Proposal of a New Academic Frame for the Civil Engineering Education in Construction Safety and Health

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Abstract — Labor accident rate constitutes, nowadays, one of the main worries of the western societies and governments, especially in Spain, where the fatality ratio is far above the European average in the construction industry. This paper carries out an analysis of the university education in construction safety and health. An important deficit is detected in the civil engineering professionals, derived by a specific lack of academic education in construction safety and health. The causes of this deficit are shown and explained. Furthermore, the paper wants to meet the challenge of proposing a new academic frame that improves the current situation. This problem can be approached by two procedures. The first one (a long term solution) is to modify the university program (syllabus). The other one (a short-term solution) is to adapt some courses in order to focus the teaching in construction safety and health. A change in the syllabus involves a slow administrative process and a previous debate by the university faculty. Because of this reason, the second alternative is chosen; it implies the adjustment of some courses. For a suitable development of this proposal, an Educational Guide in Construction Safety is outlined; it may introduce the culture of construction safety and health in the curricula of the civil engineering students. The authors understand that the university has to face the worries and demands of the society and must contribute with its experience and scientific knowledge to the creation of a better environment in the Spanish construction industry.

Index Terms — Civil Engineering, Construction Industry, Educational Guide, Safety and Health.

LABOR ACCIDENT RATE IN THE CONSTRUCTION INDUSTRY

Labor accident rate constitutes, nowadays, one of the main worries of the western societies and governments, especially in Spain, where the fatality ratio is far above the European average. The number of labor accidents has maintained the growing tendency in last years: from 677.138 (1997) to 946.600 (2001) [1]. Even though the importance of the workers’ health is invaluables, these accidents suppose a huge economic cost. According to several studies [2], the total cost of labor accidents is 5% of the companies’ profit, approximately.

Construction industry has the highest labor accident ratio, regarding the rest of productive sectors in Spain, as it can be observed in table I [1]. In the last decade, the construction industry rates have increased, compared to the other productive sectors; the ratios are between 80% and 90% above those of the industrial sector, as it is shown in figure I [1]. The fatalities not only present a social drama, but also suppose important consequences from the legal point of view; data is displayed in figure II [1].

In United States, where the labor accident ratio is half the Spanish one, approximately, the construction industry has the highest rate of injuries among all workers too.

This high ratio is due to the particularities of the construction industry:
- The work center (construction) is mobile.
- The work center (construction) is temporal.
- Many agents participate in the construction process.
- Mainly in Spain, most of the construction companies are small, specially the ones focused on building construction.
- The margin of profit is narrow, thus companies tend to reduce costs in prevention.
- Workers that intervene in the process have scarce professional qualification, due to the employment temporality and the lack of training.
- Engineers and architects that manage the design-construction cycle have a specific lack of education in construction safety and health.
- The growth of the construction industry has brought many inexperienced workers into the field.
The first three particularities are inherent to any construction work; its consequences can only be palliated applying appropriate measures, partially included in the current legislation. The fourth and fifth factors highlight two characteristics of the construction market in Spain: too many small or medium companies that compete aggressively for a piece of the market. Finally, the last three aspects should be regulated by governmental agencies, construction companies and consulting firms; mainly, they imply the rationalization of the recruiting process and the personnel continuing formation.

However, the lack of performance of engineers and architects is an inexcusable responsibility of the university. The technicians that intervene in the design-construction cycle hold an academic title; it authorizes them to a full professional practice. The university main function is to educate the future professionals; thus, once the shortcoming in the preparation of engineers is detected, measures must be taken by the faculty in order to improve the current situation, as soon as possible. In this way, the quick adaptation of the university may contribute to the progress of the society.

THE CULTURE OF CONSTRUCTION SAFETY

In civil engineering, it is considered “Culture of Construction Safety” (CCS from now on) as the whole group of knowledge, habits and behaviors that drive to the application of approaches and procedures of construction safety and health, not only to design, but also to execution of projects in the construction industry [3]-[4]. The necessity of a “know-how” in the professional field is stressed with the term “culture”; it has to be a real will, not only a legal obligation.

