Basics of building structure in architectonic education

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ABSTRACT: The change of paradigm in education reflects the development of society, and thus the evolution of science and technology. New, modern drawing programs and technologies help to draw and calculate difficult shapes. For this reason, it is required that the principles, relationships and connections between architecture, structure and construction are taught within the subject, Building Structure. This approach to education is more difficult for a teacher, and partially also for a student. Their learning must be based on understanding, rather than memorising. Dealt with in this article is the education methodology of the basics and building structure principles in the field of architecture and urbanism, taught at the Faculty of Architecture, Slovak University of Technology in Bratislava (FA-STU). Documented here are the methods and content taught, including the gradual laying down of knowledge and skills in the area of building structure in architecture. The stress is put on the presentation of the educational steps and the order of difficulty in structural understanding within the context of architectural expression.

Keywords: Building structure, theoretical knowledge, practical skills, architecture education

INTRODUCTION

For a student of architecture, the basics of buildings structures are as important as is the basics of a building at its construction. For example, the problem of dealing with these issues, and also the way of teaching the subject, should be considered. It is necessary to evaluate first, what is the first step in changing the paradigm of the present education of an architect. The subject of study requires a complex view and an overview of it by an experienced teacher and an architect at the same time. Connected subjects from the category of building and construction must reflect the requirements of architectonic design and create a *jigsaw* of knowledge - and not just a set of information. A well-known statement that architecture is a unity of art and science, function and form is the reason to accentuate the importance of a tight connection between structure and architecture. The studying of architectonic works means orientation not only on expression of a building as a result of creation by an architect, but also the importance of seeing the context and process of its origin [1].

CHARACTERISTICS OF THE PROBLEM

The *poetry* of a structure is said to be hidden under the surface of it. On the surface, there can be a footprint of what is inside. If a student learns to see the footprint - or if they try to search for what is under the surface, then the effort of a pedagogue to teach the student how to think is not useless. Architecture becomes real if it is materialised by the structure and material, while keeping the balance produced from *Vitruvia triad utilitas - venustas - firmitas* (Vitruvian values of strength, functionality and beauty). The unity and harmony of building parts must be on such a level that taking away one part disturbs the overall harmony. The question is how to define that level for unity of architecture and construction [2].

The search for a suitable methodology based on creativity and the problems in teaching the various subjects of architects' education have been included in this article. The point is, to think architecture, to feel the structure [3]. For example, what is the most suitable methodology for subjects in the area of structure? It is not possible to give a definite answer. The reason is a connection of the subject with other subjects and a great amount of educational content. The authors deal in the article mainly with the subject of basics of structure, which is taught in the first semester of study, where students build their knowledge base. Other levels of knowledge depend on these basics. The character of the subject and the goal of the subject require application of problem-oriented thinking and critical thinking versus design thinking applied in the design of architecture. The reasoning for this was also found by authors Pusca and Northwood:

> *The question* how *identifies design thinking as the enabler of forward-thinking ideas to find a creative solution to the problem. As a result of such analysis, it was concluded that problem-oriented thinking is closely linked to critical thinking, and questions like why? and what? help with the formulation of the problem, whereas solution-focused thinking is linked to creativity and as a result to the question how* [4].

In teaching the basics of structure the stress is put on knowing the first construction steps. It is essential that the semester's teaching is designed, so as to cover the content and allocate enough time to enable the actual level of students' abilities to be taken into consideration. The level of abilities of the secondary school students is individual, different and also changeable over the years. It is desired to find a proper level of setting the learning difficulty, such that the students manage the study and, at the same time, gain the necessary level of skills and knowledge for the next set of study.

The speed, difficulty and methodology of subject teaching at the FA-STU in Bratislava is adjusted to this goal. The approach is characterised by a change in the paradigm of architects' education, by having a higher level of context in teaching. The trend is to point less at the norms of teaching *that it is like that*, and to dedicate more time in content and methodology to the presentation of connections and answers to the question, *why* it *is like that*. It is a more demanding form of education, but it is necessary for the basics of structure. It can influence a student in development of structural thinking.

