

Integration of structural analysis of monuments and historical constructions in engineering and architecture studies

A. Mosseri

The David Azrieli School of Architecture. The Faculty of the Arts, Tel Aviv University, Israel

ABSTRACT: This article focuses on the integration of historical construction knowledge during the earliest phase of the engineering and architectural education. An historical review of the specialization process in the field of historical construction is introduced, from early days until present, and current problems are analyzed in relation to our era. As an outcome, different possible strategies are developed and introduced.

1 INTRODUCTION

The field of historical construction is one of the most important fields in conservation and restoration of the built heritage. The structural system, especially in historic projects, is considered an integral and essential part of many architectural creations. The development of scientific capacities in the field of historical construction enabled, until now, to save some important heritage of the built environment.

Future challenges are considered even more unique and complex, mainly because of the growing amounts of information and knowledge, environmental and sustainability problems, social and cultural developments, public involvement etc. Consequently, it is really possible to see, nowadays, an increasing awareness and a growing activity in relation to this issue. But, in spite of these increasing positive trends, bringing the knowledge in this field to a higher level and getting people and institutions more qualified – is still a challenge. This kind of activity has to be multidimensional and multidisciplinary.

One of the most influential disciplines with regard to the activity in the field of historical construction is the academic discipline. Indeed, many constructive efforts are made in this area, especially in advanced studies, but we are still facing the great challenge of raising the level of integration of historical construction, especially earlier in engineering and architectural education for academic qualification. It is an imperative stage which must be reached prior to continuing towards professional certifications in architecture or engineering (there are different approaches to studies for academic qualification in different countries but in each country these studies are the minimal academic requirements). The proposal presented in this paper

is a first step, which has to be further developed in a continuous process, to improve the historical construction knowledge in early stages – as part of the studies for academic qualification in engineering and architecture.

2 HISTORICAL BACKGROUND – ENGINEERING, ARCHITECTURE AND HISTORICAL CONSTRUCTION

2.1 *Engineering, architecture studies and historical construction prior to the industrial revolution*

Since the early days of history man has been dealing with erection of the built environments as a natural process. The art of creating buildings and settlements was part of the daily life of every human being. The professional knowledge used to be passed on from one generation to another, from father to son. In this process the structural aspects were integrated with other aspects such as: climate, lighting, culture, etc. It is reasonable to assume that the level of integration thereof was relatively high, in spite of the lack of any specific expertise, or any public system of studying the art of building.

At a later stage, we could already identify the special expert – the master builder – who possessed the knowledge of “how to build”. This professional entity was in many cases a polymath personality, who dealt in an integrative way, with different aspects of the built environment. At that time it was still impossible to make a distinction between professions like architecture, civil engineering or structural engineering of historic buildings. All these areas were at that time under the same

umbrella. The climax of this unity between the different areas can be noted in the era of the Renaissance. It is important to stress that one of the most common ways of studying at that time, and even before, was mainly based on apprenticeships.

The professional body of knowledge of the built environment, including structural analysis, was mainly qualitative. It was based on intuition and empirical experience, acquired by observations and studies of long-standing historic buildings. The lack of extensive theoretical infrastructure about the behavior of structures highlighted the importance of such historic buildings as an essential source of knowledge and expertise. In the light of this situation it is possible to say that the master builders had a strong historic dimension in their structural thinking.

These facts can be substantiated by a variety of documents, considered as the origin of the studies and organized knowledge in the field of historical construction. This knowledge was documented in a way that retained and preserved it for the next generations, in books or codex. Examples can be found in different eras along history. Among the most famous documents we may find Vitruvius's book "De Architectura Libri Decem", known today as "Ten Books on Architecture" (Vitruvius), the Codex of Leonardo Da-Vinci and other works like the book of Andreas Palladio: "Il Quattro Libri dell'Architettura" – "Four Books on Architecture" (Palladio, 1570). In Vitruvius's book, for example, there are different instructions regarding structural aspects. These instructions are based in many cases on empirical studies and analysis of historic buildings, studied and described in his book. The same can be said about Andrea Palladio and others. From this point of view, it is indeed possible to see that the historic dimension was very crucial in their structural thinking.

