Structural and Building Engineering – an Introduction

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Abstract. Construction is a reflection of the current state of society. The construction is created as a result of a creative process including preparation, all stages of design and implementation. Current trends of modern building structures with a large span are characterized by the introduction of new types of load-bearing structural systems with excellent ecological, economic and aesthetic properties. The paper aim is to introduce the interaction and context in design and create a reliable economic and environmental friendly structure that will serve the required purposes.

1. Introduction

There is often a parallel between a prosperous society and a prosperous construction industry, or in other terms, where there is all-round economic development, construction is also developing, and vice versa, where the economy is stagnant, roads, bridges and buildings are not designed and built. Thus, construction is a reflection of the current state of society. It intervenes in all its development areas associated with capital expenditures, respectively with investment.

There is perhaps no human activity with which we would come into everyday contact as often and multilaterally as building. According to the purpose, we distinguish between buildings, resp. civil, engineering, transport, industrial, agricultural works, etc. Depending on the type of material used, we are talking about masonry, wooden, concrete, steel, plastic etc. Construction generally deals with building structures and works, preparation, design and implementation of buildings, building materials, building economics, etc. With the gradual development of architectural art and its knowledge, construction becomes a testimony to the development of society. The construction is created as a result of a creative process including preparation, all stages of design and implementation. It is necessary to realize that this process has its historical development and is historically connected with the period; it has its developmental connections and regularities. These are a source of new inspiration and knowledge. For general orientation in the field of building engineering, it is necessary to know the history of construction and architecture, development of materials, development of structures, systems and methods of construction, styles and their characteristic architectural and expressive means, aesthetics, development of functionality of buildings and their layout - operational solutions, technologies, as well as development of technical equipment of buildings. Through the synthesis of existing knowledge and their thorough analysis, we can arrive at a new quality, new shapes and forms, better construction systems, etc. There is another important reason why it is necessary for the current practical activity to know and study the historical development of buildings.
This reason is that historic buildings are part of today's architecture, which we functionally use, maintain, restore, reconstruct, etc. As a country cares about its historical cultural heritage, the maturity of its nation is measured.

Many new scientific and technical problems arise because technical works have to operate in increasingly demanding conditions, with ever-increasing sizes and loads. The growing quantity of relevant quantities is growing into a new quality, which requires new theoretical and experimental approaches, more complex models, new methods and algorithms in design and assessment.

2. Conceptual designs of the structures

Let's ask ourselves when the first conceptual design of a building structure was created. Today, it is generally accepted that Poleni, with his expertise in St. Peter's Dome in Rome, in 1748, carried out the first formal analysis of the stability of the structure, and thus a professional structural engineer was born. At the end of the 19th century, industrial, exhibition, transport and other buildings were covered with large-span three-joint arches [1].

The beginning of conceptual design of the structure can be characterized by the construction of the Palace of Machines of the World's Fair in Paris in 1889, which integrated new technological and scientific knowledge. The innovative construction, which summarized everything that was built before, had two principled original peculiarities. The first was the use of a new material - steel, which has excellent properties (high tensile strength) compared to the cast iron used until then. The second was the application of the newly discovered Winkler's analytical method for solving truss bar arches from 1868. It was also understood that the appropriate situation of the joints can handle the problem of additional forces from thermal effects and settling. The engineer became a conceptual designer. He was no longer limited in analyzing and verifying his design and was able to direct the flow of forces by appropriate placement of structural elements and details. He could imagine the behavior of the proposed structures and discover their new corresponding shapes.

The period of admirable masters - builders who built without knowledge of the theory of structures, who had a "feeling" but no knowledge of the rules of the design gradually ended and came the period of engineers - conceptual designers armed with new discoveries, ideas and tools.

The development of structures and technologies for the construction of buildings is part of the development of science and technology and thus the social development of mankind. It is therefore directly affected by their level in a given period. Until the beginning of the 20th century, the traditional material base dominated (buildings made of stone and brick and others). Realizations of steel building structures were unique in the 19th century. The decisive milestone in the development was the discovery of reinforced concrete and its use since the end of the 19th century. Reinforced concrete has gradually become the most widespread structural material for load-bearing structures of multi-storey buildings [1].