The teaching of building structure can be divided into three basic levels, shown in Figure 1:

1. Basic knowledge (structural basics) - dedicated to the questions, *what and how to display and design.*
2. Routine application (skills development) - dedicated to the question, *what principles.*
3. Creative application (creativity in design) - dedicated to the questions, *why - because ... (creative ability).*

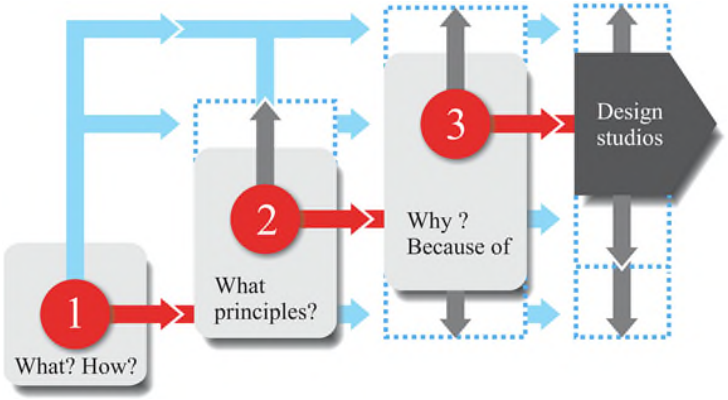

Figure 1: Education methodology model.

BUILDING STRUCTURE 1

> *Experience in the teaching of structures within the academic architecture syllabus faces a fundamental problem of difficulty in understanding structures. Architecture students struggle with a traditional engineering based approach to structures, which is increasingly proving to be ineffective. The following are observations of architecture students; 1. students struggle to understand formulae and mathematical procedures to solve structural problems, 2. there is inadequate time to teach statically indeterminate structures and other systems that are a bit more complex than simple beams and columns, 3. there is a perceived separation between design disciplines and structures* [5].

These observations indicate there is a need for a new educational model for teaching structures to architecture students. This is supported by the fact that content must be based on structure (official title: Building Structure 1), based on structural connection and knowledge integration. Teaching is from the view of methodology, divided into two equal parts:

- Study of the theoretical part (supports gaining of theoretical knowledge).
- A drawing part (supports gaining practical skills).

The study part represents a theoretical platform, where a student creates *a personal working book*, where he/she writes and sketches his/her notes from lectures, practice lessons and special literature. The drawing part (portfolio of a student) is a practical-application platform, which synthesises the studied topical area. Both parts are proportionally divided; they gradually are completed in the course of study according to the content. Examples of study and application are shown in Figure 2a and b, as well as in Figure 3. Pedagogical practice showed that it is a structure, which has a potential of mutual interaction and it also has a motivational meaning for students. A student can obtain basic knowledge in the subject: interaction of architecture and building in historical context, from classification and terminology of buildings and rules of display, to drawing of structures, and materials in the drawing of building construction.

A student then can understand different types of sets of buildings; the rules of design of vertical and horizontal building structure. He/she can record a simple detached house object in different scales and materials, according to a pattern.

