INTERNATIONAL CONFERENCE ON STRUCTURAL ENGINEERING EDUCATION WITHOUT BORDERS

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Forward

There are many conferences or symposiums where the latest advances in research and design of engineering structures are presented. However, there are few forums where structural engineering education is discussed with a multidisciplinary view. This scarcity seems astonishing, since more dialogue is required to improve education as a way towards a better profession.

Aware of the necessity of such a forum, the Spanish Association for Structural Engineering (ACHE) organized three symposiums in 2001, 2007 and 2013 focused on the education of the structural engineer. These symposiums were national events where academics and practitioners always had interesting discussions in an enriching and relaxed environment. The time has arrived to broaden the organization's reach and make ACHE's symposiums international.

The theme chosen for doing this first international ACHE conference is "Structural engineering education without borders". In the past, the skills required by the structural engineer were always well defined and mainly remained within the technical domain. In addition, the typical structural engineer worked within the constraints of his/her country. The present situation is much different. The modern structural engineer must be creative, communicative, and able to work with others in an international setting involving a range of social and environmental issues. Consequently, a new type of education is needed to develop modern engineers. This conference shows how the training of both engineers and architects has changed to face these new challenges through the presentation of 75 papers from 14 different countries. The papers will be presented under the following broad topics:

- Multidisciplinary Education
- Teaching with Models
- Active Learning Methodologies
- The Art of Teaching
- Internet-Based Teaching
- New Perspectives for the Education of the Engineer
- Development of Transversal Skills
- Construction History and Cultural Heritage
- Conceptual Design and Philosophy of Structures

In addition, the conference also includes three workshops where the participants can experience first-hand, new methodologies that can be applied to improve the teaching/learning process.

We would like to thank the organising institutions, ACHE and the Eduardo Torroja Institute for Construction Science, for their enthusiastic support and the members of the organising and scientific committees and the workshop organisers for their invaluable work. We are also grateful for the support of some of the most important international associations of structural engineers: the International Association for Bridge and Structural Engineering (IABSE), the International Federation for Structural Concrete (fib), the International Association for Shell and Spatial Structures (IASS), the Institution of Structural Engineers (ICE) and the American Concrete Institute (ACI). Additionally, we would like to thank the Eduardo Torroja Foundation, for making a guided visit to the "Eduardo Torroja museum" at La Zarzuela Racecourse possible. Our last thank you goes of course to the authors, because their remarkable work and effort ensure the success of the conference.

Current social, economic and environmental context is creating new professional challenges in structural engineering. Education is crucial to face these challenges successfully and, to improve education, it is necessary to promote discussion, share experiences, work hard and, above all, be passionate… passionate about structural engineering and about teaching and learning.

Ignacio Payá Zaforteza, Chair of the Scientific Committee
Alejandro Bernabeu Larena, Chair of the Organising Committee
Madrid, May 31st 2018

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CLASSROOM – OFFICE PROJECT: INTEGRATION OF STRUCTURE DESIGN WITH URBAN PLANNING AND TRANSPORTATION SCIENCES

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ABSTRACT

The Classroom – Office Project falls into the Project-Based Learning approach at Universidad Europea. The students who take the subjects of Transportation, Urban Planning and Building Structures in Civil Engineering Bachelor's Degree are set with the task of designing an intermodal transportation hub in an urban area of a real city. The Classroom – Office Project involves the integration of these three different subjects into the project to be carried out by groups of students. The teams analyze the transportation needs of the urban area they've been assigned to, having to determine the program requirements of the intermodal hub. They then have to develop the building design, particularly its structure and foundation. The students develop their learning and understanding of structures and foundations of a building while carrying out the project. Theoretical master classes are minimal, in favour of team-work directly applied on the project.

KEYWORDS: Project based learning, Teamwork, Professional real-world environment simulation teaching.

1. Purpose and scope

The modern engineering profession deals constantly with uncertainty, incomplete data and competing (often conflicting) demands from different clients and disciplines. Project-based learning is a learning framework designed to engage students in facing authentic problems including a transversal approach that allows them to take into account the needs of each discipline, how they relate to each other and, in short, learn to face a real problem taking into account the different phases of a project. The use of problem-based learning in engineering programs has been reported by several authors (see (1), (2) o (3)) although the practice is still far from widespread. However, in Universidad Europea it is one of the hallmarks of the education. The Classroom – Office Project falls into the project-based learning approach at Universidad Europea.

