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THE GROUP OF PROJECTS: DESIGNING DIFFERENT FOOTBRIDGES FOR THE SAME SITE.

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Abstract. This paper deals with the experience of the first author, who created the so-called "group of projects" at the Civil Engineering School of UPCT. This informal group was composed of five students (four graduate and one undergraduate) who wrote their thesis during the same term, advised by the author. All of them designed a footbridge over an artificial channel in Cartagena for their thesis. The main feature of the group is that all the designs were intended for the same site, but all of their structural typologies were different.

Since a small footbridge had already been built recently on the same site, actual data were available, such as topography, geotechnical reports or the location of existing sewage networks.

As a result of this strategy, the group developed a very inspiring and hard-working collaborative spirit that lead the students to develop jointly a lot of documents, design techniques, specific software, technical detailing, drawings, etc.

Besides, since the office hours were for the all the students simultaneously, the advisor could save time in the common tasks and devote more hours to the specific aspects of each project, such as the conceptual design.

As an additional consequence of this novel approach, the students could focus on the structural aspects of their projects, allowing them to achieve better results when understanding and designing complex structural typologies.

1 INTRODUCTION

This paper deals with the so-called "group of projects", an informal workgroup created by the author in 2014, at the Civil Engineering School of the Polytechnic University of Cartagena, Spain. This group was composed of five students (four graduate and one undergraduate), who wrote their thesis during the same term advised by the author. All of them, who had chosen structural engineering optional courses, designed a footbridge over a channel in Cartagena for their thesis. The main feature of the group is that all the projects were intended for the same site, but all of their structural typologies were different.

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2 ORIGIN AND ACADEMIC CONTEXT

3.1 Birth of the group: an "engineering" solution.

In the master program in Civil Engineering, professors do not advise a fixed number of students' thesis per term, but the students ask for advisory to the professor they choose. The professor may accept them or not, depending mainly on his/her availability and the type of project. The limited number of students in our school and the variety of the topics that they learn (in three sub-programs about structural engineering, transport engineering and hydraulic engineering) make this system work without significant problems. The most common problem is the lack of time of a given professor to advise all the students interested in working with him/her.

This was the origin of the group of projects, when five students asked, simultaneously, for the author to be their advisor of their graduate and undergraduate thesis. All the students had attended courses taught by the author, all of them were motivated and brilliant, and, simply, the author did not want neither to miss the opportunity to work with them, nor, obviously, disappoint them. The main problem to advise all of them simultaneously is that all the master thesis are different, usually in different sites, and in the office hours the advisor meets with only one student at the same time. Therefore, to be honest, the group of projects was not a strategy planned beforehand, but it can be defined as an "engineering" solution, developed in order to solve, practically, an advisory problem.

3.2 Master thesis in Spanish Civil Engineering programs.

All the students had chosen the courses corresponding to the structural engineering sub-progam and its optional courses. Thus, all of them had received advanced training in foundation engineering, finite element method, bridge engineering and structural typology, according to the organization of courses in the CE school of UPCT [1]. Our Engineering program, as it happens in Spanish universities, enables the student to become a professional engineer in Spain (the equivalent to a CE or PE in UK and USA, respectively) and to become a member of the "Colegio de Ingenieros de Caminos, Canales y Puertos" (a Spanish national institution similar, for example, to the ICE or ASCE).

According to the Spanish law that regulates the Master in Civil Engineering ("Ingeniero de Caminos, Canales y Puertos" in Spain) studies, the master thesis consists of a *"realization, presentation and defense, once all the credits of the master have been obtained, of an original exercise carried out individually before a university committee, consisting of an integral project of Civil Engineering of professional nature in which the skills acquired in the teachings are* *synthesized"* (See [2]). Therefore, the master and undergraduate thesis are usually construction projects, with a level of detail and difficulty according to its complexity, but always with a near-professional level of detailing. It easy to imagine that the work of the advisor is crucial for the final result and that a properly advised master thesis may demand a lot of time, both for the student and the advisor.

