Geotechnical aspects of the final year “Technical project” in the Civil Engineering Department of INSA Lyon, France

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ABSTRACT: During the final year of civil engineering studies at INSA Lyon, students can choose, in addition to their final year research project, a so-called „Technical project“ in three different majors: Urban development, Building and Public works. Every year more than 30 % of the students choose the Building technical project. This paper first presents the genesis and general organization of the Building technical project, in particular the close association with the Lyon School of Architecture. A detailed analysis of the way geotechnical considerations are introduced is then proposed. Finally, several examples of programs, sites and students designs illustrate this paper.

1 INTRODUCTION

INSA Lyon delivers engineering degrees after 5 years of an integrated program in which students can choose a major for the last 3 years. One of these majors is civil engineering. During the final year of civil engineering studies at INSA Lyon, in addition to their final year research project, students have to realise a so-called „Technical project“ in one of the three different majors proposed by the Civil Engineering Department: Urban development, Building and Public works. Every year more than 30 % of the 100 students choose the Building technical project.

The “technical project” corresponds to 12 ECTS credits and covers the second semester of the final year (from February to June) with approximately 12 hours scheduled per week. It is associated with elective courses (total of 5 representing each 2 ECTS credits) taught in the second part of the first semester.

The Building technical project is a unique experience in the civil engineering studies in France and possibly in Europe for several reasons, the most important being the association with the Lyon School of Architecture (EAL) and the fact that the students have to work by groups of 6 (3 students from INSA and 3 from EAL) on the architectural and technical design of a building or group of building.

This paper presents the genesis and general organization of the Building technical project, in particular the close association with the Lyon School of Architecture. A detailed analysis of the way geotechnical considerations are introduced and managed is then proposed.

2 THE GENESIS

2.1 *INSA-EAL association for the Building technical project*

Created in 1980, the concept of technical projects in the final year of the Civil Engineering studies was first limited to technical considerations. It has been a first step to the integration of different disciplines in the analysis of one single problem, for instance the design of a building.

Rapidly, it appeared that some architectural consideration was required, thus a few professional architects were included in the team of academics and professionals managing the students groups. There was then a smooth evolution of the objectives of the technical project, moving from the technical design phase to the general design. This evolution was also necessary to avoid redundancy between the 4th and 5th year programs.

In 1983, the idea was raised to initiate a collaboration with the Lyon School of Architecture (EAL), first limited to one third of the students, in which groups of INSA and EAL final year students would work on both the architectural and technical design of a defined program.

The collaboration proved to be successful, students being satisfied of this experience. Since 1983, the number of students concerned has increased and is now close to 80 % of the 30 students choosing the Building technical project.

Up to now, this experience is still unique in French Technical Universities.

2.2 *INSA-EAL double degree*

Based on this successful collaboration between INSA Lyon and EAL and on the willingness of some of the students to develop knowledge and competences in both majors, the Civil Engineering Department of INSA Lyon and the Lyon School of Architecture have proposed in 1992 a double degree program.

At the beginning, the agreement was designed for a few selected students from INSA Lyon (7 per year on an average). During their 3 final years of engineering studies, they have to take courses in the EAL (approximately 150 hours / year) and they are exempt of some of the courses at INSA. At the end of the 3 years, they get their civil engineer degree and the equivalence of the first 3 years of architecture. They can then enter at a master level in any of the French schools of architecture (generally they choose the Lyon School of Architecture).

Since 1999, the agreement also applies for some of the EAL students in architecture (generally 2 to 5 per year). During their last 3 years at EAL, they have to take 450 hours of classes at INSA (mathematics, physics, mechanics, heat transfer and strength of material). After they get their architect degree, they can enrol in the Civil Engineering Department of INSA at the master level and in 2 years get the engineer degree.

Also in 1999, the EAL signed an equivalent agreement with the ENTPE (National School of Engineer for Public Work). In recent years, similar types of double degree programs have been created in France.

3 THE GENERAL ORGANIZATION

The technical project is the main element of the second semester of the final year (with the final year research project). It corresponds to at least 12 hours per week and to 12 ECTS credits.

Even if it's an academic project, the students are not asked to just apply the knowledge acquired during the courses of the 3rd and 4th years, but they have to face a situation that more or less resembles what they will face during their professional life as civil engineers in the construction industry.

They have to actively participate as engineers in the design of one or several buildings and public services, taking into consideration architectural, sociological, societal, economical and technical constraints and their interactions.

Based on these principles, groups of 6 students are formed (3 from INSA Lyon and 3 from EAL). The same program and site are proposed to the groups. Nevertheless, a large variety of architectural and technical designs is observed.