From the very beginning, the students develop their learning and understanding of structures and foundations of a building while carrying out the project. Theoretical master classes are minimal, in favour of applied team-work directly on the project.

The Classroom – Office Project goes a step further, as it involves the integration of three different subjects into the project to be carried out by the groups of students. In fact, the teams analyze the transportation needs of the urban area they've been assigned to, having to determine the program requirements of the intermodal transportation hub building to house it. They then have to develop the building design, particularly its structure and foundation. In parallel, the students have to assess the impact of their proposal on the urban planning.

The educational model is completed with the figure of "the client", a role played by an independent teacher –not linked to the any of the three subjects- to whom each of the teams regularly report to and must attend to its suggestions.

The three subjects –transportation, urban planning and building structures- are therefore interlinked and frequently impose or require changes between them as the design develops. The teachers play the role of technical advisors during the whole process.

In this way, the students are trained for a close-to real-world scenario they will soon have to face in their professional career on engineering firms. Also, the students learn the importance that other subjects have on structural design, and the other way round: how structure typologies regarding materials, construction means, etc. condition other urban and transportation aspects around the intermodal transportation hub.

The structure must be designed with technical criteria, but also taking into account other variables such as minimizing the impact on the urban surroundings, schedule, etc. And, most importantly, the construction process –usually complex in underground constructions set in high-traffic areas, close to buildings, tunnels and other civil works-, must be carefully considered.

The final result of the work is a global project of an intermodal transportation hub, which integrates the transportation and urban planning studies, the justification of the requirements that, according to the said studies, may impose on the building characteristics, and the final design of its structure and foundation.

Finally, this work is presented by each group in front of a panel formed by several teachers of other subjects, who play the roles of the private developer, public companies, organisms and neighborhood associations, and analyze and grade the project. This contributes to the development of other skills (communication, use of novel presentation techniques, etc.).

2. Organisation of the Classroom - Company Project

Structures are very often taught in a succession of courses that are independent, not only from other aspects of Civil Engineering (Hydraulics, Urban Development, Transportation, etc.), but also from each other. The traditional model is based on theoretical explanations plus the practical application of the knowledge through isolated internships or in some cases, through small projects that generally cover a single course topic.

The goal of the Classroom-Company Project has been to help students learn in the context in which they will carry out their professional activity: to integrate them into work teams, analyse the client's needs, gather information, project development, informational meetings with the client regarding the progress of the project, and discussion with clients regarding alternatives, cost management, and deadlines in the development of the project, etc. And this, as is often the case in Engineering firms, coordinating the different departments that develop their respective specialisations in the Project (in our case, Urban Development, Transportation, and Building Engineering). Prior experiences such as that of the Aalborg School of Engineering, Denmark (1), and even others developed in the European University in other Engineering schools (2) indicated that this could be an excellent teaching tool.

The definition of the work is covered in a series of documents prepared by the professors, which describe, like technical specifications in public tendering processes, the general aspects to be developed in the project, and other aspects such as partial deliveries, deadlines, etc. This document also defines the evaluation criteria, so that the students will understand them from the start. The subjects covered so far in the Classroom-Company Project have been bus stations and intermodal transportation hub.

The students are distributed into groups that make up an "Engineering Company", and they themselves designate a Manager (who is the one who periodically informs the Client of the status of the Project) and formulating the rules of operation of the Company, in regard to internal organisation, penalties in case of non-compliance, etc.

This formation of the teams is a very complex part because the students have different situations (from students who are taking only one of the courses to students who are taking all three), and in addition, sometimes students with conflicts between them are assigned to the same group. The latter situation is considered another incentive of this model of learning, because in their future professional activity, they must be prepared for situations like this.

The role of the teachers of each subject is that of the Technical Manager, who does not resolve the issues but rather provides guidance as to how to obtain the information and the procedures to do so, based on the knowledge that they already have from previous courses completed by the students (construction materials, materials resistance, structural analysis, concrete structures, metal structures, etc.).

Teachers from outside the courses involved are chosen to play the role of the Client. Periodically, these teachers call meetings, either with the Manager of each Company or with all of its members, to receive information regarding the progress status of the Project.

The students, in their work, may request information from the Client such as Geotechnical Reports, underground infrastructure, services affected, applicable municipal ordinances, etc.

