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VOLUMETRIC-SPATIAL SOLUTIONS OF MODERN SKYSCRAPERS

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A R T I C L E I N F O.

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Abstract

The paper classifies the main types of high-rise buildings taking into account modern requirements of sustainable development. It is shown that the use of green building principles in the construction of skyscrapers allows organizing comfortable space inside high-rise buildings.

There are two relatively new trends in construction in the world:

1. the height of high-rise buildings is growing rapidly, sky scrapers have already reached a height of more than 800 meters (OAU); buildings with a height of 1.2 and 1.5 km are being constructed (at the same time, the growth in height is not always caused by the shortage of free space in cities).
2. In an effort to reduce the area of cities, a number of countries have proposed projects of "compact" cities with a height of 1 km, accommodating 1 million inhabitants. A significant part of these structures is spatial; they are made in the form of shells. When erecting very tall buildings, and even more so when creating tall compact cities, there are new problems that complicate their construction and operation. At the same time, their creators introduce a number of new environmentally friendly solutions that distinguish high-rise buildings from conventional ones.

High-rise buildings are objects of the highest level of responsibility and reliability class. Emergencies in high-rise buildings lead to great material, economic, ecological and social consequences. Nevertheless, high-rise buildings solve some urban problems to a certain extent (they make it possible to get large residential, retail, office, recreational and other areas with the deficit of free territories in the city). The peculiarities of high-rise buildings include: increased role of horizontal wind loads compared to vertical ones; increased load on load-bearing structures, including bases and foundations; increased influence of natural influences (seismics, solar radiation, etc.) and techno genic factors (vibrations, accidents, fires, sabotage, local destructions) on operational safety; problems of ensuring joint operation in load-bearing structures of concrete, including foundations and bases, and anthropogenic factors (vibrations, accidents, fires, sabotage, local destruction) on operational safety; problems of ensuring joint operation of concrete and steel in load-bearing structures and unequally loaded structural elements, such as columns and walls. These peculiarities should be taken into account when selecting the structural scheme of a high-rise building and designing load-bearing structures [1, 2]. For example, under the influence of wind loads, tensile forces may occur in vertical, usually compressed, load-bearing structures. Due to the small area of foundations, stresses in the base can reach 0.8-1 MPa, and in vertical load-bearing structures (columns, partitions) - 50-70 MPa. Heating of the facade of a high-rise building leads to additional bending de- formations and loads on load-bearing structures.

When assessing the necessity to erect skyscrapers, the possible difficulties of construction are taken into account: transportation problems; problems of water supply, sewerage, storm water drainage; insolation; excessive energy consumption; increased vulnerability during special impacts (earthquakes, fires, terrorism, etc.); difficulties of dismantling and waste disposal.

Modern skyscrapers are characterized not only by their architectural expressiveness, but also by the use of high-tech solutions that improve their environmental performance:

- the use of shells and spatial curvilinear shape of buildings improves their visual perception, leads to natural resemblance and increases the spatial rigidity of buildings;
- the use of renewable energy sources (solar, wind, geothermal) with the help of installations built into the skyscraper structures allows to partially or completely reduce the energy costs of the building;
- greening of facades and roofs increases the environmental friendliness of buildings, leads to an increase in the area of greenery in the city, and improves the visual perception of skyscrapers;
- arrangement of "sky gardens" on the height of buildings (fully occupied by gardens and recreational areas within 1-3 floors, placed after several floors in height) allows to create conditions for recreation of residents or employees without going to the ground level and without prolonged use of elevators;
- maximum use of secondary and other renewable resources and materials (utilization of heat discharged with polluted air, collection of atmospheric and other water, etc.);
- use of effective passive seismic protection systems in buildings in earthquake-prone areas;
- use of energy saving methods - improving daylight input, increasing the light penetration of buildings, using "intelligent" building systems, etc.

Greening the walls and roofs of skyscrapers has long been one of the most effective ways to improve their ecological properties and attractiveness for residents. In recent years, buildings in the form of "green hills" have appeared, designed to improve the visual perception of flat urban areas. In the Netherlands, a 19-storey residential building Urban Cactus is under construction (fig.1). Its peculiarity is the stepped architecture, thanks to which many bushes and trees have been placed on the floors. The oxygen they produce will significantly offset harmful carbon dioxide emissions. The white color of the walls is intended to reduce the heating of the rooms from the sun's rays. Small swimming pools are planned to be built into the balconies of the building.

