interest in this subject. However, it was not until the early 1980s that the road engineer M. MARTIN create the concept of national projects on experimental research in Civil Engineering. Its principle can be summed up in two essential points. Frist, to make a large-scale project and to bring together public and private partners on the same research topic. Participants are asked to contribute during the time of the project and to help finance the research (provision of equipment, experimental site, time etc.). On the other hand, the Ministry of Public Works and/or the National Research Agency are expected to provide a grant of 15% to 20% of the total amount of the project.

Today, the Institute for Research and Experimentation in Civil Engineering (IREX) ensures the administrative and financial management, monitoring and dissemination of results for a National Project. It was created jointly by the French Research Ministry, and Equipment's Ministry (now the Ministry of Ecological Transition) and the FNTP (National Federation of Public Works Contractors).

Despite its name, the Nationals Projects (NPs) are not restricted to French partners. Indeed, foreign partners have been present in several NPs, for example: the Ministry of Transport of Quebec was a partner in the CLOUTERRE project; the Federal Highway Administration (USA) and the University of Canterbury (New Zealand) were partners in the FOREVER project.

National projects (NP) in geotechnical engineering

National Project Program covers several sectors of civil engineering: materials, construction processes, rehabilitation and maintenance, sustainable development and finally geotechnics, mainly on foundations subjects.

This document present the main NPs carried out in the field of geotechnical engineering.

CLOUTERRE I & II

In-place soil reinforcement with passive bars is a technique known in France since the early 1970s. It has several advantages, in particular the economic aspect, the flexibility of use and implementation. As a result, nailing was deployed very quickly and applied to numerous structures (tunnels, retaining walls, slope and embankment stabilization). It should be noted that despite the success of the technique, the stability of the structures reinforced by this technique was not guaranteed all the time.

The aim of this NP was to promote soil nailing, especially for permanent retaining structures, while developing knowledge of the process, the determination of the limits of the process, the development of reliable design methods and the publication of recommendations. For this project, three full-scale experiments where conducted at the CEBTP experimental site in Saint-Rémy-Lès-Chevreuse [2].

A design method for the ultimate limit state (ELU) based on the Schlosser criterion 1982 was developed. This design method used semi-probabilistic calculation with partial safety coefficients and weighting coefficients on the actions, thus becoming a first in soil mechanics.

In 1993, the CLOUTERRE II NP started to complete the research, to enrich the CLOUTERRE I data bank and to develop a design method for nailed soil structures, considering on the one hand the particular stresses and on the other hand different types of structures (nail-reinforced face in tunnels in soft ground).

The research program included the instrumentation of structures in France (measurements on the walls of the highway A12 road built in 1994-1995, tests and controls on the Toulon tunnel, La Galaure tunnel and Tartaiguille tunnel sites). Experiments were also carried out overseas in the USA by the FHWA.

The outcome of the national projects CLOUTERRE I and II are associated. In France, these two projects have led to the design of a significant number of nailed soil walls as permanent structures (giving here the example of the nailed soil retaining walls limiting the excavations around one of the piers of the Millau viaduct where the nailing has been made permanent). In addition, they made it possible to develop and publish in 1998 the XP 94-240 standard entitled "Nail-reinforced soil retaining walls and embankments" and its transformation into the European standard PR-94270 in 2009.

Finally, the experience of these two NPs opened the doors for future projects in geotechnics, particularly in the field of soil reinforcement (ASIRI project, detailed further in the documents)

Internationally, it is undoubtedly the CLOUTERRE I NP, with the English translation of the 1991 CLOUTERRE recommendations, which has been at the origin of a strong influence of the French technique, notably led to the participation of the US Federal Highway Administration (FHWA) as a partner in CLOUTERRE II, and later in the FOREVER NP. It is interesting to note that the Talren software, designed and developed by Terrasol, has been and still is widely used in many countries for the design of nailed soil structures (walls, embankments and slopes). CLOUTERRE Recommendations (1991) have also been translated into Korean. In the early 1990s, the FHWA and the TRB (Transportation Research Board) of the United States organized a scanning tour of Europe to learn about the development of nailing. They were favorably impressed by the development of nailing in France. In the same way as the *Terre Armée* Company has developed remarkably in the United States, soil nailing has developed rapidly and undoubtedly to such an extent that the cumulative benefit obtained using this technique was estimated a few years ago by the American administration at several hundred million dollars. Today, soil nailing is used almost everywhere in the world, as it is a simple, easy-to-use and patent-free technique [1].