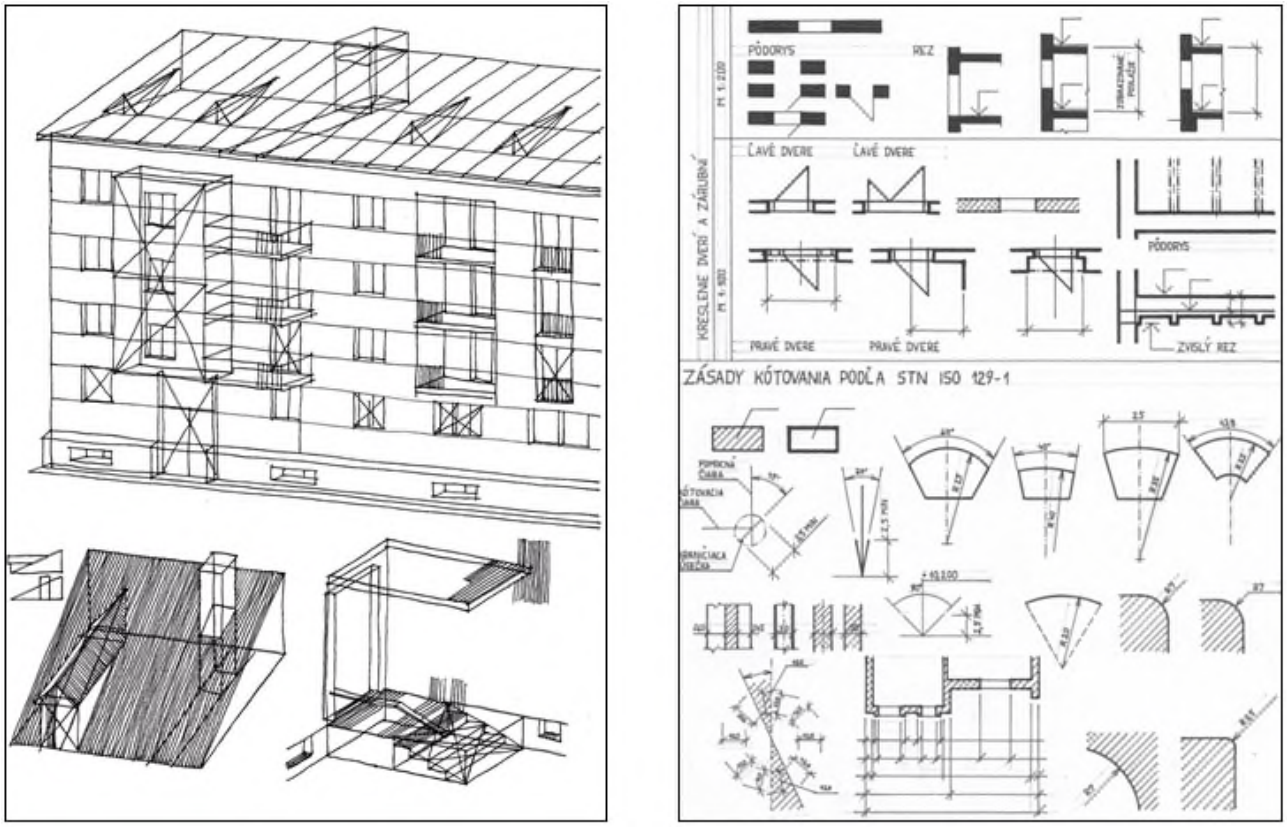

Figure 2: a) and b): Example of student work - the study part from the subject, Building Structures 1.