3 THE SITE

The site is located in Cartagena (Fig. 1), in southern Spain.

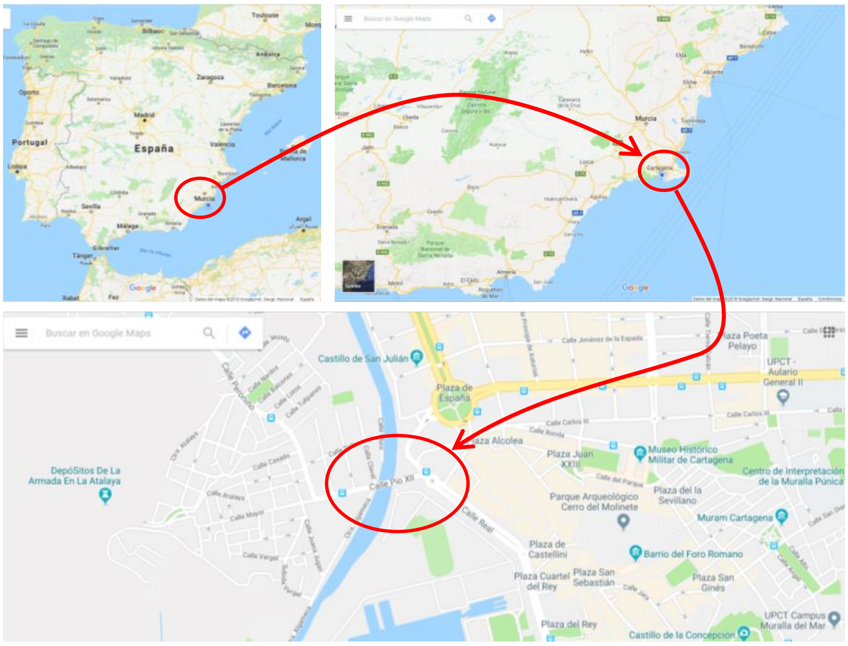

Figure 1: Geographical location of the site: Cartagena, Spain.

Figure 2: Benipila Channel (Source: Wikipedia commons)

The footbridge crosses over the Rambla de Benipila, an artificial channel (Fig. 2). A previous existing road bridge is very close to the footbridge to be designed (Fig. 3 and 4). This footbridge is a diagonal arch bridge.

Figure 3: Existing bridge and footbridge: View from the Pio XII street. (Source: Google maps)

Figure 4: Existing bridge and footbridge: View from the Real street. (Source: Google maps)

One of the main reasons to choose this site was that the documentation related to the construction project of the arch footbridge shown in Fig. 3 and 4 was available to us. Since, from the legal point of view, the owner of the technical documentation is the Cartagena City Council, all the people involved with the group were subjected to a confidentiality agreement that prevented the information to be divulged.

3 THE DESIGNS

The projects are shown in Fig. 5 and 6. In order to reduce the effect of floods, none of the bridges has intermediate supports in the artificial channel. Thus, the main span was approximately 50 m.

Similarly, the structures are designed independently of the existing concrete road bridge because this bridge, built approximately 50 years ago, will be likely replaced soon.

The designs are:

a) A Warren-type truss, where both chords are curved, which gives it a lenticular shape. The cross-section is composed of three steel circular hollow sections (CHS). The upper chord is composed of two semicircular CHS whereas the lower chord is a complete CHS (Fig. 6-b). The main span corresponds to the artificial channel, whereas the lateral spans are very short and provide some elastic clamping, to reduce the sagging bending moment at midspan.

b) A typical two girder composite bridge (Fig. 5-b). It is a frequent solution. However it has two features: In order to reduce the sensitivity to the level of the water in the artificial channel the depth of the beam is very strict. In order to reduce the depth of the girders, it also has short lateral spans with elastic clamping, in a solution similar to that used in the previously described solution.