FOREVER

A micropile has a diameter of less than 250 mm, usually drilled, and with a central reinforcement embedded in a mortar or cement grout. Used for many years, micropiles offer a wide range of applications in groups (set of vertical micropiles) or in networks (set of vertical and inclined micropiles). Their bearing capacity is essentially ensured by the friction between the micropile and the soil. They are primarily used for the underpinning and reinforcement of existing buildings or structures, but also for the foundations of new structures in difficult soils, for the stabilization of slopes and embankments as well as for retaining walls, tunnels and the protection of buried structures. Micropile networks also have remarkable resistance to seismic actions. The FOREVER NP, through a program of studies and tests, was to specify the behavior of micropiles in isolation, in groups and in networks, and to establish rules of the art as well as a dimensioning method allowing to extend their fields of application [1].

It should be noted that three foreign partners were involved in Forever: The Federal Highway Administration (USA), the University of Canterbury (New Zealand) and the Polytechnic University of New York (USA) [2].

TUBA

The TUBA National Project, launched in June 1993, was the result of the reflections of the main actors in the field of marine works, who had been meeting since 1990 in the "IREX Port Works Club". Three main ideas quickly emerged:

- the economic need to promote a revival of foundations on driven metal piles
- the observation that there was a certain technical delay, particularly in the field of pile driving forecasting and control
- the existence of significant know-how in the offshore oil sector, where pile foundations are used in more than 90% of cases

These ideas led to the elaboration of a National Research Project with the objective of developing a complete procedure for the prediction and control of steel pile driving adapted to French harbor works.

The program was widely based on the methodology developed in offshore works and based on three decades of experience. However, modifications or adaptations have been introduced to consider certain specificities:

- the type of geotechnical survey that can be carried out in shallow water,
- French practice in terms of pressure-meter tests,
- the nature of the soils encountered in active port areas,
- the relatively short length of the piles and their mode of operation,
- the type of driving equipment used (diesel and electric hammers).

The project was divided into five phases:

- a bibliographic study and a theoretical study,
- two on-site experimental studies,
- the development of the CALYPSO software "CALcul Informatique Intégré des Pieux de Structures Océaniques",
- the publication of the procedure: the “Practical Procedure”, the ultimate objective of the project, proposes a complete and homogeneous methodology for the treatment of the prediction of the driving control of driven metal piles [1].

The reconstruction of post 9 in Djibouti, carried out by Roland BOUTIN - STTIM *Marine Nationale*, is a successful example of the use of CALYPSO software coupled with instrumentation during piling.

ASIRI & ASIRI+

The vertical rigid inclusion soil improvement technique combines several elements to form a composite foundation system when the subsoil has low support capacity:

- the rigid inclusions themselves, which are installed in a regular network, generally with a square mesh of between 2 and 3 m. When they are made of concrete or mortar, they usually have a diameter of between 30 and 50 cm. Their head is sometimes enlarged by a scupper,
- a granular mattress with a thickness of between 50 cm and 1 m, in which a reinforcing layer (metal mesh or geotextile) is sometimes placed.

This foundation system allows the transfer of loads from a structure to a deep bearing horizon and can be applied to various structures: embankment foundations, industrial and commercial paving, foundations for purification basins and oil reservoirs, port medians, etc., as well as to exceptional structures such as the foundation of the piers of the Rion-Antirion bridge over the Corinthian Strait in a particularly severe seismic environment.