3.1 *INSA-EAL association*

The association between INSA Lyon and EAL gives an opportunity to the future engineers and architects to work together and discover each other. It can be considered as a way to close the existing gap between the two majors and cultures.

3.2 *The program*

The program is different every year and corresponds generally to a public equipment (theatre or conference centre, recreational or sport equipment such as swimming pools, housing programs) located in urban areas with specific problems of integration in the existing urban network. Nevertheless all the groups of students have to work on the same program and site with the same initial constraints.

3.3 *Academic requirements and time schedule*

The technical analysis and design covers the geotechnical, structural and material aspects of the project as well as acoustics and heating and cooling consideration. A one-hour public defence is organized at the end of the semester and a final written report should be provided. An intermediate oral presentation (30 min) is also scheduled.

Every week, one day is scheduled for work in common and discussions with both academics (INSA and EAL) and consultants, mainly for the technical aspects.

A total of 16 persons are in this way regularly in contact with the students to answer their questions and analyze the progression of their work:

- 3 architects (professionals and academics)
- 6 academics of INSA (specialized in structural, geotechnical engineering, heating/cooling systems, acoustics, sociological issues, …)
- 7 senior professional consultants (covering also all the technical aspects of the construction industry).

3.4 *Recent developments*

In the recent years, programs are focussing on Sustainable Development and High Environmental Quality, French equivalent of Green Building (US) or Comprehensive Assessment System for Building Environmental Efficiency (Japan).

4 GEOTECHNICAL ENGINEERING ASPECTS

4.1 *General aims and organization*

The geotechnical part of the technical project is aimed at applying the different elements of the Soil Mechanics and Geotechnical Engineering courses on a specific case. It should cover the geotechnical analysis of the site (site investigation and data collection) and the design of the building or equipment including:

1. foundations (bearing capacity and settlements),
2. retaining structures or slope stability,
3. analysis of the effect on surrounding existing structures (requiring for example underpinning, strutting or anchoring),
4. effect of underground water and flow.
5. design under specific loading such as earthquake.

When defining the program, academics and consultants in charge of the geotechnical part make sure that each group of students will have to analyze on at least one element of the program problems in the first 3 points of the above list. Nevertheless, the aim is not to induce the students to face very complex design situations. On the contrary, the students are encouraged, in the design phase of the project, to look for the "simplest" solution, should they modify their architectural design, in order to avoid complex technical problems to solve or the use of costly design or techniques in the second phase.

4.2 *First part*

This first part is dedicated to the geotechnical analysis of the site. It should correspond to the G11 and G12 geotechnical missions defined by the French norm NF-P-94-500 revised in 2006 (AFNOR 2006).

Mission G11 is the preliminary geotechnical analysis of the site and the first identification and assessment of the geological and geotechnical risks associated with the site.

It includes first the collection and analysis of data available on the specific site: the students shall use all sources of information to determine the geological profile and geotechnical characteristics of the soil. They can find some of these informations by contacting local geotechnical consulting companies and/or using Infoterre web site (www.infoterre.brgm.fr) developed by the BRGM for the french authorities. One of the main points is to determine if there are surrounding building or equipments (water or sewer networks, ..) that could be concerned by the project and what are the available information on these.

The program of geotechnical investigation is not defined by the students. The academics and consultants, based on the data gathered by the students, choose the elements to use in the sequel. If the amount of data or their quality is not sufficient, they propose a collection of geotechnical investigation results (introducing if necessary one "difficulty" to the site).

The written report submitted by the students corresponds to the G12 mission. It should:

- propose an analysis of the site (including a geological model and several profiles, geotechnical characteristics retained for the design),
- present and justify the general principles of the adaptation of their project to the site (excavation, retaining structures, foundations, …). A rough evaluation is generally required and based on classical charts and rules of thumb.
- analyze specifically the risks of deformation of the site (slope stability, settlements, …) and the way they will limit the impact on the existing buildings or equipments concerned by the project and its construction.

If applicable, they shall also analyze dynamic loading (such as earthquake) and justify the way the structural design of their project and its adaptation to the site gives a satisfying answer to this problem.

During this phase, the general aim is the discussion with the architects in order to:

- propose an answer to the program satisfying the architectural requirements and analyze the technical consequences,
- modify the global design of the project if these technical or financial consequences are to high.

This general design and discussion process corresponds to approximately 40 % of the time allocated for the project.

4.3 *Second part*

The second part corresponds to the technical aspects of G2 mission, i.e. an in-depth analysis of the geotechnical project and a precise design and justification of all the elements:

- Foundations (geotechnical and structural design),
- retaining structures,
- slope stability,
- protection of surrounding structures (for example underpinning).

