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THE HISTORY OF ARCHITECTURE DEVELOPMENT, FORMS OF BUILDING CONSTRUCTIONS AND THE ESTABLISHMENT OF COMPUTING METHODS IN THE FIRST HALF OF THE 20TH CENTURY

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The work of an architect is impossible without the engineering calculations as well as construction methods can't provide the aesthetic needs of a person by themselves only. The significant bond between architecture and engineering was formed at the beginning of the 20th century. The following article describes this relationship.

Scientific research aims to identify the correlation between forms of building constructions and their computing methods and architecture from the end of the 19th century to the beginning of the 20th century. The hypothesis of the research is the assumption that it was during this period that the consistent link of the engineer and architect's occupations was formed despite the established division of these two areas.

The main objective of architecture is the design of the inhabited space. Building constructions is a tool for solving this task as soon as it carries out the following assignments: 1) expression of the architect's concept; 2) load-bearing structure of the building; 3) utilitarian function. One of the main problems of architecture planning is the expression of the architect's concept through the construction. This can be managed with the tectonics principals which are the following: 1) the artistic expression; 2) the reflection of the statics; 3) the effective usage of building materials [1].

The history of the building's construction can be divided into two periods. The first one defines the computing methods as the experiment. During the second period the technology, construction machinery, and equipment were based on scientific research (since the 19th century) [1].

The connection between structural analysis calculations in the 19th and the 20th centuries should be taken into account mainly because of the reinforced concrete discovery by J.L. Lambot in 1849. The engineers faced a significant challenge on the way of the reinforced concrete research being that it wasn't possible to apply old computing methods to the newest material. The tensions between the permitted stress calculations and the reinforced concrete's actual behavior appeared. The searches of the new computing methods resulted in the following additional requirements: 1. The reduction factor was added to the calculation. Now every cross-section unit of the armature was replaced by nth units of the concrete cross-section. 2. The tensile strength of concrete was neglected [2].

In 1904 the calculation analysis of the pedestrian bridge in Vienna made by A.F. Loleit was the important conclusion in the research of the reinforced concrete. It resulted in calculations of bending reinforced concrete elements at the elastic stage being unacceptable [2].

The architecture of the 20th century shows a range of new architectural styles (for example, constructivism, functionalism, etc.), types of buildings (skyscrapers, etc.), design solutions, and the usage of new and improved materials and structures. The connections between engineering and architecture will be examined on the example of the USA architecture in the 20th century.

The specific feature of the building's construction in the USA at the beginning of the 20th century is its great extent. The technology level was higher than in other countries. Here the mounting methods were combined with machinery, for example, derrick cranes and tower cranes facilitated the lifting of the large constructive elements. At the beginning of the 20th century, old frames were replaced with lightened frames with joints in the bearing units. The skyscrapers spread widely. The framework took its place as the main constructive system. One of the first examples of the new building type was a ten-story Home Insurance Building (1883-1885) made by W. Le Baron Jenney, where the cast-iron columns and posts alongside Bessemer steel frames [3]. The Bessemer steel is steel manufactured as a result of the Bessemer process. The key principle of the process is the removal of impurities from the iron by oxidation with air being blown through the molten iron [4]. Home Insurance Building is the first example of such a wide usage of iron constructions and the beginning of the steel construction spread across the USA [3].

The skyscrapers' design began from the inside, from the small unit to the building in its entirety. The unit was a typical office inscribed into the rational plan of the level of the building. Even if space wasn't divided but rather was a solid structure, it depended on the measurement of the span and the window opening's distribution on the building surface [3].

The features of the typical skyscraper of this period best represented in the Woolworth Building. 55-storey in height, it was built in 1913 by architect C. Gilbert and structural engineers G. Aus and K. Berle. The building's construction faced its main engineering problems which were the bearing of the horizontal load of the wind and the vertical load of the weight of the building itself. The steel columns of the building are composite joined by rivets and have a cross-section of a never-before-seen width. For the bearing of the wind load engineers used all of the known joints such as diagonals in the plane of the floors, bracing on the main elements' crossings, etc [3].

The USA wasn't immune to the usage of the reinforced concrete patented in 1867. The research of this material began here as well. By the end of the 19th century in general terms, the theory of the permitted stress calculation of the reinforced concrete was formed based on the computing methods of the strengths of the elastic materials. For the calculations, one should assume that support reactions of the capital are distributed by the triangle, and the calculated span of the panel is the distance between the centers of gravity of these triangles. The whole bending moment calculation is given in equation 1.

$$M = \frac{1}{8} \cdot W \cdot L \cdot \left(1 - \frac{2c}{3L}\right) \cdot \left(1 - \frac{2c}{3L}\right) \tag{1}$$

W is the whole load on the floor unit, L is the width of the column spacing, c is the size of the capital. This equation was derived by G.R. Nichols in 1914 [5]. The beamless floor is shown in the figure 1.