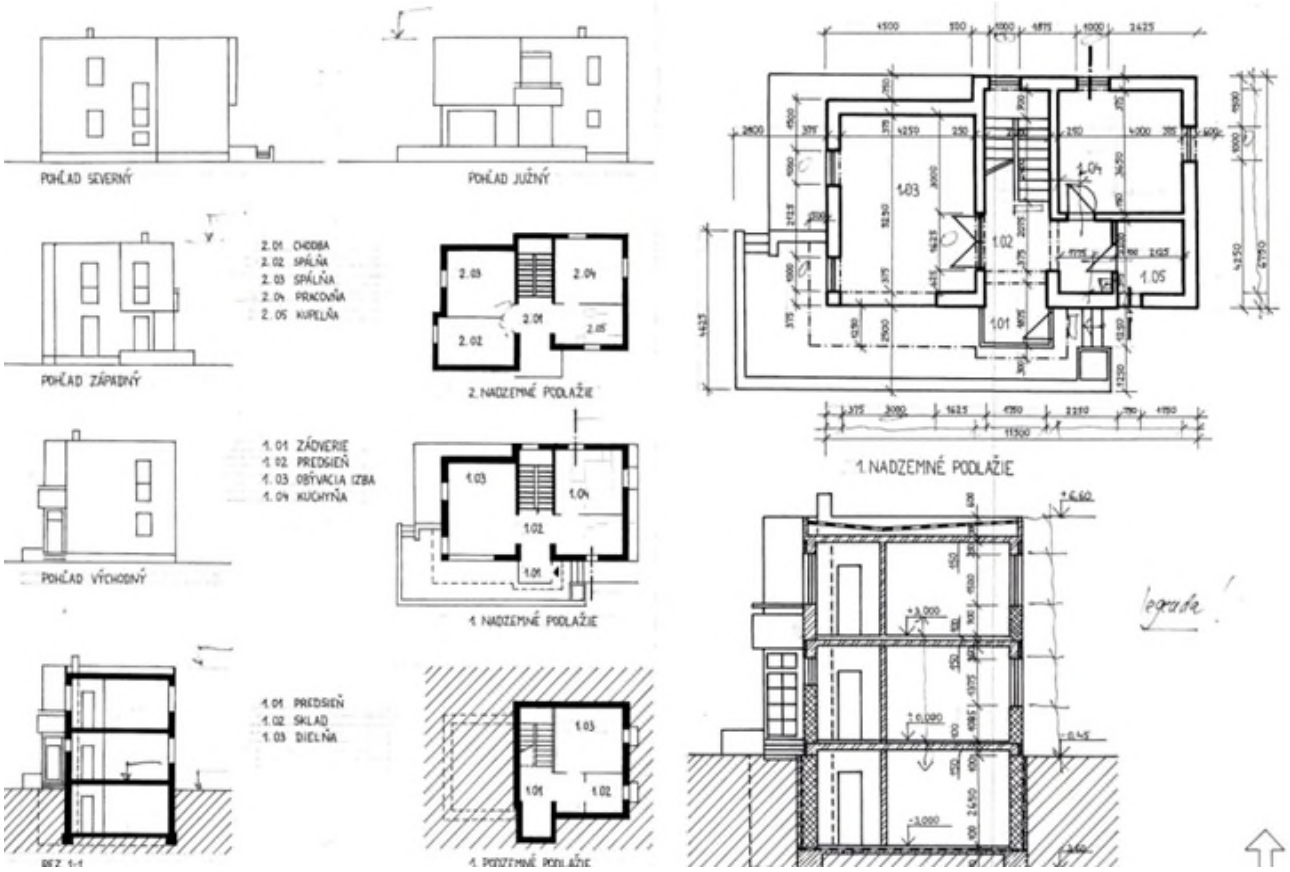

Figure 3: Example of student work - a plan, from the subject, Building Structures 1.

The student gains an ability to design a ceiling structure empirically, above a simple ground plan. The result is the content of the subject, which includes three main areas and one supplementary area:

- theory and rules of display and drawing of a structure in building drawings;
- theory and basic rules of design: the vertical bearing structure sets of simple buildings;
- theory and basics: principles of horizontal bearing structure in buildings;
- supplementary building structure.

Individual parts are integrated and they create a logical hierarchy of basic knowledge in building structure. This methodology model of teaching the structural basics was created as a mixture of pedagogical experience, goals and internal research of comparison of student competencies when finishing the Bachelor's study [6].

DISCUSSION

It is important for the structure and content of the subject, Building Structure 1, that the design of architecture and the design of structure and structural elements are not the same. Design in architecture has a strong creative element; it focuses more on spatial functionality and aesthetics, and is more concerned with the visuality and functionality of the design. Structure and construction have reflected design, but is determined by an empirical formula and/or by calculations. This exactness then transforms the architect's vision into realisation. According to Kuc:

> *The close co-operation between both courses (Construction and Building Construction) in developing architectural and construction design projects increases their technical quality. The lectures prepare students to take on the role of designer by acquainting them with the applicable regulations, standards and materials required by building construction solutions. Construction consultations allow for the implementation of previously learned arcana of constructional knowledge in design* [7].