During this phase, the students are encouraged to use french professional softwares such as:

- Foxta (Terrasol 2005) for foundation design,
- Geostab (GEOS 2004) for slope stability analysis and reinforcement by nailing or geosynthetics,
- Rido (RFL, 2004) for retaining structures design.

All these softwares are presented to the students and they learn how to use them on simple pedagogic examples during the "Excavation and soil improvement and reinforcement" and "Foundations" courses taking place in the first semester of the 5th year.

5 EXAMPLES OF PROGRAMS AND STUDENT DESIGNS

This section presents examples of recent programs (5 last years) and at least one example of student answer to these programs.

5.1 *Technical project 2002*

This program was called “urban cultures institute” and included a theater (600 persons), meeting rooms, library, offices and parking lots. This program was located in Annemasse (close to Geneva) in the city center.

The main geotechnical difficulties were due to the existing building and the seismic constraints.

Figure 1 gives an example of students’ design for the offices and library building and the underground parking lots. A detail on the anchor system for the deep excavation required by the parking lot is also presented in Figure 2.

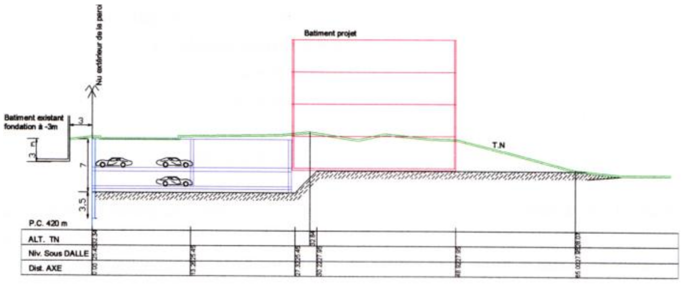

Figure 1. Vertical profile of the project with underground parking lot

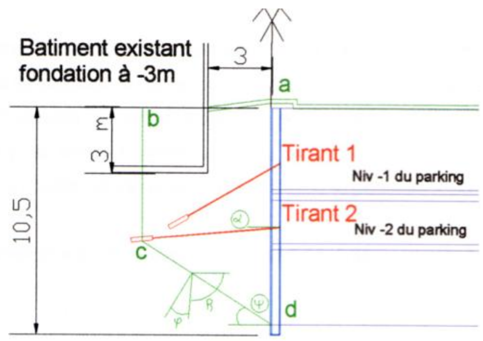

Figure 2. Detailed view of the deep excavation and anchors.

5.2 *Technical project 2003 and 2004*

This program included a sport center (with swimming pool of Olympic dimensions, judo hall and dance hall), private and student housing and a place of worship. Underground public or private parking space was required for all these elements. This program was located on a site in the outskirts of Lyon in a medium to dense urban environment. The geotechnical characteristics of the soil were generally good (alluvium) with possible lenses of silts. The main difficulty was due to the water table found just 1 m below ground level.

Figures 3 and 4 give an example of students’ design for the sport center.

Figures 5 to 7 give an other example of students’ design for the sport center with a foundation problem for the specific roof of the structure.

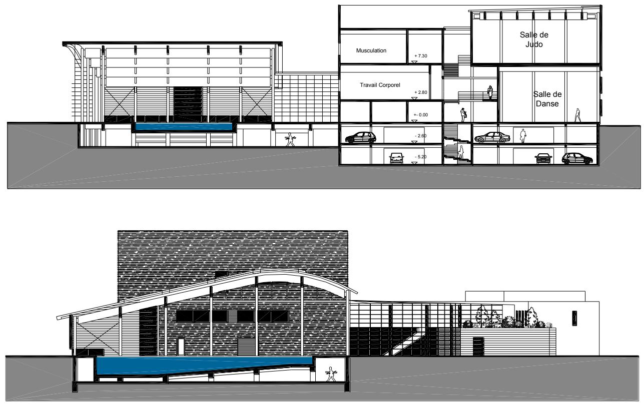

Figure 3. 1st example - The sport center: East-West and North-South profiles.

