STRUCTURAL SYSTEMS INFLUENCE THE AESTHETICS OF SKYSCRAPERS

MOLDOVAN Ioana Mădălina*, MOLDOVAN Silivan Valentin,
Technical University of Cluj-Napoca, e-mail: Ioana.MURESANU@cif.utcluj.ro (corresponding adress)

ABSTRACT

Skyscrapers, since their appearance were a symbol of power and wealth. Moreover, the race for the sky called out for new structural solutions in order to make what was dreamed and then sketched, a possible reality. Usually the structure of a building acts for it like the skeleton of the human body, which is afterward covered with layers of muscles and skin in order to shape it. The same thing happens in buildings, the envelope of the building discloses its silhouette. For more than fifty years now, the skeleton of the building is proudly revealed; furthermore it becomes the ornament of the building. This paper is a study about the way structures, trough time, besides helping the constructor reach taller heights are influencing skyscraper’s looks.

Keywords: architectural expression, frame, tube, central core, bundled tube, diagrid system, outrigger system, prefabrication

INTRODUCTION

The monumentality of skyscraper is a direct result of their dimensions and makes their architectural expression to be very important in any urban context. Thus, the construction of any high-rise building requires careful studies concerning the aesthetic fairness of the new structure inserted in the existing urban scenario. Some structural systems for high-rise buildings had a major impact on the aesthetics of the resulting building, while others had only a minor one.

MATERIALS AND METHODS

1. Early structural systems for high-rise buildings

The development of tall buildings, especially those with metal structures, is due particularly to the created context of late nineteenth and early twentieth century in Chicago (Fig. 1.a.).

In the late 19th century, Chicago became one of the most important cities of North America. Also, in the same period, due to the socio-economic conditions, the city passes a period of investment and real estate boom.

An amalgam of events led to the development of Chicago:

- The Great Fire of 1871,
- evolution of the technology in constructions through the appearance of metallic structures,
- invention of the elevator,
- economic context,
- massive population migration, etc. [1]
The structural systems that we find today in tall buildings evolved from the traditional networks of columns and beams employed in the late nineteenth century. These involved the use of massive slabs of stone or brick and the vertical elements, the columns, were hidden in large masonry walls. The development of the technology of construction led to the emergence of a network of frames as main structural system, where the columns were placed at equal distances in both directions. At the beginning bearing masonry walls are still employed in constructions using frame structures. The architectural expression of tall buildings was dominated for a long period of time by this type of structure that didn’t allow the use of very large windows. The silhouettes of tall buildings, until the Zoning Resolution of 1916 (New York), was quite similar in all the cities where they were elevated, mainly prismatic volumes, sometimes marked by a corner tower. After 1916, Art Deco (Fig. 1.b.) style will offer some distance from the prismatic figures, previously used, by composing the building from successive rectangular plans, rotated or setback in height. The emblematic skyscrapers of New York represent the testimony of the structural evolution in skyscrapers. In terms of structure, the bays did not allow openings larger than 7.5 meters.

In time, tall buildings became fashionable, in order to accommodate the increasing demand, they had to be lighter and easier to build. Therefore, the bearing walls started to be removed from the designs, leaving more space to the frame structures (the structural elements begin to receive additional reinforcements in joints and bracings for the inner columns, that later will be transformed in a core of concrete diaphragms). Lighter walls replaced the bearing masonry walls and protection against fire was no longer made through concrete elements, but by spraying fireproof substances on the building elements.
The design of tall buildings in the second half of the twentieth century wanted to offer more space, with larger openings and simpler facades. Mies van der Rohe is the figure which will strongly influence the expression of skyscrapers, modeling the facades in such a way that the structure would be perceptible from the outside (Fig. 2.a.). The appearance of glass curtain façades gave birth to lighter perimeter closures, which led to significant reductions of loads for constructions. In terms of plan, the frame structure offered the alternative for crowded spaces, the open space, divided in regular bays in both directions (between 7.5 and 10.5 meters).

In what regards metallic structures, employed in tall buildings, the elements could be composed in such a way as to form a tree-dimensional structure that would work and resist external forces as unitary system.

2. Structural innovation

One of the persons who have promoted complex systems of structures for tall buildings was Fazlur Khan, founding his arguments on the premise that different heights (number of levels) require new compositions of structural elements [7]. Thus, besides the system consisting of concrete or steel frames, he introduced combinations of systems: frame-shear truss, frame and belt truss, framed tube, truss-tube, bundled tube, etc. All these led to a more technical architectural expression, especially in the skyscrapers built in the 1960s and 1970s. In terms of silhouettes, tall buildings from this period are simple, prismatic with rectangular and symmetrical plans.