However, although this technique has been used for more than 20 years, question remains on these technics:

- certain aspects of the composite system behavior are still poorly understood,

- the dimensioning methods vary widely according to the participants,
- the practices observed abroad are very diverse,
- soils studies are often poorly adapted to the design and implementation of this technique.

Based on these observations, the ASIRI National Project was born in 2003, on the initiative of the IREX Soil Competence Centre, with the following main objectives:

- improve the knowledge of the complex interaction mechanisms involved in this reinforcement technique,
- evaluate the existing design methods in the light of the experimental results,
- develop and qualify design methods at various levels of complexity.

The ASIRI National Project aimed to publish "Recommendations concerning the implementation and design of embankments and slabs on soil reinforced with rigid inclusions" [1].

Thirteen years later, a second national Project ASIRI+ was launch aiming to study the load transfer platforms, the behavior of structures reinforced by rigid inclusions under quasi-static and/or inclined, dynamic and seismic loads. This new project has started in 2019 for four years. Under the direction of Bruno Simon (Terrasol) as project president and Laurent Briançon (INSA Lyon) and Luc Thorel (Université Gustave Eiffel) as technical director.

SOLCYP

The SOLCYP National Project was founded to study and analyze the behavior of piles subjected to vertical or horizontal cyclic stresses. The objective is to develop methods for designing structures considering the effect of cycles.

There is no specific document at national, European (CEN) or international (ISO) level (standard, regulatory text, professional recommendation) that considers the effect of cyclic stresses in the design of foundations. There are a few exceptions such as:

- In the field of the oil industry, professional recommendations API RP 2GEO, 2011; ISO 19901-4, 2003 have been developed to consider the effect of waves on the foundations of offshore structures. These recommendations are adapted in the case of offshore wind turbines (DNV-OS-J101, 2011, 2014; BSH, 2007, 2011),
- In the field of construction in general, there are only a few rules for calculating soil liquefaction under earthquakes or pavement fatigue.

Therefore, this is why the use of a PN like SOLCYP is necessary in order to enrich the technical and regulatory documentation. This need is growing with the appearance of new types of foundation structures in the field of energy, transport and industrial engineering.

Cyclic stresses include all actions that vary over time. These actions can be of environmental origin (wind, swell, earthquakes, tides, fluctuations of various environmental parameters) or of industrial origin (rotating, vibrating machinery, presses, rail, road, airport traffic, movement of handling equipment, emptying/filling of tanks, etc.). Examples of structures concerned by this type of request are cited as follows:

- Fixed or floating oil structures,
- Offshore wind turbine foundations (monopies, multipods),
- Maritime or port projects (dikes, jetties, quay walls),
- Railway bridges,
- High-rise buildings and towers,
- Storage tanks (emptying-filling cycles).

The research and development program of the SOLCYP project included the following points:

- Characterization of loads,
- Response of soils under cyclic loading,
- Behavior of soil-pile interfaces,
- Behavior of soil-pile interfaces under cyclic loading,
- Obtaining cyclic parameters,
- Sizing methods.

This work was completed by the drafting of the SOLCYP Recommendations. They propose a methodological approach and calculation methods to consider the effects of cyclic loads in the design of pile foundations [3].

Conclusion

The IREX is the fundamental core of the organization and management of the PNs. A successful NP hinges on a sufficient number of partners who participate with a majority of funding.

The geotechnical PNs that have been taken here as examples (Clouterre I and II - soil nailing; Forever-micropiles; TUBA; ASIRI - reinforcement by rigid inclusions and ASIRI+; Solcyp-piles under cyclic stresses) clearly show their innovation, the specificity, the experimental nature of the research and the dissemination of the results.

It should be noted that there are other PN in geotechnics that we have not detailed in this report:

- Observational method (2003 - 2005),
- CRITERION (1998 - 2002),
- C2ROP (2015 - 2021),
- ARSCOP (in progress).

The common pillar between these different projects is undoubtedly the full-scale experiments and structures in service made available by the partners, experiments in centrifuges, etc.