As stated in reference [5], the design-construction cycle includes several phases: feasibility, design, construction, operation & maintenance, and sometimes, dismantlement; later on, new problems and feedback of the process could appear. If an interviewer requests to a civil engineer terms related to the design-construction cycle, the answers may be: project, cost, budget, payment, calculation, technique, process, method, material, equipment, etc. The order of the terms is not important, even if some main concept has been forgotten; very rarely the engineer will respond with the term “safety”, and, when it is done, it will be possibly referred to the structural safety of the infrastructure. To implant the CCS in civil engineering implies that one of the first answers be “safety and health”, as a fruit of the knowledge, habits and latent behaviors in the engineer's mental outline.

This mental outline solidifies and forges in the first years of labor experience based on the knowledge, habits and behaviors acquired in their formation stage. The student is the raw material from which the future engineer emerges, as well as the customer of the educational system [6]. The terms “knowledge”, “habits” and “behaviors” are constantly repeated, because it is the way they are acquired: with the repetition or repetitive appearance in several disciplines. The same happens with concepts like “structural safety coefficient”, “design, calculation and verification”, “technical-economic commitment”, etc. These repetitions drive to take root deeply in the junior engineers.

Very few engineers think of safety and health in construction, as a reflective act. Generally, it is not because of the knowledge, habits and behaviors acquired at the university, but, mainly, due to one of the two following reasons:

- Punishment (bitter experiences from the professional practice).
- Graduate degree education (conviction, necessity, normative or, generally, the former reason).

The lack of formation in construction safety and health is so obvious that Mr. Álvarez-Cascos (current Spanish Minister of Public Works) encouraged to the construction industry and the governmental organizations to change this situation; his speech was carried out during the last National Conference on Construction Safety and Health promoted by the Ministry of Public Works of Spain and held this year in Madrid.

This deficit acquires more relevance taking into account that the CCS should be generated and impelled by the technical personnel that intervene in the design-construction cycle (mainly engineers and architects), jointly with legislative and governmental support. From the top, it could be better implanted into the hard-working mass that suffers most of the casualties.

THE CURRENT ACADEMIC SCENARIO

At present, the authors teach at the “Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos de Valencia” (ETSICCP), one of the schools at the “Universidad Politécnica de Valencia” (UPV). The ETSICCP offers a variety of programs adapted at the need of the students interested in the Civil and Environmental Engineering fields [7]. Two of the programs grant a degree in Civil Engineering: a first cycle (three years) undergraduate program (“Ingeniero Técnico de Obras Públicas” or ITOP), and a first and second cycles (five years) undergraduate program (“Ingeniero de Caminos, Canales y Puertos” or ICCP). A second cycle (two years) leads to the degree of “Licenciado en Ciencias Ambientales” or Bachelor in Environmental Sciences. And, finally, a two years (second cycle) undergraduate program grants the degree of “Ingeniero Geólogo” or Bachelor in Geological Engineering.

From now on the paper will be focused in the two degrees that allow the students a career in civil engineering (ITOP and ICCP). Both degrees share the first and second year of the academic syllabus. Thus, a student that obtains the three year degree (ITOP) may join the third academic year of the five year degree (ICCP). This could be stated as a 2+1 program for
ITOP and a 2+3 program for ICCP; the UPV is the only Spanish university that combines both degrees in this innovative fashion.

The Spanish academic system uses the “credit” as a measure unit. A credit is equivalent to ten hours of teaching (classroom or laboratory), but it is not interchangeable with the “European credit” as defined by the European Union [8]. The ICCP degree needs 400 credits to be fulfilled, while the ITOP degree needs 250 credits only. There are three types of courses: “basic” (mandatory), “specialized” (intensive essential) or “elective” (intensive non essential). The degrees have the following distribution of credits:

- **ICCP:** 258 basic + 45 specialized + 97 elective.
- **ITOP:** 154 basic + 45 specialized + 51 elective.