In the second half of the last century four main types of structures were identified: diaphragms, frames, tubes and braced cores. Their derivate, each one is suitable for different solutions and heights.

Today, the silhouette of the construction comes first and the structural systems employed look like they were mixed and matched, fragments of structures are combined in order to create a system that is able to respond to the particularities of one shape. For super tall buildings, the silhouette does not represent only a purely aesthetic aspect, for technical reasons (wind behavior for instance) some options may be preferable to others.
In classical structures, frames with supplementary braces, the braces – responsible for lateral stiffness – were generally limited in the interior core and had a purely structural function. Consequently these structural elements, the bracings, have not shown their aesthetic potential until the appearance of tube structures that had diagonal braces on the building envelope, such as John Hancock Center in Chicago (Fig. 2.b.).

In outrigger structures, a system capable to absorb lateral loads is extended from the conventional core, towards the columns from the building’s perimeter. This basic configuration often requires massive columns to be placed on the perimeter of the construction and/or trusses for the levels were the structural connections between the core and the perimeter is made. These elements from the outrigger system are not always hidden in behind the facades; often they are exposed, conferring unique aesthetical characteristics to individual buildings. For example, First Wisconsin Center in Milwaukee (Fig. 3.) evidently expresses the additional braces of its structure, as aesthetical elements.

Tall buildings made out of tubes and frames, with dense orthogonal structural elements on their elevations, were successful in the modern architecture of 1960s and 1970s. They mainly consisted in vertical and horizontal elements. In contrast, in the contemporary urban context tall structures using diagrid systems a quite different from their tall veteran neighbors. While many contemporary aesthetic decisions are strongly guided by subjective visual opinions, diagrid’s use is an innovation that requires a partnership between technical and compositional interests.

Fig.4. a – Bundled Tubes - Willis Tower (Sears Tower), Chicago, USA - S.O.M., 1974 [8], b - Diagrid Structure - 30 St. Mary Axe Swizz Reinsurance Headquarters, London UK - Foster & Partners, 2004 [9]
Bundled tubes (Fig. 4.a.) – joined tubes, with cores that are reciprocally reinforcing each other, while working as independent systems – represent the recent evolution of tall building typology. This system also attempts to improve the means of egress, to increase safety and to reduce significantly the thickness of the building’s floors, as well as the need for additional interior structures.

3. Structures today

Tubular structures, including the recent type of structures called diagrid (Fig.4.b), are placing the main structural elements with resistance to lateral loads on the perimeter of the building, at skin level, creating a structural dominant in the aesthetic expression.

This association between the structure and the skin of the building leads naturally to a design approach that would solve the compositions by combining the structural system with the aesthetic elevation. Therefore, in tall buildings were these structural elements are employed, the technological and architectural components of the elevation are inseparable, completing each other.

The diagrid structure typology, or structural braced membrane, completed with a central core – sometimes on the contrary, it excludes the need for a central core or intermediate vertical structural elements – is probably the most notable innovation in terms of skyscrapers.

These external or marginal structures can create a certain type of aesthetics, the so called structural expression, as underlined by Fazlur Khan.

However, the notion of structural expression today seems to be on a descending spiral, the diagrid system apparently remains the exception.

Also, regarding the evolution of structures, today, the computer aids us to find the most advanced answers through extremely sophisticated simulations.

The use of the computer for the calculations and simulations of structures greatly reduces the working time and makes the most complicated structural solutions achievable today.

Structure can be revealed in various forms, not only just by leaving the structural elements visible, although this is the easiest way.

On the run to make tall building more efficient and fast to build another trend emerges. It is not a new one; it was promoted by the architects following the metabolist current widely in the twentieth century.

Prefabricated cells, for residences or offices, easy to attach to a central core seem to captivate the developer’s eye. Such systems can work with the traditional orthogonal frames, or arranged around central cores and afterwards consolidated by additional marginal structures.

CONCLUSIONS

In the last years, it seems that in what regards very tall buildings, the structure will continue to influence the shape and architectural expression of skyscrapers. The architects, together with the engineers, imagine vertical cities, capable to accommodate up to one million inhabitants.

For these projects, called megastructures, the structure itself becomes almost as important as the sum of the other components of the project, without it, living close to the clouds remains a dream.

REFERENCES


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