It is important to add that the purpose of analyzing the historic buildings was not only to acquire knowledge in order to build new buildings, but also to enable conservation. Whenever conservation was required, as in cases of earthquakes or in cases like the Pisa tower, structural analysis of historic buildings could be found and made use of.

Structural analysis has been conducted, during all these years, without the help of quantitative-scientific tools. At later stages, the development of quantitative analysis was a direct expansion of early understanding of different structural subjects. Galileo, Newton, Hook and others, laid the foundations for the development of accurate and versatile techniques for structural analysis (Mainstone, 1973). The time, between the 15th–18th centuries, can be considered as the era of transition to the era of industrial revolution. From that time on, more scientific, accurate and theoretical-structural knowledge started to accumulate, in addition to the empirical knowledge and experience. Mainstone

(1968) mentioned the year 1742 as a significant point in the history of the theory of structural analysis.

2.2 *Engineering, architecture studies and historical construction after the industrial revolution*

The industrial revolution, which symbolizes the modern era, accelerated the specialization in our life and since then we have been able to distinguish numerous fields of expertise, which have become more and more specific. In this situation, the built environment area, as an interdisciplinary one, was divided mainly into architecture and civil engineering and other fields (Mosseri, 2005). The main landmark for this separation occurred in the 18th century with the establishment of the Ecole des Beaux-Arts in Paris, France. In this school, architecture was taught as a distinct discipline, separated from civil engineering. Many schools of architecture, founded later all over the world, were influenced by the heritage of the Beaux Arts. At the same time, first specific institutions for civil engineering were erected in France, and later in Germany and the United States. Structural analysis of monuments and historical construction, as an academic discipline, was developed also as part of the specialization process in the field of civil engineering.

The specialization process created profound theoretical knowledge in the different academic areas of activity, including the area of monuments and historical construction. Many advanced theories and other different research tools were developed, thus enabling the continuation of the process of enlightening the field of structural analysis of historical monuments and construction.

3 ENGINEERING, ARCHITECTURE AND HISTORICAL CONSTRUCTION NOWADAYS

Nowadays, in the information era, it is possible to identify many academic institutions of architecture and civil engineering all over the world granting various levels of academic degrees – starting with a Bachelor's degree up to a Master's and Ph.D degree. In most cases architecture and civil engineering are studied in separate programs, sometimes even in separate departments or schools. Nevertheless, it is possible to find places which have integrated studies of civil engineering and architecture as one joint degree (architect and engineer).

There is a large variety of programs of academic qualifications all over the world. There are institutions in which the academic qualification is considered to be a Bachelor's degree (for example B.Arch.) whereas in others, the academic qualification is given only after the completion of a Master's degree (for example M.Sc. in architecture).

With regards to the study of historical construction – the academic activity in this area is often done within the framework of advanced studies, after completion of studies for an academic degree in architecture or civil engineering. This activity includes a growing advanced research activity. Thanks to that, and to the developments in other fields, such as computer sciences, there is a large gamut of relatively advanced theoretical and empirical tools, giving us a relatively high level of structural analysis of monuments and historical construction.

4 PROBLEM DIAGNOSIS

In spite of the efforts devoted to the development of a profound and extensive infrastructure in the field of historical construction, the activity in education and research in many cases appears at later stages in specific advanced studies, following the academic qualification in engineering or architecture.

As a result, some engineers and architects who finished their studies have barely been exposed to historical construction, if at all. In this situation they not only lack a professional knowledge regarding historical construction, but have also no historic perspective of the structural aspects. However, this historical aspect of structural thinking has indeed been an important element for thousands of years of history.

Studying engineering and architecture, without historic structural precedents, not being exposed to the way of thinking of the master builders of the historical construction, can limit the opportunity to enrich the rational and modern way of thinking in structural design.