An effective way to make non-boscrapers more environmentally friendly is to utilize renewable energy; for this purpose, the facades are curved to increase wind speed.

The most environmentally friendly skyscraper in New York has recently been erected, which has floor-to-ceiling external glazing so that light can penetrate the building (for this purpose, all internal partitions are made of glass). Heat from solar collectors reduces the load on the heating system. The building has an adjustable lighting system: in each room there is a light sensor that will change the lighting depending on the intensity of outdoor light. For New York, the building has become an air filter: four times more air is supplied to the building than the air exchange requirements. Excess air removed from the building will also be cleaned and its volumes will be supplied to the city. Rainwater collectors on the roof are combined with water supply systems for sanitation, condensate collection from the building's air conditioning system and from the use of steam supplied to the building. The water collected in this way is used for drainage in the sanitary facilities and as a make-up water.

The Bahrain World Trade Center consists of two towers with three wind turbines with 30-meter diameter wind wheels between them (fig.2). The building will generate more than 1 GW of electricity per year, which will be able to supply it with electricity. Dubai is planning to build the tallest ecofriendly skyscraper in the world, which will be fully self-sufficient in electricity. For this purpose, solar panels with a total area of 15,000 m2 will be installed on the roof and walls. A 61-meter-high turbine will be installed on the roof, which will ventilate the skyscraper using the difference in air pressure between the lower and upper floors. The Lighthouse Tower in Dubai will be fully self-sufficient in energy. For this purpose, four thousand solar panels will be placed on the walls of the building and three wind turbines on the roof with a capacity of 225 kW each (fig.3).

New York's Bank of America Tower is equipped with a rainwater harvesting system (fig.4). The building is equipped with large windows that let in a lot of light and sensors that regulate the level of light in the rooms. A special feature of the Waugh Thistleton Residential Tower, which is planned to be built in London, is the thickness of the building - it looks like a flat sheet. Thanks to this, the rooms are fully illuminated by daylight. On the sides of the building are designed turbines, which with wind power will be able to generate about 40000 kWh per year. This will cover an electricity demand of 15%.

An interesting design direction is the erection of tall and environmentally friendly buildings - agricultural farms in cities. For example, the 132-story building

"Dragonfly" includes 28 different agricultural fields and is adapted to produce fruits, vegetables, meat, oil and grain, as well as to house laboratories, offices and apartments. The Vancouver Vertical Farm building project is designed to grow fruits, vegetables, fish, chickens and more. The building will utilize solar, geothermal and wind energy.

A new trend in skyscraper design is the arrangement of ecological gardens through several floors in height.

With the development of high-rise construction, several structural schemes of skyscrapers have been developed: The basic form of buildings is tower, with increased stability in all directions (due to the developed list section) and streamlined volume (cylindrical, pyramidal, prismatic with rounded corners). In order to reduce the horizontal displacement of the top of buildings to avoid distortions of enclosing structures and violations in the operation of elevators with an increase in the number of floors of the building, the ratio of its width to height should not be less than 1/8-1/10.

Four structural systems of high-rise buildings are known - frame, wall (frameless, diafragm), trunk and shell. Along with this, combined structural systems are widely used [1]. Since the 1960s, new structural systems - trunk and shell - have been actively introduced in high-rise construction. In the trunk structural system, the main load-bearing structure of the building is the crust, which causes significant displacements and accelerations on the upper floors.

The main load-bearing structure of the building is the crust, which causes significant displacements and accelerations on the upper floors. With a more flexible frame, significant vibrations are observed on the upper floors. To eliminate large oscillations in buildings with a height of 300 m, passive pendulum dampers are arranged on the upper floors. For example, in a skyscraper in Taipei, a damper in the form of a ball weighing about 800 tons is suspended on the 92nd floor and is designed to dampen vibrations. Under normal operating conditions, the damper allows the top of the building to deflect up to 10 centimeters (fig.5).

In an effort to reduce the area of cities, a number of countries have proposed projects of "compact" cities with a height of 1 km, accommodating 1 million inhabitants. The lighting of internal volumes is envisaged through large "light boats", which is unlikely to achieve the goal. These are the first projects in history and do not solve the most important problems, such as natural lighting of the numerous floors inside the "pyramids", etc. Such spatial city buildings occupy a much smaller area than sprawling modern cities and therefore attract the interest of designers.

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