The final project is evaluated insofar as it corresponds to each course by the teachers who are responsible for them. But a fraction of the grade corresponds to the external evaluation of the Project, through a defence before a panel made up of professors from other courses and prestigious professionals from private companies. The grade that is obtained, along with the grades of the written theoretical tests and other ongoing evaluation activities (each with a previously specified weight), constitutes the final grade for the course.

As an example, the following section describe the most recent Classroom-Company Project that was carried out, corresponding to an intermodal transportation hub in the Latina and Carabanchel districts (Madrid, Spain).

3. Definition of the Programme of Needs of the Intermodal transportation hub. Analysis of its urban impact

The project carried out by the Civil Engineering students throughout the course involves three subjects: transportation planning, urban planning and building structures and facilities. The first two are taken at the same time, so that it is possible to go forward in them jointly although in each of them the students deepened in certain aspects.

In the case of the transport planning part, the students carry out a first territorial analysis of the selected territory (Latina and Carabanchel districts, in Madrid, Spain) to evaluate which of the current transport stations with at least two transport modes are likely to become modal interchange stations in the future. From the urbanism part, territorial analysis propose an holistic diagnosis taking in account several variables such as Mobility System, urban fabric morphology, Land use and urban centralities, Facilities System and Natural and green areas System.

Within this evaluation three analyzes are carried out:

The first is to study the offer of transports and the demand of commuters of the candidate stations to become modal interchange stations. Those stations where the demand is closer to the capacity of commuters that allows the offer, or those located in places where demand can be induced, are more appropriate to be modal interchange station.

The second tries to identify where are the preferred places to localize the interchange station mainly considering possible impacts in mobility (specially pedestrian and bike accessibility) and parking necessities, synergy in between land uses in the surroundings, and possible townscape transformations.

Thirdly, students visited the candidate stations and surrounding neighbourhoods for a visual inspection. The goals were to validate the statistical data about supply and demand, take subjective impressions not given by the data and establish conclusions about the conditioning factors of the environment; both from the point of view of the urban realm and the space availability for the work, like build the accesses to the modal interchange station, etc.

In addition, this analysis composes the evaluation of the urban impacts that could take place with the station implementation, especially about how they would affect the everyday life of neighbours.

Merging all this information, the students made several multicriteria tables to assess, in a coordinated way in between the two subjects, the station that most benefited the city becoming an interchange station. From these alternatives, two stations were selected, so that each team developed the work in one of them: *Aluche* or Colonia *Jardín*.

Figure 1. Visit to one of the candidate stations to become a modal interchange station

Once the location of the transport interchange was selected by each team, they had to make a sizing of the part of the station dedicated to buses. This facility is a bus terminal station, so students should consider the following aspects: 1) the number of platforms according to the transport services (lines, urban or inter-urban services, schedules, types of vehicles, .. .); 2) the bands of parking and lanes of circulation of buses, the lanes of circulation of emergency vehicles, the bus turning radios, etc; 3) the solutions for access to each of the floors from the street and connections between them; and 4) the pedestrian paths connecting the space dedicated to buses within the interchange station and the space for other modes of transport (mainly subway and light train). The result of this part is the "volume of the station" that is given to the teachers of the Building Structures subject to continue from this point the design of the structural and equipment aspects.