It is interesting to follow the development of engineering thinking and technical possibilities of implementation of very progressive and interesting construction solutions for the time being. Often limiting factors of engineering thinking and slick designs developed at the time were the technological possibilities and existing structural elements and materials. The precursors of creative ideas have always surpassed its time and its real possibilities. The power of the spirit often preceded the material conditions.

A beautiful example is the work of the Czech engineer B. Schnirch, who was the first in the world to be granted a patent for fiber roof structures in 1826. He built several such roofs on the territory of the former Czechoslovakia. In 1824, the engineer Schnirch designed the load-bearing system of the
roof of the theater building in Strážnice, with floor plan dimensions of 30 x 76 m, which he described in the article "On wrought iron trusses, their lightness, low conversion cost and usability". The supporting system consisted of chains designed under the ridge and on all corners, to which weaker chains were connected instead of traditional wooden structures. Later, in 1964, K. Tang, Y.Tsuboi, and M. Kawaguchi designed a suspended roof structure for the Tokyo Olympics. The supporting system consists of an impressive rope structure with floor plan dimensions of 120 x 214 m. Here, however, modern technologies and new technical elements such as high-strength ropes and special dampers have already been used to eliminate the adverse dynamic effects of oscillations.

The ideas were thus similar, resp. the same, but the method of implementation was dictated by time and its technological possibilities, significantly supplemented by the progress made in the field of science and technology. Intuition and empire have grown into a science-based theory. Computational resources have been transformed into computer technology, which has become a powerful tool in the hands of civil engineers. We can find many such examples; let’s call them "analogies in thinking with the time lag of perfection of realization", in the analysis of technology and construction history. It is important for us that at present the time interval between the progressive idea of an engineer and its implementation, thanks to exponentially developing technological possibilities and scientific discovery, are rapidly shortening.

Current trends of modern building structures with a large span are characterized by the introduction of new types of load-bearing structural systems with excellent environmental, economic and aesthetic properties, with very flexible use for variable spatial shapes and different floor plans. By suitable alternation of various materials (steel, concrete, wood, composite materials based on glass fibres and plastics, high-strength fibres, etc.) and through rational positioning of elements or subsystems with required properties in global construction, we obtain highly efficient combined - hybrid systems. We can also find their wide application in building construction. When we design modern intelligent structures the multidisciplinary approach is required. Such structures also include mobile systems. Example of this is a mobile roof structure. It is type of structure in which part or all of the roof structure can move resp. relocate so that the object can be used for both short periods of the roof, when it is fixed in the open or closed state.

3. Building materials
A number of materials are used to create the construction work, from its birth in the design studio, through implementation, to protection from the surrounding environment, which are to ensure trouble-free function. For centuries, classic natural materials based on inorganic and organic substances, such as stone, sand, wood and the like, have been used. The principal artificial building material was and still is a brick that has changed its form, but the content remains the same. Cast iron and later steel began to be used in the 19th century, and the first half of the last century was marked by the development of concrete, reinforced concrete and later prestressed concrete. Recently, a large number of new materials have emerged, which are gradually penetrating the construction industry. These are concretes with special properties, insulating materials, plastics, composite materials and substances combined from classic materials with various chemical additives. At the same time, a number of new types of structural elements and structures appear, such as thin-walled and sandwich structural elements, the already mentioned hybrid systems, etc. All this requires increased demands on the quality of the materials used and the need for comprehensive knowledge of their behaviour under different conditions. To do this, it is necessary to control their physical and chemical properties and the laws that characterize them. The correct and optimal choice of necessary materials and products requires knowing their technical parameters, which depend on the origin of the material used, the technology of its production and possible changes in certain characteristics and properties due to the environment during the life of the construction [2].
At present, the period of significant growth in the consumption of materials is behind us and a clear trend is being used to use less material. The tendencies are towards recycling and reuse of materials, replacement with inert materials and the use of innovative modern construction systems that consume less of materials. The reason is not only the global saving of materials, but also the fact that materials will be more expensive because there will not be enough increasingly cost-effective energy. The energy intensity of processes and products is becoming an important factor in the material industry, which is characterized by the interactions between raw materials, energy and environment.