Many students memorise the graphical form of drawings as a sequence of triangles, squares, schema, and so on. This enables students to reproduce mechanically a simple drawing during an examination without understanding the relationships between the drawn elements, what they would have had to learn [8].

The goal is to move the understanding of astudent from mechanical visual memorising to creative knowledge application. For structure in lower years, it is enough for student thinking to be oriented to *What?* and *How is it done?* Questions and answers to *Why? How does it work*? are for study in higher years, where the reasoning of solution is required. Also, it is necessary to think of the *level* of introductory material for study, as it must be suitable for supporting students in the use of modern technologies. There is an opinion expressed by Siagian et al [9] and also expressed by Chatwattana that:

> *Today's learning faces two challenges. The first challenge comes from a change of perception about learning itself, and the second comes from the presence of information and telecommunication technologies that continue to show tremendous growth. Hence, according to this view, learning should provide the opportunity for students to construct their own knowledge actively. Meanwhile, the rapid advancement of information and telecommunication technology offering new easiness in learning enables the shift of learning orientation from outside-guided to self-managed, and from knowledge as a possession to knowledge as a construction* [10].

The correct attitude is to use everything to some extent but not to misuse it. For specifics of building structure disciplines in architecture, it means to encourage education in the given area of IT and TLT. In practising the knowledge, it is suitable for combining with computer skills. The drawing itself or sketch helps to develop critical thinking.

At present, almost unlimited possibilities (shape and material) of the design of modern buildings require ready specialists. Foresight and early co-operation of architects and engineers bring elegant, modern and effective solutions. Ability to co-operate in a team is more important than ever before and it is connected with preparation and education of students of construction disciplines [11].

The problem is then explained by the opinions of authors, who characterise a specific view of engineers oriented to performance, exactness and cheaper operation in construction. *What do they do? They just make things stand up* [12].

This contrasts with an architect who has an image and feeling first, which comes out of the design concept. Holgate described: *This wall should be brick because I feel it will express what I want to say about the nature of this building* [13].

In this context, Norberg-Schulz said that: *…we have today a better knowledge in most fields than ever before, and better technological means at our disposal, but still, in most places, the built environment is decaying because of meaningless construction* [14].

Buildings have a multi-faceted existence ...their materiality can embody everything, from what is practicable (or not) to being built in a particular place, to the attitudes that inform construction and detailing, to what values are to be projected back to their audience. The structure of a building defines and gives form to these layers of programmed space [15].

A change of models in education is determined by developments in science and technology. Advanced technologies, computer programs and drawing programs require a specialist who can work with them, just as an architect and an engineer mastered a pencil, calculator and logarithmic ruler in the past. Such tools make drawing easier and they help when calculating difficult shapes; they supplement demanding *manual* work. It is much more desirable to teach relationships and connections: but these are more difficult for a teacher and partially also, for a student. It may be noted that the highly important contributor to learning satisfaction is the interaction between teacher and student - early feedback [16]. It is essential to show through uncomplicated examples and tools the principle of understanding construction, rather than just memorising it.

A methodological background for research was the creation of a general comparative model of education, and then applying it to the basic teaching of construction (models are shown in Figure 4 and Figure 5). A part of the methodology from the research was a statistical comparison of results of education in the past four years, based on data from an academic information system. The research documents the comparison of the education results from the basics of construction in three levels.

Comparison of:

- overall results of the study of the subject;
- partial results from practice lessons;
- overall and partial results in the subject.