c) The third solution is a spatial truss. The main feature is that the diagonals are attached eccentrically to the edge of the deck. Attached to the upper chord, a secondary horizontal truss helps to withstand a textile structure to shed the pedestrians. Thus, the cross section is similar to a C-shaped section (Fig. 6-c), which makes torsional moments to be resisted mainly by warping, as it corresponds to an open section. Since the separation between the deck and the roof truss is defined by the clearance requirements the structure could be relatively light.

d) A spatial arch bridge composed of a leaning arch attached eccentrically to the edge of the deck. The arch and the deck are linked by a Nielsen-Lohse cable arrangement (Fig. 5-d). The cross section is composed of a torsion bar with ribs that support the deck (Fig. 6-d).

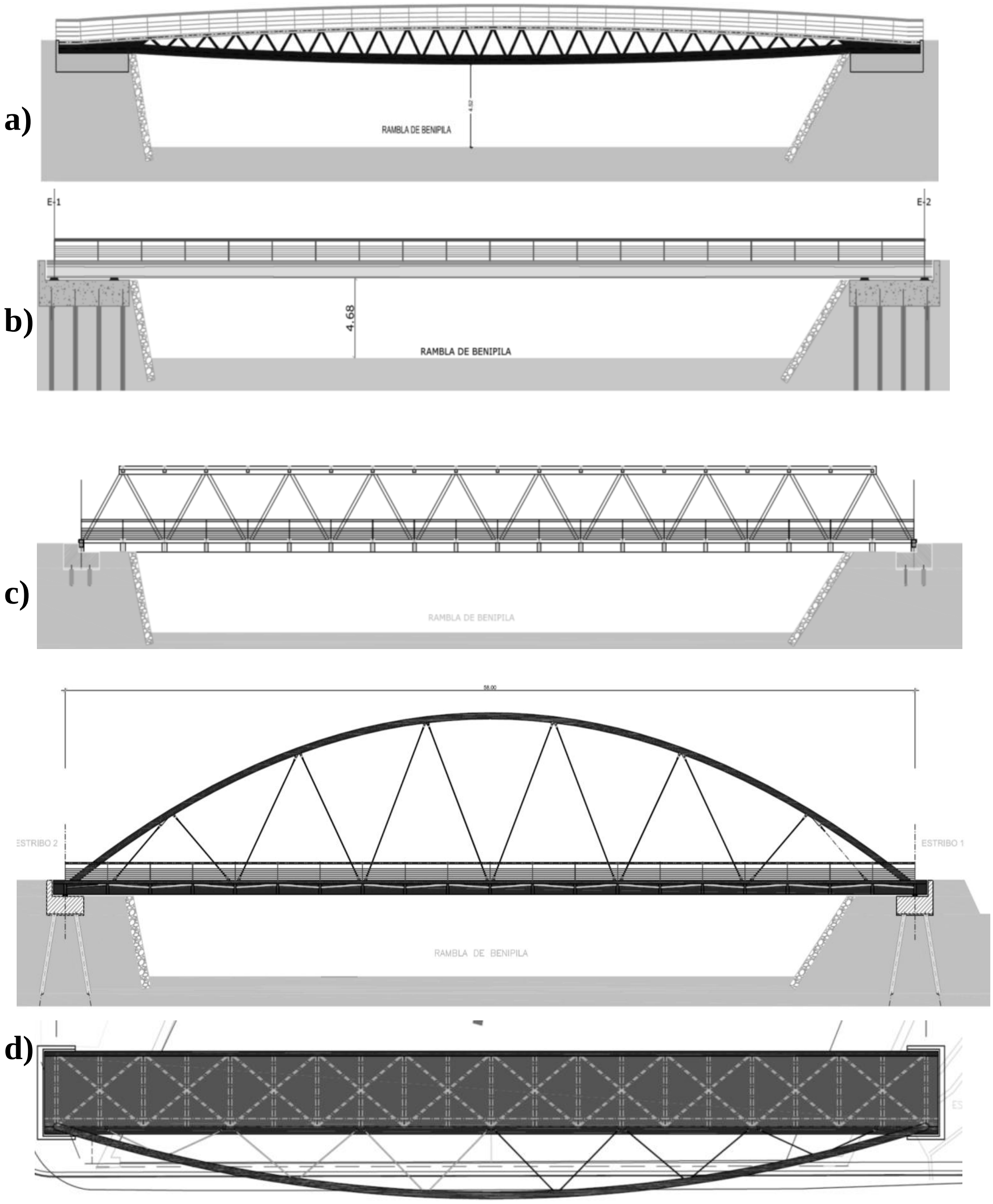

Figure 5: Graduate students' designs. Elevations.