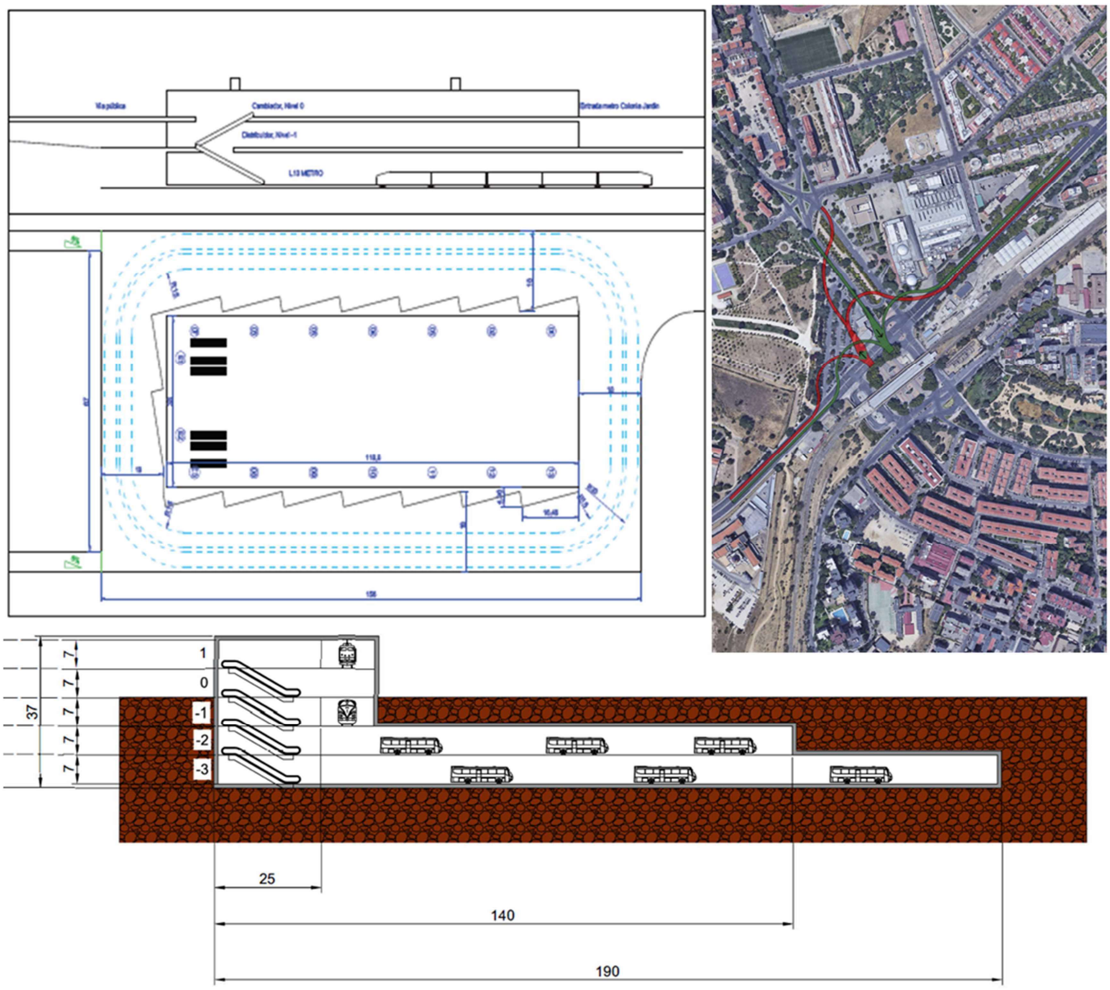

Figure 2 Example of results of the part of transportation planning

4. Definition of the structure and foundation

4.1. Structural concept of the transportation hub

Based on the set of needs defined in the previous phase, the first task of the work teams is to establish the resistance layout of the transportation hub, which is constructed on two underground levels.

This resistance layout can have an impact on the geometric definitions established previously. For example, the location of the pillars is conditioned by the platforms, pedestrian zones, etc. But the logical concept of the distribution of those pillars may in turn require changes to the geometry that was planned initially.

The construction process is also analysed, in regard not only to the deadlines and optimum planning from the economic perspective, but also in regard to the impact on traffic, public transportation, and mobility of people in the proximity of the project, as well as the impact on the neighbours. All of this can condition the type of structure, and in turn affect the geometry of the levels of the transportation hub.

The information requested by the work teams to the Client, mainly geotechnical information and the description of the underground infrastructure and services, also affects this iterative process, which culminates in an "optimum" interior pillar distribution and a horizontal structural typology consistent with the existing spans and loads, as well as the definition of the perimeter containment.

The expansion joints are defined in this phase, based on the dimensions and possibly different uses at the street level.