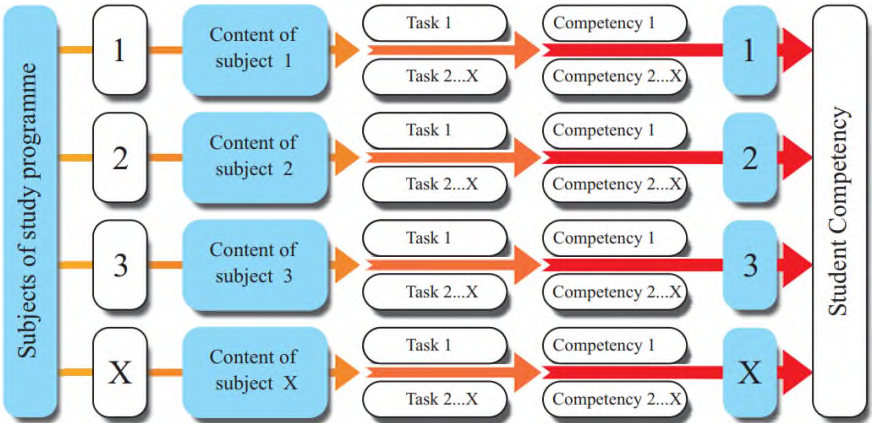

Figure 4: General educational model.

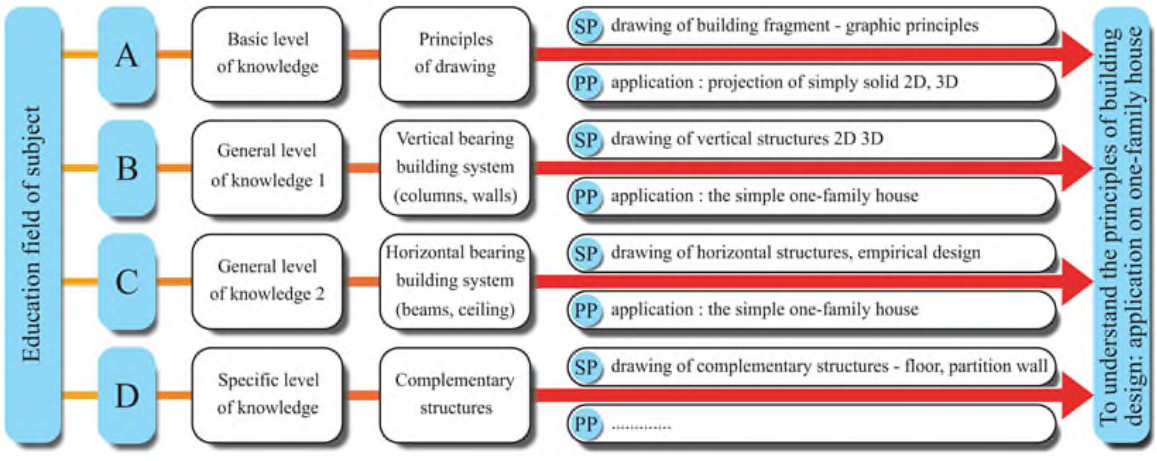

Figure 5: Education model of Building Structure 1 (SP - study part, PP - plan part).

In this version, the results are relatively steady long-term. Good results are achieved by students in practice lessons. But this is not strongly reflected in the overall study results of the subject, even though proportional weight of practice lessons is only 20 percent of all the results (see Figure 6). It can be stated that students at the beginning of the study manage better the practical work focused on skills (mechanical work), and they cope less well with theory. At the start of study, they learn *how to study better*. The basics of structure are learnt mechanically and without internal connections, as students do not have knowledge yet from other disciplines. The changeover for a student from the system of study at secondary school also definitely influences overall results; particularly so with students from humanity-oriented schools. The results are a *tax* for the adaptation process of the study, but they are also a confirmation of supposition for the next round of study.