Nowadays, the term "sustainable development" is often used. It is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs, so as not to devastate the diversity of nature and preserve the natural functions of ecosystems. In connection with construction, we talk about the creation of a healthy exposed environment and responsible management of it, based on the principles of efficient use of resources and environmental principles. Thus, the rational use of material resources, as well as the materials themselves, is closely linked to the problem of energy and environmental problems. The recognition of local and global environmental problems have stimulated considerable process which has been made during the past years toward a more complete understanding of design and construction requirements for buildings. The building design and construction toward sustainable practices were slowly shifted by awareness of environmental problems. Many environmental-friendly design and construction principles are widely accepted, but designers and constructors often fail to recommended practices or their clients fail to adopt state-of-the-art practices. Reasons for these failures include preference for and adherence to traditional practices, lack of expertise or short-term financial considerations. Meanwhile, awareness of environmental problems has produced an emerging shift toward purportedly green building practices that presume to include buildings that are healthy for their occupants [3].

The main purpose of buildings is to create a climate more suitable for persons and processes than outdoor climate. However in buildings and shelters it is not only the thermal climate that is changed. The climate shell also stops the free air movement. The dilution of pollutants from close to man pollutants sources is diminished. The environment within building is always more polluted from indoor sources as building materials and indoor activities than outdoor air. This was and is the basis of the need for ventilation and for discussions on indoor air quality. Consequently, the main aim of building ventilation is to create the indoor air quality more suitable for persons and processes than what naturally occurs in the unventilated building, and to reintroduce the positive effect of being exposed to the wind, to dilute and remove the pollutants that man himself, his activities, and the indoor surrounding produce.

Sustainable buildings design depends significantly on the used criteria for the indoor environment and building design and operation. Indoor environment also affects health, productivity and comfort of the occupants. Recent studies have shown that cost of the deteriorated indoor environment for the society, employer and building owner are often higher than the cost of energy used in the same buildings. An energy declaration without a declaration related to the indoor environment makes no sense. There is therefore a need for specifying criteria for the indoor environment for design, energy calculations, performance and operation [4].

When we realize that about half of the price of buildings is the price of materials, it is clear that knowledge of the nature and properties of materials is very important for construction. For various structures and their parts, construction materials with different properties are needed, but common and most important are the properties ensuring quality and durability during the specified period of operation of the object.
The future is mainly focused on the purposeful preparation of new, composite materials - composites, materials with new properties and significantly more efficient use of matter and energy. A composite is any material system which consists of several phases (at least two), of which at least one is solid, with a macroscopically recognizable interface between the phases and which achieves properties which cannot be achieved by any component alone or by simple summation. Composite materials are combined from all major classes, e.g. metals, ceramics and other inorganic materials, polymers, into the final composite structure. The engineer must see in these materials a specific system instead of a simple mass with certain properties.

The main prerequisite for a significant increase in the efficiency of the structure is the combination of material design and structural design. Traditional methods of calculating the load-bearing capacity of a structure are changing.

Development is increasingly focused on the intelligent materials, which replace simple traditional materials with substances with higher material and energy efficiency. For example, polymer or metal composites reinforced with different fibres provide several times higher strength and stiffness than the best alloys, even in cases of high temperatures. The insulation board made of integral polyurethane foam insulates 25 times better than a brick wall with the same thickness, with a weight of 750 times less.

The using of material composites (carbon-fibre-reinforced plastics, ceramic-fibre-reinforced metals, fibre-reinforced concrete, etc.) and development of composites for construction purposes are increased. The mechanics of materials, which deals with structure of material and their reflections on external performance and properties of material systems, is rapidly developing. It involves the study of structural characteristics at several levels - from bond forces to the geometric arrangement of particles in a composite. Depending on the physical property being investigated, the desired characteristics have a microscopic or macroscopic expression.

4. Structural and building engineering

Concept design is the first design stage. They are preliminary studies whose purpose is to establish whether the project is viable, to assist in the development of the project brief and to aid the identification of feasible options. The preferred option is then being developed into a concept design which is a response to the project brief. The project brief will continue to develop as the concept design is prepared, but is then frozen at the end of the concept design stage and change control procedures are introduced. Concept design is followed by detailed structural design during which the design develops to describe all the main components of the building and how they fit together [5].