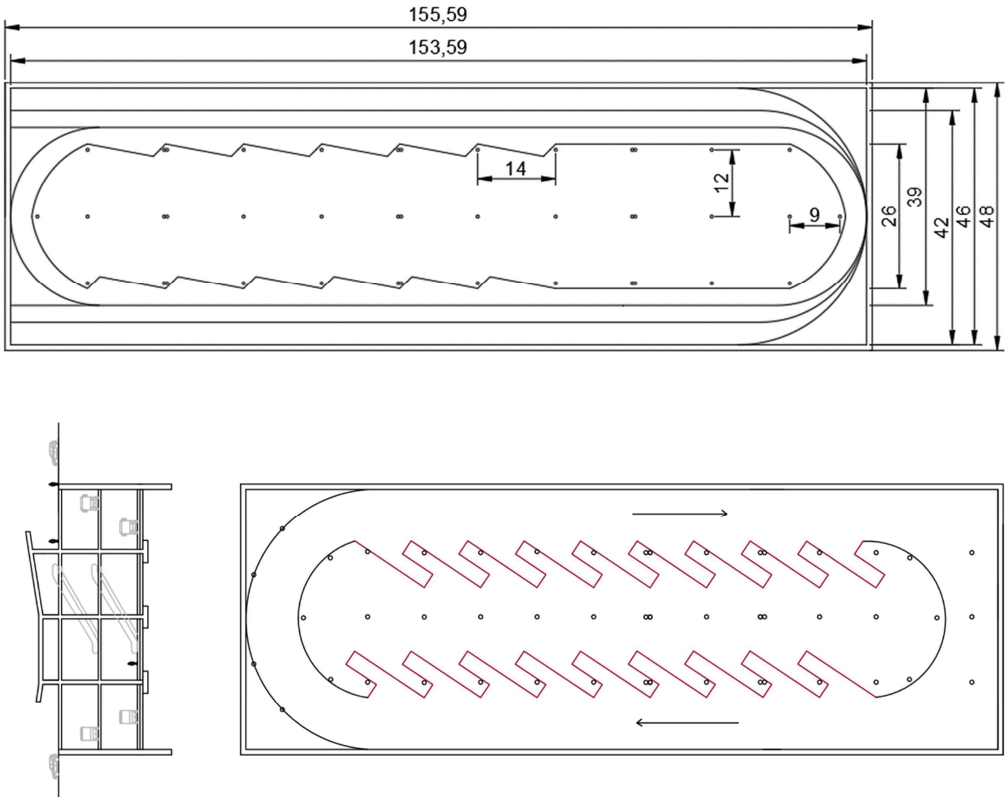

Figure 3. Examples of structural solutions for one of the levels of the intermodal transportation hub developed by two of the teams.

This part of the Project is where the students gain an understanding of the most common structural types in construction, with the course teachers offering theoretical support classes, but in any case it requires a significant amount of independent study, always under the guidance of the teachers.

In parallel with all of these aspects, the students must define the actions on the structure. They have to determine the permanent loads associated with flooring, landscaped areas, etc. and the live loads, taking the different zones into account (vehicle traffic, pedestrian zones, etc.). They must also determine the specifications regarding accidental actions, such as fire and earthquake (the latter is not a determining factor in Madrid); and the requirements in municipal ordinances and codes in regard to emergency vehicles. All this requires a significant amount of research by the students to determine types of pavements (both outdoors and indoors), landscaped areas, overloads associated with traffic on roads and buses in the interior, etc.

Another aspect that they analyse are the environmental factors that affect durability, an aspect that along with some of the ones mentioned before, conditions the selection of materials, surfacing, etc.

All of these element make up the principal part of the Project. The rest consists of the development of skills already acquired in previous courses, such as materials resistance, structural analysis, and concrete and metal structures, although the students must learn specific design procedures for these construction structures. With this, they proceed to calculate the structure and prepare the plans. Special emphasis is placed on the development of the construction details of the structure, specifically those that are typical in construction. Due to time limitations, the detailed design is limited to a fraction of the construction (normally two thirds of the floorspace), even though the modulation of the structure in this type of building construction means that practically the entire structure is designed.