**INTRODUCING THE CULTURE OF CONSTRUCTION SAFETY IN THE ACADEMIC SCENARIO**

Examined both current university programs (ITOP and ICCP), there is only one course that deals specifically with construction safety. It is an elective course (4.5 credits) placed in the last year of the academic syllabus; it is named “Construction Safety and Hygiene”. Only some of the students will attend this course (because it is an elective one), and most of them will start their careers with no intensive knowledge on the construction safety culture. A student that takes this course gets very valuable education, and his/her formation lack in construction safety will not be as huge as others but, nevertheless, habits and behaviors will not take root.

Therefore, could this problem be solved?

Several authors established different approaches to the implementation of a certain subject or field in an academic curriculum. Four of them are cited:

- Management in an engineering curriculum [6].
- Environment in a safety curriculum [9].
- Construction in a safety curriculum [10].

Two different solutions could be applied to solve the problem. Firstable, a change in the syllabus that enforces a necessary formation on the CCS is proposed. For example, it is suggested a new mandatory course (“basic”) on CCS of six credits in the last year of each one of the undergraduate programs (ITOP and ICCP). It implies a slow administrative process, that needs to be passed by several governmental agencies, including the ETSICCP and the UPV. Besides, the current academic programs were passed seven years ago and they will have to be modified in three years to comply with European Union directives [12]. This proposal needs to take a long administrative process, to be debated by the ETSICCP faculty and to be approved by many different agents, so it is ruled out.

The second solution assumes the introduction of the CCS in some courses of the current syllabus. Repetitive appearance in several disciplines could achieve the goal: to think of safety and health as a determining factor in the design-construction cycle.

This approach seems more feasible in the future frame of a European higher education area. Furthermore, the CCS can be introduced in the syllabus without increasing, or even modifying, the credits of the courses. Nevertheless, it may have to beat low faculty interest or established departmental priorities [10].

Following this performance line, the authors want to focus, enlarge and improve the teaching of the CCS in the Civil Engineering Degrees offered by the ETSICCP (ITOP and ICCP). The final product is the development of an Education Guide in Construction Safety for the ETSICCP.

Besides, four years ago, the UPV started the “EUROPA” project with the general objective of promoting positive initiatives towards the improvement of the teaching quality. One of the sub-projects, called ADO, seeks the improvement of the educational organization in schools and departments [8]. The introduction of the CCS in some courses and the development of the Educational Guide in Construction Safety fits perfectly well in this sub-project that allows to coordinate courses and to focus the syllabus contents in the CCS.

**DEVELOPING THE CULTURE OF CONSTRUCTION SAFETY IN THE ACADEMIC SCENARIO**

The first step to develop the CCS is to establish the technical background needed for civil engineers. This background must include, at least: description of the construction industry, analysis of safety rates, definition of construction safety management, differences with fixed-site industries, legislation, design for a safety environment, construction methods (and their safety violations, injuries and protections), safety prevention, etc.

Next, it is necessary to identify the courses that could implement the CCS. Therefore, a classification of courses in four categories is proposed, as follows:

- Category A: CCS can not be implemented.
- Category B: CCS may be implemented in specific topics.
• Category C: CCS can be implemented as one of its main contents.
• Category D: CCS is the subject of the course; as it was said previously, there is only one elective course named “Construction Safety and Hygiene” (4.5 credits) that is placed in the last year of both degrees (ITOP and ICCP).

A classification of courses in categories B and C is proposed in tables II and III for both degrees (ITOP and ICCP). Previous background confirms the possibility to implement, partially, the CCS in a course [13]. Category C is composed of very few courses, but at least one per academic year is chosen. The basic (mandatory) courses are highlighted in black. Most of the courses in the category B are specific or elective.

Identified the courses that are within categories B and C (tables II and III), a questionnaire is sent to each professor. The information that can be obtained from the questionnaire is:
• The professor's will to implement the CCS.
• The real possibility of this implementation, taking into account that contents are very tight.
• Contents the professor wants to include.
• The advice the professor needs to implement the CCS.

