

Planning construction history for a civil engineering curriculum

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ABSTRACT: The focus of this article is a proposal for the optimum content of a *construction history* module for the civil engineering curricula in Greece. The orientation of the students' approach towards the history of various structural systems of buildings and the projection of innovative solutions of the past without the today's technology tools, are the fundamental parameters concerning the elaboration of this multi-criteria problem. The planning of the course as both a conventional one and an open learning platform, as well as the outlines of the implementation in the Department of Civil Engineering of the Technological Education Institute of Piraeus have been included in this article. Part of the results of a capstone project in progress, regarding the geometric representation of a structural system during its historic evolution, are also included in this article as a case study of the research possibilities rising after the course.

INTRODUCTION

Construction history is a relatively new area of concern for engineers. The main reasons of the field development include:

- The need for the recycling of the existing buildings that produced the need to organise and group knowledge about the history of their construction and bearing system.
- The research on materials and techniques of the past related to the ecologic construction and bioclimatic design.
- The fact that reinforced concrete has become the subject of historical investigation since the late 20th Century.
- The changes in the field of architectural and structural design and related professions due mainly to the dependence upon IT tools. The dominant trends reflect basically the renewed interest of the architect on the structural logic of the buildings, as well as the introduction of the architectural design parameters in *engineer's aesthetics* [1].

The interrelations between structural and civil engineering, and architecture have led to the new synergetic profiles of the related professionals and strengthen the interdisciplinary approach as a matter of course: *New dialogues are beginning to emerge, as these two professions, which have often been perceived as quite separate areas of concern, are coming together within a culture of mutual respect* [1].

With respect to engineering disciplines, the scientific dialogues outline the subject more as an activity than an autonomous cognitive entity: *...thus as a movement rather than an academic discipline on its own* [2]. In European universities, one has to note the lack of degree programmes in construction history [3].

According to the results of an enquiry presented in 2006 regarding the content of construction teaching in European schools of architecture, construction history is taught in one module at 64%, with history of structures at 12% [4].

In the architecture schools in Greece some construction history issues are part of the modules on history of architecture and building rehabilitation. In the curricula of civil engineering departments, there are no direct modules; philosophy of technology and history and philosophy of science and technology are the usual titles of partially relevant subjects.

In the Department of Civil Engineering of the Technological Education Institute (TEI) of Piraeus Construction History has been introduced as an optional course since 2010-11 in the 5th Semester of undergraduate studies instead of the previous History of Science and Technology.

TEACHING CONSTRUCTION HISTORY - THE PLANNING OF THE COURSE

Outlines and Aims

The first idea to introduce the module in the curriculum was based on both the experience exchanged in the field within the cooperation with the Department of Landscape Architecture, Geo-informatics, Geodesy and Civil Engineering of the Neubrandenburg University of Applied Sciences (Germany) through ERASMUS student and staff mobility since 2004, as well as the research interest of the first author on the construction details of historic buildings strengthened by the creative scientific dialogue developed during the international congresses organised by the Construction History Society. Nowadays, the *...awareness of the need for a cultural and historical profile in civil engineering works* [5] reflects social demands and the recent tendencies in the construction market. On the other hand, the relevant proposals on the higher education programmes worldwide meet the new requirements regarding the structural engineer's skills.

The topics of the course focus on building history with references to infrastructure projects with a definitive role in construction innovation. According with the above mentioned, the main goals of the course development could be summarised as follows:

- knowledge of the construction process in history, necessary for the analysis and recognition of a building under investigation;
- interpretation of the historic construction and the explanation of many questions rising during conservation and refurbishment;
- strengthening of the effectiveness and efficiency of the graduates in building rehabilitation;
- mobilisation of the *structural* thought, as well as the perception of the basic functional and aesthetic issues in architectural practice.

The Problems

The main problems during the planning of a Construction History course consist in the extended subject and the wide-ranged criteria of development. Although the centre of gravity is placed in the built environment from the beginning, the organic connection of the factors influencing the building construction makes them non-detachable.

The building in its evolution is a multi-dimensional and not a 3-D object; it is not as simple as a case study of architectural design and technology implementation. It is not only a cultural object or a site of touristic attraction and educational utility, but also a product, a social and economic tool, as well as a reference point for ethics. In addition, building construction is related with all the previous aspects, shown in Figure 1.

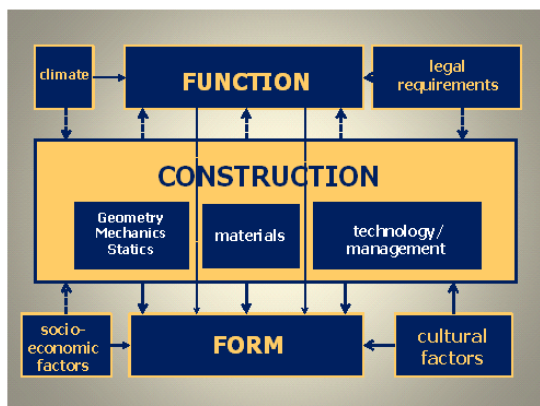


Figure 1: The interrelation of factors influencing building construction.