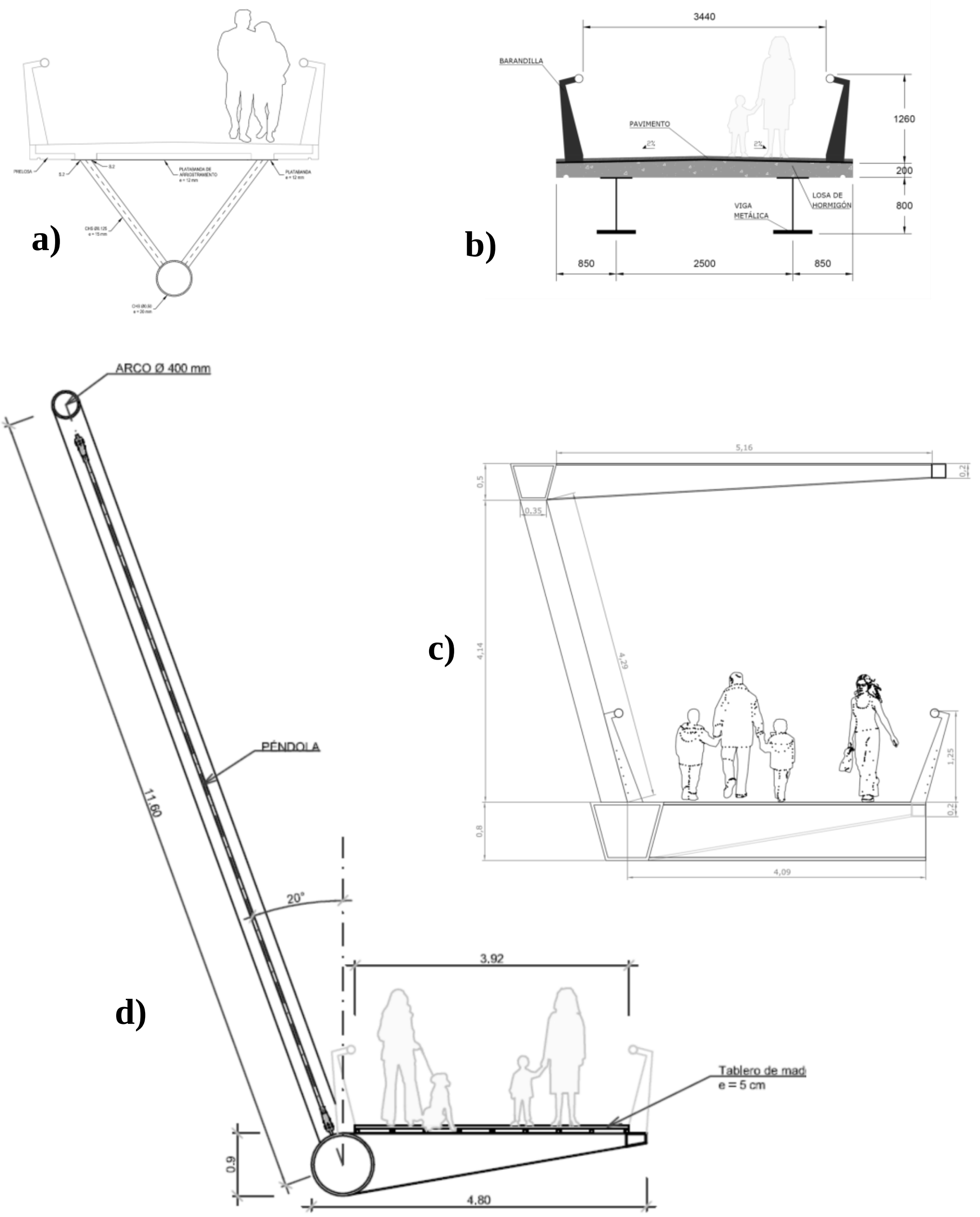

Figure 6: Graduate students' designs. Cross-sections.

4 LESSONS FROM THE EXPERIENCE

The main educational lessons the author learnt from the experience can be summarized as follows:

Office hours in groups.

In the office hours the author met with all the students simultaneously. Previously, the students knew the part of the project we were going to deal with (such as structural modelling, welding design of foundations, etc.) so they could prepare the topic in advance. This is very demanding for the students, but, at the same time, the learning is deeper. Another advantage is that the questions could be answered by the author for all the students at the same time, a fact that saved a tremendous amount of time, because the questions are usually very similar for all of them. Besides, listening the questions of one of the students made the rest of them improve the understanding of the topic.

Additionally, the advisor can save time in the common tasks and devote more hours to the specific aspects of each project, such as its conceptual design.

Design seminars

Some of the meetings were devoted to the design seminars, in which a student describes briefly his/her design to the rest of the group. The student must justify the chosen design, from the technical, functional and constructive points of view, and answer the questions. At early design steps, the questions are very general. However, in the final steps of the design, the question may refer to very specific details of the design.

Of course, the communication skill of the students is greatly enhanced by this experience. Somehow, this could be understood as a “rehearsal” of the final presentation before a committee. By the way, they learn how to summarize the information to be included in an oral presentation, and, especially, how to justify, select and defend a technical solution.

Individual office hours.

Although reduced at the minimum, the individual office hours had no difference with the common role of an advisor. The individual office hours were also available for sub-groups of students with specific or similar problems.