Structural and building design can be defined as a creative activity based on ability to meet scientific principles to technical and environmental requirements based on behaviour predicting of the structure based on knowledge of statics, dynamics, flexibility and strength, materials science and structures, evaluation methods and the like. It is important to perform physical-technical analysis of buildings and structures, diagnose of structure and building defects and solve the renovation of the buildings. The aim is to design and create a reliable economic and environmental friendly structure that will serve the required purposes.

Until the middle of the 19th century, the design of the structure was largely based on the art of intuitively determining the dimensions and placement of structural elements and details, as well as shaping the overall appearance of the structure of the building. Gradually better and more accurate understanding and knowledge of the principles influencing the behaviour of the structure, its elements and individual materials, design procedures became more and more scientific, based on a number of laws and regularities that were explicitly described by mathematical - physical computational models.
Regardless of the method used, regardless of whether "manual analysis" or any computer system has been applied, design is always an optimization process, which is usually accompanied by certain constraints, such as physical, environmental, social and psychological. It is up to the creativity of engineers and architects to deal with them. To find a rational and optimal way out where it does not seem to exist, especially in cases where the layman cannot see it.

Creative activity requires the conception of new, increasingly complex physical models, which to a greater extent and depth capture not only the structure but also the behaviour of the actual building structure. Simultaneously with the new concepts, the mathematical description is being improved, which brings the possibility of generalizing the achieved results.

Very important, in the conceptual design phase, is the creative interaction - cooperation between the architects and the civil engineers. Architects, engineers, computer and information systems can now create highly efficient flexible ones that can very quickly change configurations of variant solutions, modify the created details of the structure, compare the aesthetic and economic benefits of individual variants and gradually find the optimal final shape of the structure, resp. building.

The design process usually includes the following phases: initial thoughts and ideas, introduction of limiting factors, architectural drawings and engineering sketches, visualization, in some cases also animation, engineering analysis and reliability assessment of the designed object, its optimization, processing of drawing documentation, etc.

In the traditional design model the individual phases of creation follow in series and represent an inelastic, time - consuming rigid system. The information flow between the architect and the engineer is restricted and is limited to the gradual completion of the individual stage. Following the introduction of systems based on BIM (Building Information Modeling) and thanks to modern information technologies traditional procedures significantly modify. The transmission and exchange of information in individual phases is of the "on-line" type, the creation takes place in parallel - side by side, which significantly shortens the design time intervals. Compatibility and identity of electronically exchanged data and documents ensure high design quality. Traditional procedures devoted only 15 to 20% of the time to conceptual activities and the remaining time was needed to process the technical documentation. Correct implementation of BIM engineering allows up to approximately 70% of the total time to be used for conceptual creative activities, and the remaining 30% is spent on project development.

5. Conclusions
Many new scientific and technical problems arise because technical works have to operate in increasingly demanding conditions, with ever-increasing sizes and loads. The growing quantity of relevant quantities is growing into a new quality, which requires new theoretical and experimental approaches, more complex models, new methods and algorithms in design and assessment. Creative activity requires the conception of new, increasingly complex physical models, which to a greater extent and depth capture not only the structure but also the behavior of the actual building structure. Simultaneously with the new concepts, the mathematical description is being improved, which brings the possibility of generalizing the achieved results.

We can no longer be satisfied with the fact that any engineering construction is "only" reliable and efficient, but these properties must correlate with environmental requirements. We cannot look for environmental aspects only in nature, but the environmental principle must be reflected in all areas of building and structure design. In the current conditions of broad-spectrum requirements for knowledge and field of application, the civil engineer is often placed in the task of effectively participating in the creation of the material environment and its structures and building composition in
all stages. The inability to give construction works, as well as their parts and details, an appropriate environmental quality, is often and inappropriately obscured by arguments that the current designer and builder must be primarily pragmatic, must meet the client’s – investor requirements. He must think professionally, technically, economically, and thus he does not have the space and time to deal with the environmental impact of his work.

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