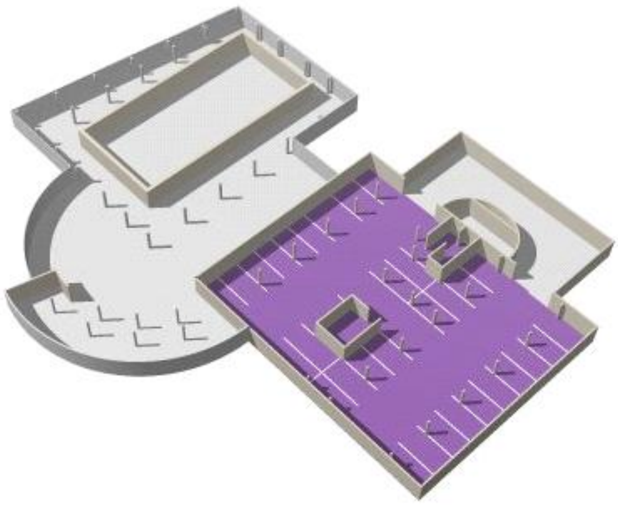

Figure 4. 1st example - 3D view of the underground level of the sport center with parking lot.

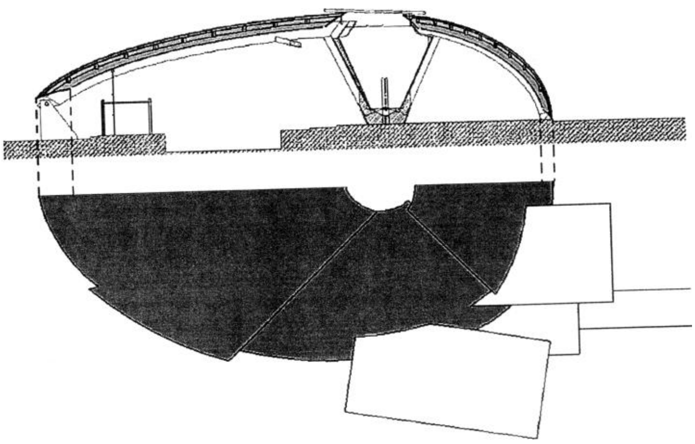

Figure 5. 2nd example - Vertical and plane views of the sport center.

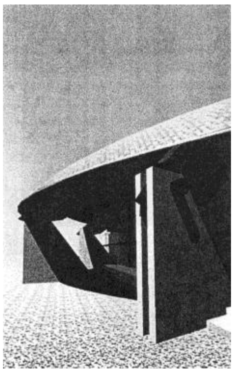

Figure 6. 2nd example - 3D view of the supporting pillar of the sport center roof.

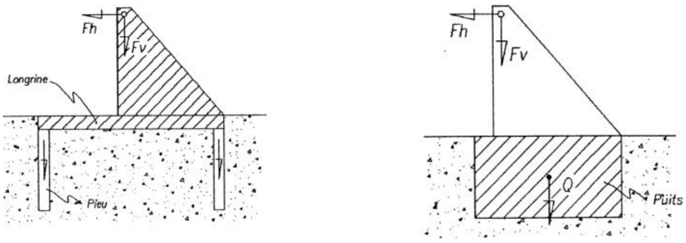

Figure 7. 2nd example - Two possible solutions for the foundations of the supporting pillar of the sport center roof.

5.3 *Technical project 2006*

This program was composed of a swimming pool of Olympic dimensions, a judo hall and a gymnastics hall, public parking lot and cafeteria. It was located on a site in the center of Lyon in a dense urban environment. The main geotechnical difficulty lied in:

- the rather limited space (15000 m^2)
- the fact that on half of the site, soil is made of fill of poor geotechnical characteristics with a thickness varying from 0 to 13 m from south to north, requiring either soil reinforcement or deep foundations,
- existing building on the surrounding plots are very close to the limits of the site even adjacent, generally requiring underpinning.

Figures 8 and 9 give an example of students' design for the sport center.

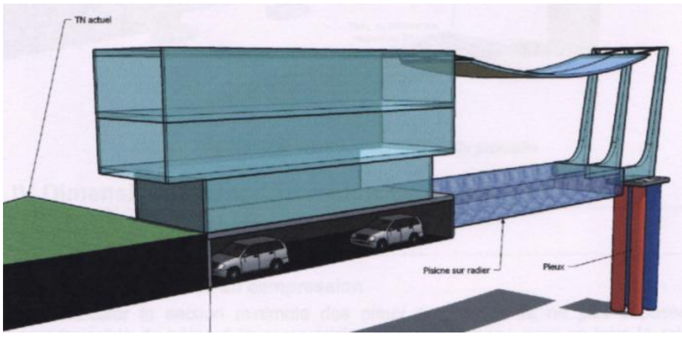

Figure 8. The sport center: East-West profile north of the site.