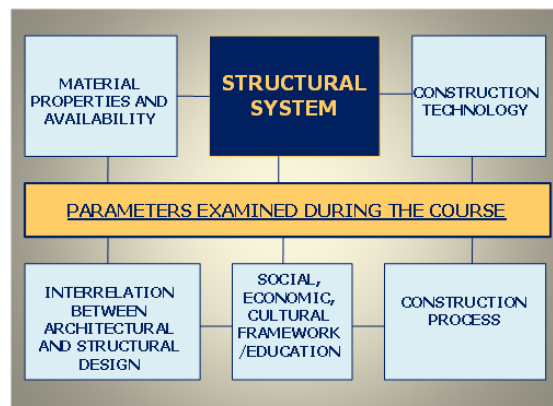


Figure 2: The parameters examined in the course.

As a consequence of the above, during the planning of a Construction History course the main questions are:

- How to bring all these factors within a course for civil engineers?
- Which range of the bibliography should be proposed?
- How to avoid the excessive reference to the features of architectural aesthetics?
- How to succeed in the balance of information in a dynamic field?
- Is there a formula for finding an attractive course?

The extent of the questioning is far-reaching. The proposal for the basic outlines of a solution sounding feasible is the focus of this article.

The Course Content Structure

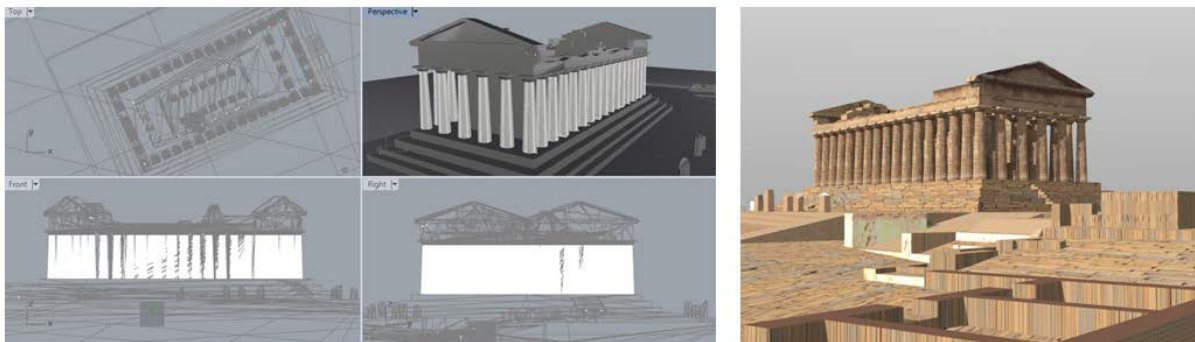
In researching the optimum axis of the content development, particular emphasis has to be placed on the strengthening of *thinking structural*, especially, in a civil-structural engineering department. The analysis and recognition of the structural systems is fundamental for the approach to the buildings in history, as well as to the understanding and respect of their structural forms. In addition, the ability to distinguish and compare structural and pure architectural aesthetic features in the historic building shells is a requirement during rehabilitation projects.

According to the previously mentioned issues, the proposed axis consists of the structural systems' evolution. The issues connected in a direct or indirect way with the bearing structure and the structural form of the building have been included and addressed in the course. The impact on the functional layout, the interrelation between architectural and structural design, the importance of geometry, the historic material properties, the process and the complexity of the construction procedures [2], the social and cultural framework, as well as the academic status are the parameters examined or roughly introduced are shown in Figure 2.

In a more detailed lining up, the proposed structure of the course regarding the division in sections and their titles is shown in Table 1.

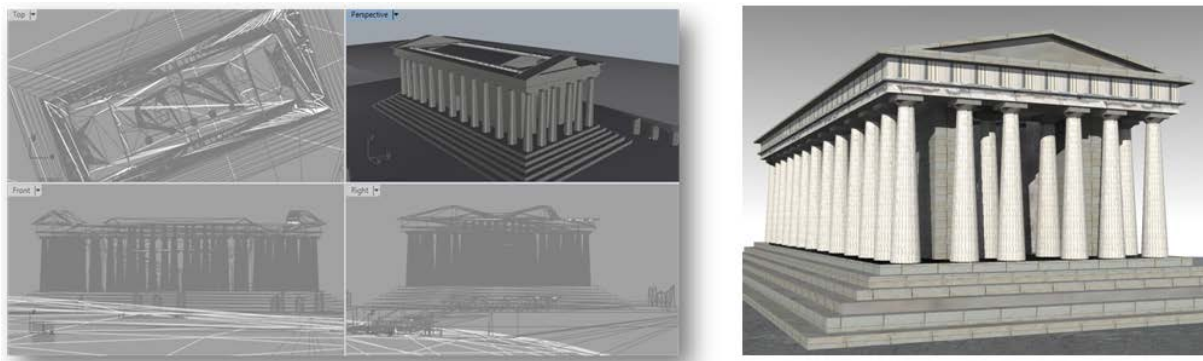
Table 1: The structure of the course contents.