The results of these projects have also contributed to enriching the library of recommendations in France and abroad.

According to Christian BERNARDINI (former General Delegate of IREX) the essential spin-off of this collective research: an osmosis between professionals and researchers which has been strengthened little by little, some appreciating the skills of others and vice versa, which is very the evolution of the number of theses carried out in these projects, non-existent or almost in the first to reach ten in the last.

Interview with Laurent Briançon

Mr. Briançon is a lecturer at INSA Lyon. His field of activity being focused on experimental research on soil reinforcement, he worked on various national projects including ASIRI (between 2005 and 2012) for which he managed all the full-scale experiments.

***Ouarda*: First of all, could you tell us about the original idea of the ASIRI project?**

Laurent: The idea behind the ASIRI NP was an observation that we had made in the profession. We have been reinforcing soils on rigid inclusions for a very long time now, but in the 1970s and 1980s we gave up this reinforcement solution. On the other hand, the difficulty that existed was that there was no normative framework. These inclusions cannot be considered as deep foundations that are treated in the standards related to soils and piles. So, it was not always easy to offer this solution as an alternative, even if we thought it was more interesting because it was less expensive than a deep foundation solution. This soil reinforcement solution made the soil participate in its own reinforcement, which means a saving in concrete, and also a saving in work time. It made it possible to significantly reduce settlements more than when pre-loading on drains. In 2002, I had just obtained my PhD and Terrasol asked me for a post-doc to do a literature review of the field of rigid inclusions and to write the feasibility file for a research in this area. Indeed, to achieve a PN, it is necessary to demonstrate interest in the profession and also show that such a project can attract enough partners to finance it.

The particularity of the PN is that they are financed by the members in the form of membership fees and donations in kind. Depending on the estimated budget, you have to count between 30 and 40 partners, set up a research project and then write recommendations. A second particularity of PNs is that they involve academics and practitioners. Finally, national projects often rely on full-scale experiments, laboratory experiments and numerical studies to then propose analytical designs.

In ASIRI, the state of the art has shown that there are two types of structures to be studied in priority:

- embankments on rigid inclusions (RI),
- slab on RI.

Slab was done a lot in France but not abroad. Therefore, we focused on this and we did an FSE (full-scale experimentation) of the slab on RI to try to understand the mechanisms and at the same time we did a second FSE of embankments on RI.

The coupling of all the lab tests, the Nantes centrifuge tests and the digital modeling made it possible to propose a dimensioning method which then resulted in a document which can be found on the IREX site, it is free to access. (ASIRI recommendation: these are rules for sizing and implementing RI)

These recommendations were quickly used in France, and as French companies have a strong export activity, the technique was naturally exported thanks also to the translation into English of the recommendations in 2013.

At the time, in the ASIRI project, there were 40 partners. It was pretty good, there were all the partners who do the RIs and the main design offices. Since then, all RI worksites that are done on paving or embankment partly use the ASIRI recommendations. In 2016, we wanted to assess the use of ASIRI recommendations and check with the profession whether they needed to be supplemented. The summary of a survey carried out by IREX was presented during a CFMS technical day. This has made it possible to identify new areas of study:

1. Improve the understanding of the mechanisms in the load transfer platform (LTP) and in particular, when they are reinforced by geosynthetics or built in treated soil.
2. Study the reinforcement of soils by rigid inclusions subjected to cyclic or inclined stresses. Indeed, in the ASIRI

framework only the vertical static stresses have been studied.
3. Study the reinforcement of soils by rigid inclusions subjected to complex stresses, either dynamic with the stresses that can be had under railway embankments, or seismic.

A feasibility file was drafted in 2017 to show the value of working on these different axes. It was submitted to the ministry and was accepted. Then, we try to bring together the profession to find out who was interested in joining the project. Here too, about forty partners responded favorably, mainly the same ones we had in 2005 ASIRI plus a few new ones, notably geosynthetics producers.

