PRINCIPLE OF SUPERPOSITION APPLIED IN DESIGN AND IN CALCULATION METHODS OF STRUCTURAL SYSTEMS

Janusz RĘBIELAK*

* Professor at Faculty of Architecture
The Tadeusz Kościuszko Cracow University of Technology
ul. Warszawska 24, 31-155 Kraków, Poland

E-mail: j.rebielak@wp.pl   URL: http://januszrebielak.pl

Key words: architecture, structural system, foundation, static calculation.

ABSTRACT

Principle of superposition is often applied in structural design of various types of bearing systems of objects including tall buildings. The main goal in design of the structural systems is the endeavor to give to the tall building structure the possible big rigidity by means of relatively simple means [1,2,3]. They can be the steel systems, the reinforced concrete systems or the compound systems for the designed high-rise buildings. First type, see Fig. 1a-c, is worked out as result of transformation of double form of the square-on-square space frame, which is located in spaces of technical storeys, while its typical form is vertically arranged along the building perimeter [4].

Fig. 1. Schemes and views of structural system of tall buildings obtained in processes of transformation of selected shapes of space structures

Another type of structural system is created on basis of the typical framed tube structure, see Fig. 1d, it is called framed polyhedron system and its certain forms are presented in Fig. 1e-h together with an example of its possible application in a tall building, see Fig. 1i.
The stress trajectories in the free-end-beam together with form of a large and shallow root system of a certain tree species were inspirations in process of invention of the system of *combined foundation* and the *combined structural system of tall building*, see Fig. 2a-d [5]. This system does not need to make deep foundation trenches, it should be relatively inexpensive and its surface is theoretically unlimited. The application of the combined foundation should make possible to erect the tallest buildings - which can be even much higher than one kilometre - on the ground of almost zero load carrying ability on one condition that the available free surface around the building is large enough. It makes also possible to shape the specific foundation headers, by means of which the load forces of a building may be spread on the ground located outside the building's base perimeter, see Fig. 2b-c. It can be also applied to straighten the previously inclined objects. The proposed combined system is able to absorb a significant part of the energy vibration induced by dynamic load evoked e.g. by the earthquake. This ability can be enhanced by special technical devices like e.g. electronically controlled hydraulic jacks purposely arranged in appropriate parts of the structural system.

When particular components parts will be constructed as the waterproof boxes then the system of combined foundation will have a huge uplift pressure. That is why it may be considered as a kind of an artificial floating islands and it could be base for a buildings placed there, see Fig. 3. The platform for Ocean Agave, see Fig. 3a, is a circular shape of structural system of combined foundation, which in theory is unrestricted in terms of area and can be applied in settling of heavily loaded objects, based on surfaces with theoretically no bearing capacity. The boxes form a circle, approximately 400 meters in diameter, supplemented with a set of triangular, reinforced concrete elements, constructed similarly to the
crates themselves, and with properly placed trapezoidal reinforced concrete elements which act as external breakwaters and allow obtaining energy from sea waves. Another form of system of combined foundation is applied in conceptual design of Floating Bay Tower, see Fig. 3b. This solution is suggested for heavy loaded buildings within coastal and bay areas, as well as within areas surrounded by piers and breakwaters that limit non-uniform and sudden sea level rises. This is important especially during tsunamis, which result in to high sea levels during the highest ebb tide possible. Floating Bay as a multipurpose structure is created by a set of three separate buildings, each with the shape of an elongated octahedron, 150 meters tall, and based on an equilateral triangle with side length of 30 meters. Each of the buildings is designed by structural system called famed polyhedron and can house a maximum of 36 typical storeys.

![Fig. 3. Proposals of application of system of combined foundation as bases for floating islands in conceptual designs prepared for architectonic competition, a) design concept of Ocean Agave, b) design concept of Floating Bay Tower](image)

Principle of superposition has been also proposed in an innovative method of static calculations [6]. Simple forms of trusses are usually the statically determine systems and for needs of calculation of the force values acting in their members one have to use e.g. the Cremona’s method, the Ritter’s, the Culmann’s method or other methods [7-9]. Trusses of the more complex patterns are usually the statically indeterminate systems, where the force transmission between their members depends also on stiffness of members connected in the same joint. From analysis of certain type of tension-strut system - being initially the statically indeterminate system – follows that after the overloading it is still able to take forces but it becomes a statically determinate truss. This remark brings to mind a following conclusion: if the overloaded structure remains a good acting truss, which can be calculated in an easy way, then maybe it could be possible – in order to calculate the force values acting in members of the more complex system – to apply equally easy and simple methods of static analyses. From the general, basic conditions of equilibrium follows, that the intended calculations
have to be carried out in two suitable stages, see Fig. 4. One should be aware that forces calculated in this way are of the approximate values in relation to the forces really acting in members of the considered truss.

Fig. 4. Concept of two-stage method of approximate static calculation of statically indeterminate trusses together with comparison of values of calculated forces.

Simplicity of the proposed two-stage method can be considered as the most important value of it that is why it can be especially useful for the preliminary static analyses of the statically indeterminate trusses. This method can give more exact results after application of suitable sets of special parameters, which in suitable way will take into account mutual differences between stiffness of the members creating the truss.

REFERENCES