Public presentations

In our School, for the sake of transparency and because of ethical motivation, the presentations of the thesis before a committee are public, and any person may attend, even non-related to the school. The audience may even ask questions to the students, provided the person who asks holds a master degree. In the group of projects all the rest of the group attended to the presentation of every student.

Group beheviour.

Perhaps the most interesting conclusions can be found when the students are part of this advisory strategy. The main features of the group behavior are:

- They tend to share all the information spontaneously. Before the second meeting all of them shared a Dropbox folder.
- They tend to “specialize” within the group. Without planning, one of the student chose to code not only his own software, but also to share it with the rest of the group and help them with their own codes. In return, other one became the “expert” in graphical design, etc. It the specialization is excessive it must be avoided by the advisor, since there is also a risk that the work is not totally personal.
- The members of the group tend to help one another apart from the advisor.
- All of them strive to maintain the same pace, because they conscious that the work

would much more difficult alone.

- The students achieve better results when understanding and designing complex structural typologies, because the students, as well as the advisor, can focus on the structural aspects of their thesis.
- As a result of this strategy, the group developed a very inspiring and hard-working collaborative spirit (Fig. 7), which can be an advantage in their integration into multidisciplinary teams.

Figure 7: A meeting of the Group of Projects

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[2] http://www.boe.es/boe/dias/2009/02/18/pdfs/BOE-A-2009-2738.pdf *Orden CIN/309/2009, de 9 de febrero, por la que se establecen los requisitos para la verificación de los títulos universitarios oficiales que habiliten para el ejercicio de la profesión de Ingeniero de Caminos, Canales y Puertos* (BOE 18/02/2009) [In Spanish] (Accessed in April 2018)