So, the PN ASIRI+ is bigger I feel in terms of workload. The first ASIRI NP was more exploratory. Now we know how to do things well and we want to go deeper into the details. This requires more complex experiments but we have the experience of ASIRI and have Also experimental and numerical tools already developed.

Another theme addressed in ASIRI+ is that of footings placed directly on RI. ASIRI recommendations did not allow to build slabs or footings directly on RI. Since then, many companies have used their own specifications validated by control offices to be able to do this and experience has shown us that there was no mess. We have therefore decided, in ASIRI+, to study this particular case in order to integrate it into the new recommendations.

***Ouarda*: If I come back to ASIRI, has it achieved all the objectives that were set at its start?**

Laurent: Yes and no. I would say that we have not gone far enough on the dimensioning of geosynthetics, for example. Although we had carried out a full-scale RI backfilling site with geosynthetics, the soil conditions that were not sufficiently compressible did not allow us to conclude on the subject. In addition, we were able to show after the ASIRI project that there was a real need for the dimensioning of geosynthetics in PTCs. In particular, VINCI called on us to validate a rail embankment solution on rigid inclusions incorporating geosynthetic reinforcement layers on the SEA line project. It was Terrasol that pre-dimensioned the reinforcement and we implemented an experimental backfill to evaluate different PTCs: with slabs on the inclusion heads or with geogrids within the mattresses. This experimental backfill demonstrated the effectiveness of geogrids, which even made it possible to reduce the number of inclusions. This project showed us that there was a lack in the ASIRI recommendations on the dimensioning of geosynthetics.

It was not at the end of ASIRI that we said to ourselves that we had to do a new project, but it was after a few years of use of these recommendations by the profession. Or by new needs, for example wind turbines are increasingly on RI but we do not really know how to consider the cyclical stresses on this type of reinforcement.

***Ouarda:* You talked about ASIRI +, you said that thanks to the feedback that you decided to launch it, so it was not in the perspectives of the first PN ASIRI?**

***Laurent*:** ASIRI's objective was to offer recommendations. I think that initially it was not planned to translate them into English. It is the use of these recommendations that prompted us to complete them. After the ASIRI+ project, I think the next step will be to move from recommendations to a standard.

***Ouarda:* How long does a PN last? Are deadlines always respected, especially for ASIRI+?**

Laurent: In general, a project lasts between 4 and 5 years. Then, we overflow a little because there is the drafting of the recommendations. We started ASIRI+ in 2019 and we should officially finish in 2023. With the confinement and the sanitary restrictions, it was not easy to progress at the desired pace, I think that we will finish ASIRI+ in 2014.

The financing due to the contributions is on 4 tranches but each tranche can last more than one year. These contributions represent approximately 700 thousand euros to work. Then, we also have donations in kind, for example when a company proposes a project or proposes to carry out an experiment on the latter, the IRs that will be made on this experiment are at its expense. Now, if we add the contributions to all the donations in kind that are made by the partners, we are on a project of around 2 million euros over 4 years.

***Ouarda:* Long before the PN ASIRI, in geotechnics, there were other PNs like CLOUTERRE I & II, FOREVER and TUBA. Do you think that these previous experiences played a role in the PN ASIRI? I am not aiming for the pure sense of technique but rather at the level of piloting, organization and management.**

Laurent: I think it's very important, the old projects really have a great interest over the new ones. The difference between PNs and ANR projects, for example, is that a PN brings together many complementary partners with the objective of obtaining very concrete and quickly applicable results. For example, the PN CLOUTERRE showed us that it was possible to bring together academics and practitioners and this type of collaboration was then reproduced in other projects.

***Ouarda:* Since the publication of the recommendations until today, what is the most remarkable project?**

Laurent: I don't know if there is one site that is more remarkable than the others. I will say that what is remarkable is the growth of this soil reinforcement technique which is partly due to the ASIRI recommendations and I hope that this growth will continue thanks to the new ASIRI+ recommendations.

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