All this may result in a reduction of the quality of advanced studies in historical construction. The lack of awareness and exposure, in the early stages of the studies, minimizes the demand for advanced studies in this subject and as a result there can be fewer candidates for higher-degree studies.

In this situation there is a necessity for a new concept, aimed at increasing the integration of structural analysis of the built heritage and historical construction in engineering and architectural studies.

5 A VISION FOR THE FUTURE

5.1 *General*

Having a vision for historical construction in engineering and architecture studies requires initially a broader perspective of the whole range of studies, starting with basic academic qualifications and up to the final expertise in the structural aspects of the built heritage. This leads to the initial need for taxonomy of the

different kinds of knowledge in the area of historical construction. Then, there should be some idea about the stages of the specialization process, and finally an overall understanding of the knowledge that has to be acquired in each stage. This will allow us to have a clear policy in relation to the studies for an academic qualification in architecture and civil engineering.

5.2 *Stages in the process of specialization in historical construction*

In the education process in the field of historical construction three main stages could be noted:

- First stage – Basic structural studies of the built heritage, including all the knowledge within the framework of the studies for academic qualification in architecture and engineering.
- Second stage – Specialization studies, including the specific studies of the built heritage construction after obtaining the academic qualification and the professional certification.
- Third stage – Specialization in the practice of the built heritage, including the experience and knowledge acquired by practical work in historical construction, after official graduation. This stage of becoming an expert can include a variety of requirements and it may differ from one place to another.

5.3 *Taxonomy of knowledge of historical construction*

There are different kinds of knowledge concerning structural aspects of the built heritage. In order to define the subjects to be included in the studies for academic qualification in architecture or engineering, it is important first to create the taxonomy of these various subjects of knowledge. Accordingly, it is suggested to distinguish between three kinds of knowledge with regard to the structural aspects in the built heritage:

- Terminological knowledge – which includes basic terms of the area of construction of the built heritage. This terminology enables communication on a basic level.
- Analytical knowledge – which enables us to analyze and understand the structural performance of different structural systems regarding the construction of the built heritage. This knowledge is more connected to dismantling of a phenomena understanding its components and their inter-relations. Naturally, it includes the terminological knowledge in the first level.
- Synthetic knowledge – relating to the ability to synthesize and create new solutions for different problems in historical constructions. It deals with invention of strategies by creative thinking.

5.4 *The matrix of the whole studies in the course of time*

The connection between the different kinds of knowledge and the various stages in the specialization process, have created the matrix of the studies in the course of time. According to that, we can identify which kind of knowledge has to be studied more thoroughly (yet, all subjects have to be studied at each stage):

- In the first stage – the main purpose, in general, is to supply the infrastructure for the academic qualification. The purpose, from the point of view of historical construction, is mainly to expose and increase the students' awareness of the subject of historical construction, and to give them initial and basic tools. Thus, the focus has to be mainly on terminological knowledge, as well as on basic analytical knowledge.
- In the second stage – the main purpose is to give the students a relatively profound and thorough knowledge, specifically on the subject of historical construction. Thus, the focus has to be mainly on analytical knowledge. At the same time, it is not less important to create the infrastructure for the synthetic knowledge and to develop initial capacities to create and to invent new strategies, in order to cope with different structural problems of historic buildings.
- In the third stage – the main purpose is to acquire a more practical orientation and to cope with daily life problems, requiring a synthetic solution. Thus, the main focus has to be on synthetic knowledge, yet also on analytical knowledge to support the synthetic one.

6 POSSIBLE STRATEGIES IN THE STUDIES FOR PROFESSIONAL DEGREE

6.1 *General*

In this paragraph possible strategies are introduced, based on the matrix for the integration of historical construction in architecture and civil engineering studies. Because of the differences, apart from similarities existing between institutions of civil engineering and architecture – these strategies are introduced as general guidelines, which can be developed in each specific institution.