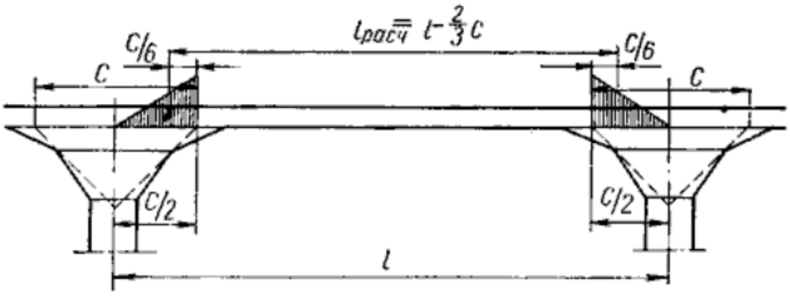
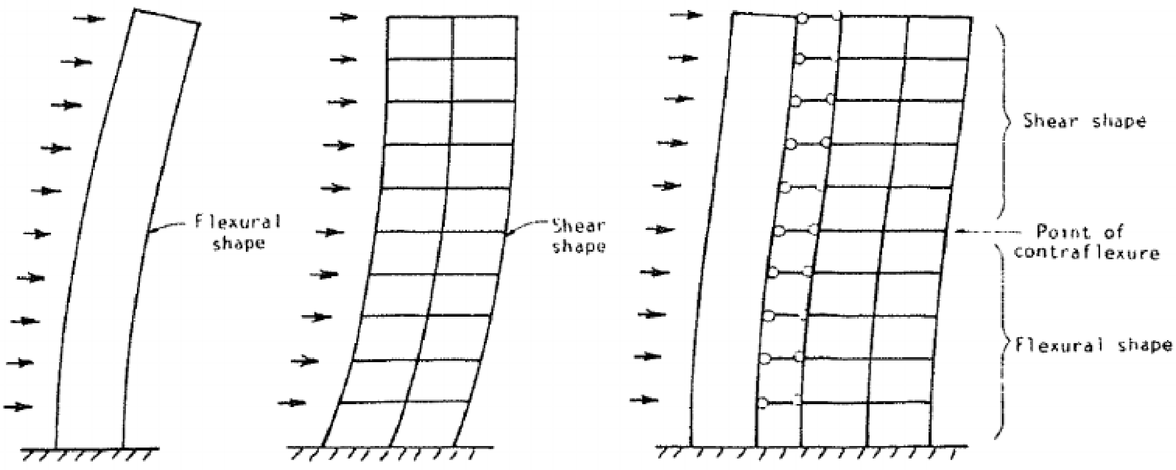


Fig.1. – Beamless floor

The high-rise buildings bear static loads as well as dynamic loads. Depends on the building's construction these indicators can vary. When calculating the static loads the reaction forces, bending moments, deflections, forces between composite elements, and the distribution of the forces between concrete cores are taken into account. For dynamic loads, resonant frequencies and accelerations are being considered. One of the main tasks when designing high-rise buildings is their ability to absorb the horizontal forces and to transmit the resulting moment into the foundation. The building behavior under the lateral loading can be seen as a cantilever fixed at the ground. If the wind is assumed to have a uniform distribution the base moment increases quadratically with the height. However, the real shape of the wind pressure is increasing with the height, which gives an even greater base moment [6].

A building needs to be stabilized for horizontal load and several different structural systems can be chosen in order to achieve this. A framed tube system and a bundled tube system were designed in the first half of the 20th century, others (a tube in tube system, a diagonalized system, etc.) appeared and began to improve later. Every one of these systems is a variation of the traditional rigidly jointed structural frame. The basic design for these systems has been to place as much of the load-carrying material as possible around the building external fringe to maximize its flexural rigidity. Advantage can be taken by locating the vertical members and, with the compressive stresses from self-weight, suppress the lateral load tensile stresses [6]. The deformation shapes of a tall building is shown in the figure 2.



a) Bending deflection, b) Shear deflection and c) Total deflection

Fig.2. – Deformation shapes of a tall building

One of the most impressive examples of the architectural and engineering excellence of this period is the Empire State Building. The building's construction ended in 1931. It has 102 stories and held the place of the highest building in the world. The building's overall height is 448 meters. This includes the antenna at the top of the building. The main construction system is the steel frame [7].

The technology of the construction is the following [7]:

A substantial concrete base was laid as a foundation in order to be able to withstand the weight of the steel framework of the building. All the steel sections were prefabricated and transported to the construction site. The sections were manufactured to exact sizes to within 2mm tolerance and prepared so that they could either be bolted together or joined with rivets. It took three days for the sections to be manufactured, transported, and positioned in the framework as part of the building's structure. Once the steel framework was fixed it was then finished with an outer skin of stone [7].

In order to join the parts of the building, two techniques were used. The first one is that the laborers walked up and down the structure as it was put together. Their job was to fix the separate sections together, using large nuts and bolts. The second technique is the usage of hot rivets. It was first used in the shipbuilding industry as a method of joining large steel plates. The steel rivet is heated until the plain end is red hot. Then it is passed through the holes of the two sections. When hot the rivet is soft and can be shaped using a rivet gun which rounds the plain end so that it is permanently fixed in the position [7].

To conclude, the beginning of the 20th century is a reflection of the strong bond between architecture and engineering. It would be impossible to implement the challenging ideas of the architects without construction engineers, the appearance of the new materials and construction systems, and its computing methods. The same goes for the ideas of the architects. Without them, there would be no place for the research of building materials and constructions.

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