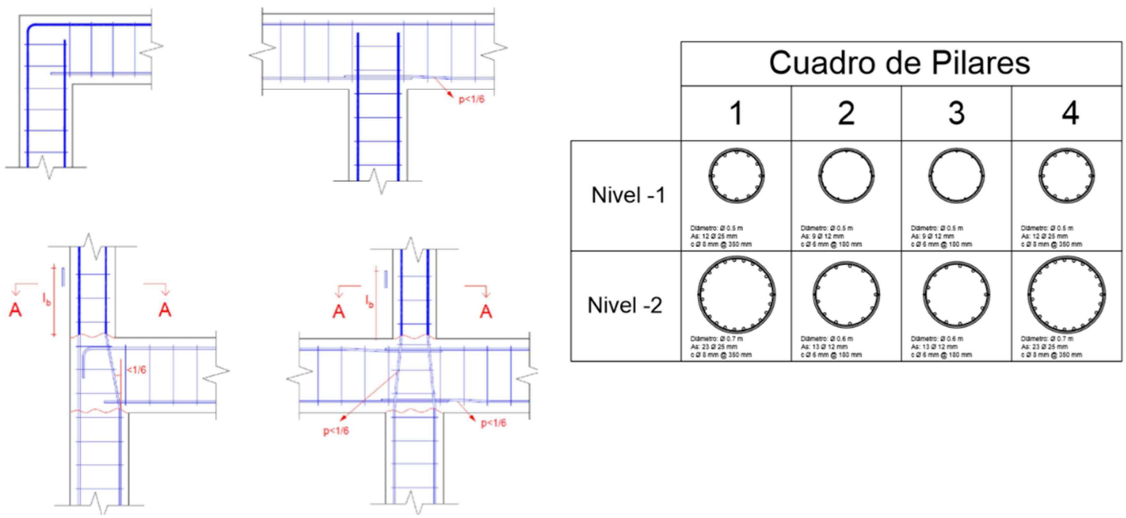

Figure 4. Examples of rebar details in a project.

4.2. Learning through the Project

Throughout the process, the Project guides the learning process. After a series of initial general theoretical classes in the classroom, students work almost exclusively on the Project, with the teacher guiding the search for information and the acquisition of knowledge on building structures that are necessary in each phase.

The experience of four years with this model is that students are very motivated and knowledge is enhanced, perhaps at the expense of covering slightly less subject matter than in previous years with classic learning models. The similarity with the professional future, the overall vision of their studies, and the satisfaction with the results obtained help generate this motivation.

Students develop other key transversal skills, such as teamwork, planning, independent learning, responsibility and communication.

4.3. Presentation of the Project

The students must submit documentation, in regard to structures and foundations, which scope they must also learn by consulting the codes and some examples of real projects. The correct presentation of the project results is key and is one of the aspects that students must learn (this is frequently not included in the study plans). From the very start, students are motivated to prepare the documentation in parallel with the rest of the work.

In general, the projects include the following in regard to structures:

1. Project design report, which must include:
    - Justification of the structural solution adopted and the construction process.
    - Calculation bases:
        - Environment and other aspects related to durability.

- Actions, characteristics of the materials and partial safety coefficients.
- Accidental situations. Fire. Earthquake.
- Actions of thermal origin.
- Multiple presence and combination of actions factors.

- Justification of the mathematical models adopted for stress calculations.
- Description of the calculation models. Stresses obtained.
- Dimensioning in Ultimate Limit State and Serviceability Limit State.
- Construction details

2. Plans. They must create a template with a box that includes the project title, client, Company, and members of the company, dates, titles, and numbering of plans. They must also include materials tables, references to covers, and all other aspects that are normally included in construction plans.