Introduction	The aims of construction history; definition of the axes of the contents; the terms structure and form; categories of the structural systems in history; reference to the structural systems of the 21st Century (<i>tensegrity</i> structures, tensile structures, air-supported structures, rods).
Post-and-beam structures	The evolution of the system. The structural model.
	The implementation in Egypt and the Ancient World (Greece and colonies).
	The classical Greek temple.
	The impact on the Hellenistic and Roman World.
Arches, domes and vaults	The evolution of the system. The structural model.
	The implementation of the system in the Roman World.
	The implementation of the system in the Byzantine World. The structural model of the Byzantine church.
	The implementation of the system in the medieval Western world. The structural model of the Romanesque church and the Gothic cathedral.
Historic composite structures	The dissemination of the Classical and Roman architectural design styles in Western Europe. The impact of the Roman and Gothic structural principles on the structure of the buildings from 15th to 19th Century.
	The use of mixed structural systems in vernacular architecture of Greece from 15th to 19th Century.
	The use of mixed structural systems in the urban centres of modern Greece during 19th and early 20th Century. The basic model and the variations.
Lattice structures	Wooden structures.
	Iron structures.
Monolithic structures	Underground and rock-cut structures.
	Reinforced concrete structures.
	Thin shell structures.
Conclusions	General conclusions on the role of the structural systems in history. Different readings of construction history according to different points of view: a) the architectural design principles; b) the technology development and innovation; c) the use of materials; d) the social and economic conditions; e) the cultural trends; and f) the status of engineering education and profession.



Figures 3-4: The Apollo Temple - part of the drawing procedure and the structural form.

With regard to the development of each section, the topics examined include the factors presented in Figure 2, but the width of each varies, according to the extent of implementation of the structural system in Greece and in Greek areas in history.



Figures 5-6: The Hephaestus Temple - part of the drawing procedure and the structural form.

TEACHING *CONSTRUCTION HISTORY* - THE IMPLEMENTATION OF THE COURSE

The Realisation of the Course

The main formal elements of the course are the lectures, visits to buildings and sites of special relevance and a short written paper also presented orally to the course audience. The paper is the result of a small scale piece of research, usually on the historic buildings of the origin place of each student. The content of the course will be available to all civil engineering departments through an open learning platform by the end of year 2014-15.

The sources for further reading proposed could be characterised generally as direct and indirect. The bibliography of direct reading comprises the proceedings of the international congresses of construction history and the history of architecture sources with the disadvantage of their focus usually on aesthetic features. The specific publications on the topic of reuse and refurbishment projects of historic buildings are a valuable source of indirect reading, as well as the known architects' biographies, and the studies on the cities and traditional settlements history. The sources related to the Greek vernacular architecture are also useful, including rich information on local construction issues.

The results of the course evaluation by the students, according to the ordinary evaluation procedure through standard questionnaire during the periods 2011-12 to 2013-14 are of two kinds: in a broad estimation, a) 85% of the students agree with the axis of the course structure, the rest 15% would decide the centre of gravity on the construction details; and b) 75% counts as positive the content of each section, the other 25% would like more information on architectural issues, regarding the architects and the styles of buildings. In addition, a common remark is the demand for a more extended discussion on the civil engineering technology during 20th Century.

The Learning Outcomes and Research Possibilities

The students who attend the lectures usually have a medium to high level of cultural background. Their interest in the interaction between civilisation and the historical built environment is obvious from the first lecture. In the course process, the change of the students' attitude towards the easier combination of the knowledge from the modules of mechanics and construction technology, and the understanding of the representation techniques is remarkable. At the end of the semester, they achieve the comparison between the basic steps of construction history to a great extent with success.

The problem to mark is the difficulty with the complete understanding of the geometric features, although they begin to approach the historic object in a new way; the detailed observation of everything in the building is a benefit during this procedure.

After the course on construction history, the students are usually interested in the elaboration of a relevant topic as the final project of their studies. The phenomenon is normal, because of the investigation motives that the kind of the course provides. In the year 2014-15, two projects with a similar concept will be completed, regarding the design of 3D models and interactive tools for the geometric representation of structural systems and the consequent structural forms in the history. The outcomes will be used in a future revision and development of related issues. As an example, the evolution of the form of the Greek temple according to the post-and-beam structural principles during approximately one century is presented in the Figures 3-6; the selected case studies are the Temple of Apollo in Syracuse (565 BC) and the Temple of Hephaestus in Athens' Agora (449 BC).

CONCLUSIONS

Construction history comprises a wide and dynamic field of learning outcomes and research incentives. According to the authors' experience after the implementation of the course in the undergraduate program of studies at the Department of Civil Engineering of TEI Piraeus, it can be assured that the related knowledge is of great importance for the formation of a civil-structural engineer's professional profile, especially, in this changing era, when engineers have to be resourceful. On the other hand, the authors bring to a further discussion the planning of such a course, searching the unified formula that could drive to the inclusion of all the necessary issues within the course boundaries effectively, and to attain the creative connection with the conservation courses.

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