This last point is very important. It will come as no surprise that the present engineering educators may be deficient in the CCS skills that the future engineers require [14]. The faculty will probably need some help from senior engineers to improve their CCS. There should be a dialog between the professionals and the faculty at the ETSICCP in order to implement correctly the CCS [6].

Furthermore, the questionnaire allows to elaborate a coordinated program among courses that may assure a complete covering of all the aspects of the CCS, it may avoid repetitions (except those that are necessary to take root the CCS) and it may palliate the formation deficit in the CCS.

A minimum itinerary along the syllabus should include the following courses:
• ITOP: Chemistry of Materials (1st year), Legislation (2nd year), Construction Equipment and Methods (3rd year) and Projects (3rd year).
• ICCP: Chemistry of Materials (1st year), Legislation (2nd year), Construction Equipment and Methods (3rd year), Projects (4th year), Geotechnics and Foundations II (4th year), Building and Precast Construction (5th year) and Organizational Behavior and Management (5th year).

As it was previously stated, the last step is to develop an Educational Guide in Construction Safety. This Educational Guide will focus and define the intensification in the construction safety field of some courses that are related to the CCS.

**Educational Guide in Construction Safety**

The goals of the Educational Guide in Construction Safety are:
• To facilitate the work of the professors that want to introduce the CCS in the contents of their courses.
• To guide the students through the academic program.

Within these broad goals, the objectives of the Educational Guide in Construction Safety can be stated with more detail, as follows:
• To define the CCS main topics.
• To approach the CCS concepts to professors and students.
• To focus the CCS for each particular course in the categories B, C and D.
• To help the implementation of the CCS for each particular course in the categories B, C and D.
• To add construction safety criteria to the teaching of each one of the courses in the categories B, C and D.
• To summarize the CCS to the professors, to the students mainly and, even, the junior engineers.

The Educational Guide in Construction Safety should be edited as a book of reference for professors, students and junior engineers. Furthermore, it could be showed up freely in the university web.

Basically, the Educational Guide in Construction Safety is structured internally in the following way:
• Main construction safety topics.
• Course classification according to the construction safety topics previously set.
• Teaching level recommended for each one of the courses in the categories B, C and D.
• Information resources (bibliography, webs, legislation, etc.) useful to implement the topics.

Finally, depending on the result of the questionnaire, additional seminars or field trips may be organized. In the former case, guest lecturers should be chosen among relevant professionals that highlighted sides of the CCS not sufficiently covered by the academic programs. In the latter, field trips should show the students, not only the CCS, but also some aspects relative to design and construction of different civil engineering infrastructures.
CONCLUSIONS

This paper presents a proposal of implementation of the Culture of Construction Safety in the current civil engineering syllabus at the ETSICCP.

The proposal implies the adaptation of some courses in order to focus the teaching in construction safety and health. On the other hand, it also aims for a coordination effort among basic courses that allows the teaching of topics related to the Culture of Construction Safety in each one of these courses; using this approach, the modification of the current academic programs is not necessary. As an important output, an Educational Guide in Construction Safety is developed to help professors and students to implement the Culture of Construction Safety.

This implementation has to be taken within the guidelines of the “EUROPA” project, with the support of the ETSICCP and the UPV.

Finally, the university has to face the worries and demands of the society and must contribute with its experience and scientific knowledge to the creation of a better environment in the Spanish construction industry, specifically in the field of the construction safety and health.

REFERENCES


FIGURES AND TABLES

TABLE I
RATES BY SECTOR IN SPAIN (2001)

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Incidence Ratio (labor accidents per 100,000 workers)</th>
<th>Frequency Ratio (labor accidents with casualties per 1,000,000 hours worked)</th>
<th>Severity Ratio (not worked days, due to labor accident, per 100 hours worked)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>3.172</td>
<td>14.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Other primary (not agriculture)</td>
<td>7.792</td>
<td>46.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Industry</td>
<td>11.044</td>
<td>64.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Construction</td>
<td>18.307</td>
<td>102.7</td>
<td>2.3</td>
</tr>
<tr>
<td>Tertiary</td>
<td>4.971</td>
<td>30.4</td>
<td>0.7</td>
</tr>
</tbody>
</table>
### TABLE II