6.2 *Possible strategies*

The act of integrating historical construction in the studies for academic qualification in architecture and engineering is multidimensional, and should consist of various strategies. Therefore, a system's point of view is needed, based on various levels of integrated

strategies, and depending on circumstances specific to each case. In some cases this integration of strategies could be made in one step, as a whole, and in other – there could be a sequence of gradual, moderate steps. Examples of such selected strategies are listed in the following paragraphs.

6.2.1 *Corresponding enrichment activities in the existing programs*

This strategy is a basic one, and does not require any significant changes. It is mainly oriented towards enriching the existing curricula in architecture and engineering, by introducing varied activities in the field of historical construction. This can be made by lectures given by experts, conferences, specific web-sites etc. The focus in this case is on terminological knowledge, to give the students a broader perspective.

6.2.2 *Integration of historical perspective in conventional construction courses*

This strategy is relatively friendly and easily implemented. It is mainly based on “injecting” historic perspectives in the existing construction courses – whether in one course, or in several selected courses. This strategy can be oriented towards terminological and analytical knowledge (but also towards synthetic knowledge in advanced courses).

In faculties of architecture, in courses dealing with the history of architecture, structural aspects can be integrated, in which case collaboration between lecturers of history and engineering will be required.

6.2.3 *Specific elective course/courses in historical construction*

This strategy focuses on creating a specific elective course, or courses, which will deal specifically with historical construction. This will enable students, interested in this subject, to enrich their knowledge and understanding from the early stages of their professional training.

6.2.4 *Specific obligatory course/courses in historical construction*

This strategy is based on the assumption that it is preferable to have obligatory requirements regarding historical construction. Accordingly, a specific obligatory course (or several courses), can be included as an integral part of the studies. Should there be a number of courses (even elective, as described in the previous paragraph) – the first one in this category would be an introductory course to all the other courses.

6.2.5 *Studio course dealing with conservation and historical construction*

This option relates mainly to schools of architecture, in which the design studio is one of the main areas of activity. In such case, it is possible to establish a

specific studio, oriented towards conservation including aspects of structural construction. In this case it is possible to collaborate with lecturers and students of civil engineering departments.

6.2.6 *Integrated strategy*

This option is the result of an attempt to create a combination of the different strategies, introduced above: Starting with the possibility of using only one strategy, and up to the possibility of using all the strategies introduced. Between these two extreme options there are other middle range options.

7 SUMMARY AND FUTURE DIRECTIONS

The area of structural analysis of monuments and historical construction has become more complex and more important. Many efforts are devoted to create new theories, tools and techniques. In spite of this, during the studies in civil engineering and architecture, the aspects of historical construction are in many cases not sufficiently emphasized, or even neglected in some cases. The integration of historical construction in studies for academic qualification in architecture and engineering can be of significant advantage.

The exposure to structural aspects of historical construction can create a better structural-historical dimension in the minds of engineers and architects. It is important to stress that this dimension used to be an important element for the builders along history.

In addition, the studies of historical construction can create an important infrastructure for understanding the behavior and the performance of historic buildings. Furthermore, the understanding of historical precedents of construction can improve the understanding of construction from the general-structural point of view, rather than from the historical construction point of view alone. The understanding of the construction of new building can be improved following the understanding of traditional constructions.

Exposure to the structural thinking of the historic master builders can contribute also to the improvement of intuitive structural thinking, which is still important, even in our present scientifically- advanced world. As aforementioned, many of the historic buildings were built, using empirical knowledge and intuition. Understanding this heritage can contribute to the improvement of the intuitive-structural thinking, besides mathematical-rational thinking that is naturally very common today.

Early exposure to historical construction, during the studies for a professional degree, will increase the quantity and improve the quality of students, wishing to continue towards advanced programs focusing on historical construction.

Because of the main reasons mentioned above, and other additional ones, it is important to continue the future development of this field of research: the educational aspects of historical construction.

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