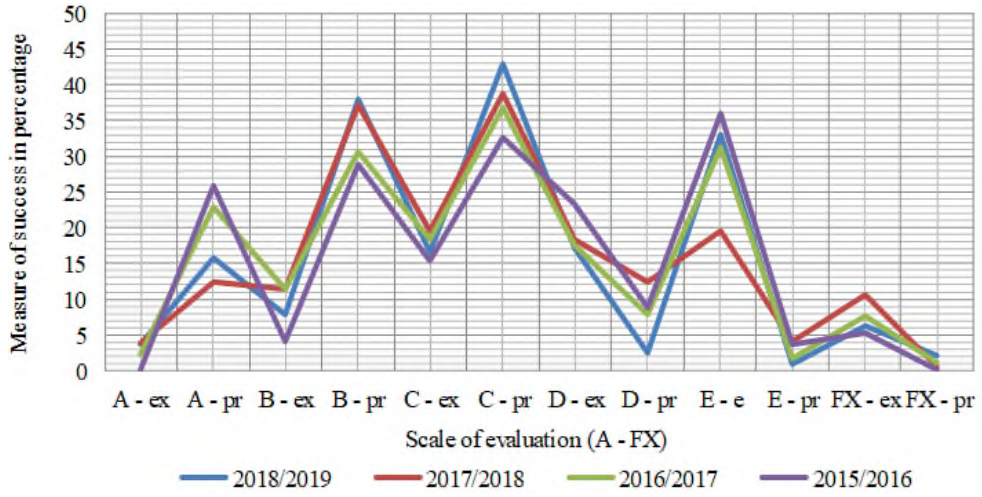

Figure 6: Comparison of study results in subject Building Structures 1.

CONCLUSIONS

Adequacy and flexibility of the given model is proved in ateliers of architectonic design. The authors incline to the opinion stated by Behnejad et al:

> *Connection of architecture and structure is also important. In solution of ateliers it is mainly in the stage of creation of the architectonic-construction concept* [17].

Unity and context in architecture is a goal, which good creators of architecture are trying to achieve. At one time architecture was perceived as a unity of form and visual unity, at another time as similarity and continuity or as a balance of harmonic relationships. The presented relationships are not only about a shape or form, they are also about building structure rules. The level of structural application, the range of its influence, is reflected in teaching architecture from its first steps. Regarding the connection of architecture and structure (in an absolute meaning), it is not a problem to define the content of teaching as a whole, but there is a difficulty in individual steps and their intersection, so that one does not absorb the other. Architecture cannot possess structure in a false form and building structure cannot absorb architecture in a spiritless concept.

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BIOGRAPHIES

Ľubica Ilkovičová graduated from the Faculty of Architecture at Slovak University of Technology, where she also completed her PhD studies in 1992. Since 1992, she has worked at the Faculty as a teacher. In 2013, she was appointed Associate Professor in the Institute of Construction in Architecture and Engineering Structures. She deals mainly with issues of production and engineering buildings, focusing on the identity of architecture of industrial and agriculture production and conversion of old industrial buildings. Assoc. Prof. Ilkovičová also teaches the topic in theoretical courses, as well as courses in architectonic design. Her scientific-research portfolio comprises four scientific monographs and contributions to more than 40 scientific publications. She has co-operated on more than 10 scientific projects, concentrating on the architecture of production and structure in architecture. She has actively participated in many national and international scientific conferences.

Ján Ilkovič graduated from the Faculty of Architecture of the STU in 1982, and in 1989 he completed his doctoral studies. He was appointed Associate Professor in 1998. As well as other posts, between 2006 and 2019, he has been the Head of the Institute of Construction in Architecture and Engineering Structures at the Faculty of Architecture, STU. Between 2010 and 2018, he held the post of Vice-Dean for Education at the Faculty of Architecture of the STU; he was a member of the Scientific Board and a member of the Editorial Boards of FA-STU. Dr Ilkovič has been the principal investigator of 10 scientific projects focused on structural design, architecture of industrial and engineering buildings and conversion of old industrial buildings. He has introduced innovative teaching methods into courses that focus on structures in architecture. He has published five scientific monographs and dozens of scientific publications. Dr Ilkovič has actively participated in many national and international scientific conferences.