**ITOP: CLASSIFICATION OF COURSES IN CATEGORIES B AND C ACCORDING TO THE CCS IMPLEMENTATION**

<table>
<thead>
<tr>
<th>ACADEMIC YEAR</th>
<th>CATEGORY B</th>
<th>CATEGORY C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Civil Engineering  History  Sociology</td>
<td>Chemistry of Materials</td>
</tr>
<tr>
<td>2</td>
<td>Construction Materials I  Economics  Geotechnics and Foundations I  Machines and Electric Facilities  Surveying</td>
<td>Legislation</td>
</tr>
<tr>
<td>3</td>
<td>Final Project in Civil Engineering  Construction Materials II  Environmental Assessment  Hydraulic Works  Irrigation and Drainage  Pavements  Prestressed Concrete  Ports and Costs  Quality Assessment  Railroads  Reinforced Concrete  River Engineering  Roads and Airports  Sanitary Engineering  Site Works  Steel Structures  Water Quality</td>
<td>Construction Equipment and Methods  Projects  Building and Precast Construction  Geotechnical Engineering</td>
</tr>
</tbody>
</table>

### TABLE III

**ICCP: CLASSIFICATION OF COURSES IN CATEGORIES B AND C ACCORDING TO THE CCS IMPLEMENTATION**

<table>
<thead>
<tr>
<th>ACADEMIC YEAR</th>
<th>CATEGORY B</th>
<th>CATEGORY C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Civil Engineering  History  Sociology</td>
<td>Chemistry of Materials</td>
</tr>
<tr>
<td>2</td>
<td>Construction Materials I  Economics  Geotechnics and Foundations I  Machines and Electric Facilities  Surveying</td>
<td>Legislation</td>
</tr>
<tr>
<td>3</td>
<td>Construction Materials II  Railroads</td>
<td>Construction Equipment and Methods</td>
</tr>
<tr>
<td>4</td>
<td>Ports and Costs  Reinforced and Prestressed Concrete  Roads and Airports  Sanitary Engineering  Steel Structures  Water Resources and Hydraulic Works</td>
<td>Projects  Geotechnics and Foundations II</td>
</tr>
<tr>
<td>5</td>
<td>Building and Precast Construction  Organizational Behavior and Management  Building Failures and Rehabilitation  Construction Management  Management of Construction and Consultant Firms  Project Management  Tunnels and Underground Works</td>
<td></td>
</tr>
</tbody>
</table>

*International Conference on Engineering Education  
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<tr>
<th>ACADEMIC YEAR</th>
<th>CATEGORY B</th>
<th>CATEGORY C</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Environmental Assessment</td>
<td>Special Foundations and Soil Improvement</td>
</tr>
<tr>
<td></td>
<td>Final Project in Civil Engineering</td>
<td>Technology of Concrete Construction</td>
</tr>
<tr>
<td></td>
<td>Bridges</td>
<td>Technology of Steel Construction</td>
</tr>
<tr>
<td></td>
<td>Coastal Engineering</td>
<td>Water Quality</td>
</tr>
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<td></td>
<td>Dams</td>
<td></td>
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<tr>
<td></td>
<td>Design Projects Workshop</td>
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<td></td>
<td>Geological Engineering</td>
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<td></td>
<td>Irrigation and Drainage</td>
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<td></td>
<td>Marine Works</td>
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<tr>
<td></td>
<td>Operation and Maintenance of Railroads</td>
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<tr>
<td></td>
<td>Quality Assessment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>River Engineering</td>
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<tr>
<td></td>
<td>Seismic Engineering</td>
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</table>

FIGURE I
INCIDENCE RATIO (LABOR ACCIDENTS PER 100,000 WORKERS)

![Incidence Ratio Chart]

FIGURE II
LABOR FATALITIES PER PRODUCTIVE SECTOR

![Labor Fatalities Chart]