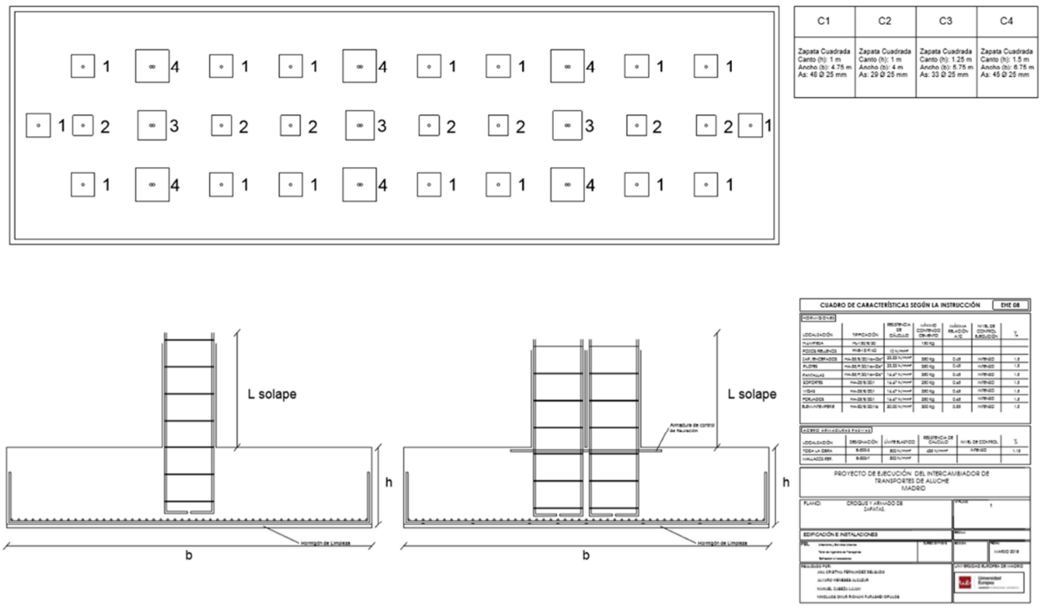

Figure 5. Example of a structural plan of one of the projects.

5. Evaluation

As indicated before, the grade for each course is made up of:

- A grade given to the Project by the teacher of each course.
- A grade given by the teachers to the written tests, practical exercises, and ongoing evaluation of the course. In effect, students are given an exam to evaluate the knowledge they have gained, and it is important to emphasise that the level of knowledge that is acquired is notable, higher than the results obtained in past years with classic models of theoretical and practical classes.
- A grade given by an external panel. The students must prepare a presentation of between fifteen and twenty minutes before a panel made up of professors from the European University who are not associated with the courses involved (and in some

cases from other departments in the University, such as Architecture), and also by prestigious professionals from engineering firms and construction companies in the field of structural construction. The members of the panel are given the Project documentation prior to the presentation and can ask any questions that they deem necessary to the members of the team.

It should be noted that these professionals from outside of the University have expressed high opinions after the evaluation of the work.

One difficulty is when students leave the program during the period when the course is taking place. On one hand, this affects their team, whose objectives must be reoriented by the Client, and on the other, it is a difficulty when proposing the extraordinary examination that in any case is proposed with the same scheme.

6. Conclusions

The most important conclusions that can be drawn from the experience with the Classroom-Company Project carried out in the School of Civil Engineering at the European University of Madrid, involving the courses of Urban Development, Transportation and Structures, and Building Foundations, are the following:

- The model provides greater motivation for students, because they value the development of real projects, gain an in-depth understanding of transversal skills such as teamwork, independent learning, and communication, and experience great satisfaction with the final result that is obtained.
- Students gain a more comprehensive view of the design of structures and foundations, and recognise the interaction between the design of the structure and aspects such as the construction process, the urban environment, and the program of needs deduced from the preliminary studies associated with the use of the building.
- The knowledge is enhanced, perhaps at the expense of covering slightly less subject matter than in earlier years with classic learning models.
- It is very important that students, from the very beginning, understand the setting of the simulation of an engineering company and the proposed learning approach, because any deviation from the principles could mean the failure of the learning process. Teachers must be constantly aware to prevent this situation. In any case, the personal situations of some students make a certain number of dropouts unavoidable (as is the case with traditional learning models) and teachers must quickly readjust the objectives of the group.
- The creation of the groups is very complex because the students have different situations (from students who are taking only one of the courses to students who are taking all three), and in addition, sometimes students with conflicts between them are assigned to the same group. The latter situation is considered another incentive of this model, because in their future professional activity, they must be prepared for situations like this.
- In general, the external professionals who have participated in the evaluation panels have expressed a very positive impression of what the students have learned.

7. References

1. *Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning.* **Phyllis C. Blumenfeld, Elliot Soloway, Ronald W. Marx, Joseph S. Krajcik, Mark Guzdial & Annemarie Palincsar.** 26:3-4, 369-398, s.l. : Educational Psychologist, 2001. DOI: 10.1080/00461520.1991.9653139.

2. *Engineering education—Is problem-based or project-based learning the answer.* **Mills, J. E., & Treagust, D. F.** 3(2), 2-16, s.l. : Australasian journal of engineering education, 2003.

3. *Pedagogies of engagement: Classroom-based practices.* **Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T.** 94(1), 87-101, s.l. : Journal of engineering education, 2005.

4. *Conceptualizations on Innovation Competency in a Problem- and Project-Based Learning Curriculum: From an Activity Theory Perspective.* . **Zhang, F., Kolmos, A., de Graaff, E.** 2013.

5. *Project Based Engineering School, Una escuela conectada con un mundo profesional sostenible.* **Flores, V., Lara, P., Gaya, M.C.** s.l. : X Jornadas Internacionales de Inovación Universitaria. Educar para transformar.