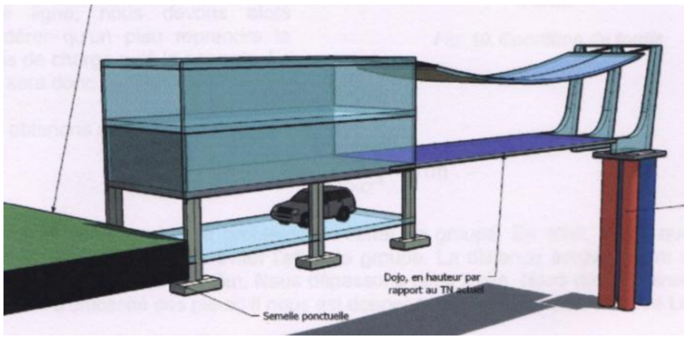

Figure 9. The sport center: East-West profile north of the site.

5.4 *Technical project 2007*

This project, located on the INSA campus, included two parts: the creation of a new building and the rehabilitation of an existing research and teaching building (4 levels + basement, 1000 m^2 each). The aim was to create:

- a research laboratory with a hall of 300 m^2 minimum and 5 m headroom minimum (with a crane covering all of the surface), offices and meeting rooms for the researchers,
- teaching center for 300 students (3 different years) with amphitheater, classrooms, lab rooms, offices and meeting rooms for teachers,
- underground parking lots.

Since the research activities of the laboratory concerns thermal sciences, the new building was supposed to be designed as a demo-building for the new techniques for the preservation of the environment. The main geotechnical difficulties were linked to the rehabilitation of the old building, the evolution of loads on the existing foundations, the possible need for underpinning, the limitation of the effect of excavation close to this building. The water table generally found 3 m below ground level also required specific attention.

Figure 10 give an example of students' design for the rehabilitation of the existing building and figure 11 a proposal for the new building and its foundations.

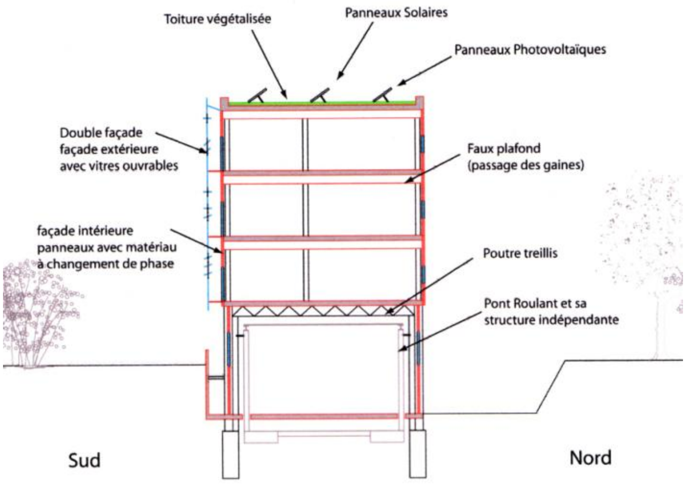

Figure 10. Rehabilitation and creation of a 5m headroom research laboratory covering the basement and first floor of the existing building with crane.

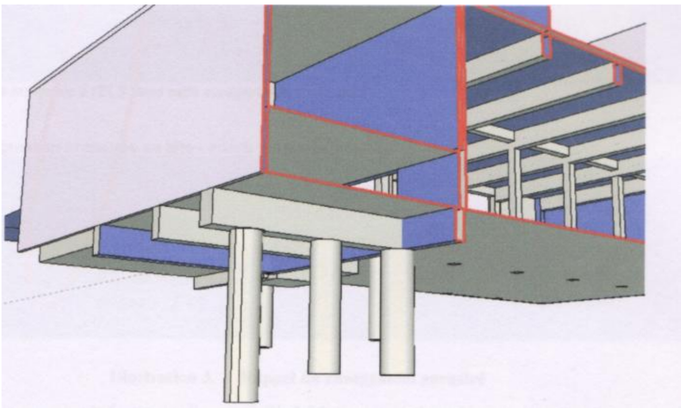

Figure 11. Project of the new building and its foundations.

6 CONCLUSION

The Building technical project is a way to make the students in civil engineering and architecture more aware of the necessity to have a multidisciplinary approach for the design of a building.

Civil engineering students must apply the basic knowledge they acquired during their engineering studies, develop new knowledge and competences and, through a dialogue with senior consultants, propose technical solutions for sometimes very complex problems.

Considering the size of the student groups, the complexity of the interactions between the different technical aspects and the limited time allowed, the technical project is also a way to introduce project management. The final oral defence is therefore an important element of the exercise.

Despite the difficulties and difference between the two cultures, the collaboration between students in civil engineering and architecture is always a profitable experience. In particular, it is way to discover a different approach of the design of a building.

7 REFERENCES

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