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# Innovative solutions implemented in design of iset tower

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**Abstract.** A significant increase in the construction of high-rise buildings in Russia is observed in the last decades. Ekaterinburg takes the second place in Russia after Moscow as regards the annual construction volumes. The first high-rise buildings in the Urals region were built as early as in 19th century and the height of these buildings reached approximately 75 meters. Nowadays, two northernmost skyscrapers in the world are located in Ekaterinburg, one of which is a part of a business district "Ekaterinburg-City". The height of these skyscrapers is above 150 meters. The incompleteness of the Russian regulatory basis for designing high-rise buildings makes it necessary to carry out a large amount of additional design and construction processes. Therefore, despite the experience of previous projects, designers have to create individual innovative design solutions for every new high-rise building. This article describes the features of design of the high-rise building is the Iset Tower, located in Ekaterinburg. Basic design conditions are described and architectural, planning, and design features of the building are reviewed. The effects of harmful factors, acting on the building frame and including the wind loads, are analyzed. Some distinctive features of the analysis of the bearing structures are given. The conclusion contains the summary on specifics of high-rise buildings design and construction in the Urals.

## 1. Introduction

A significant increase in the construction of high-rise buildings in Russia is observed in the last decades. The development of high-rise building construction rates is directly linked to the growth of major cities. If in the beginning of the last century there were only several scores of high-rise buildings in Russia, but today their number exceeds several hundreds.

The first high-rise buildings in the Urals region were built as early as in 19th century, and the height of these buildings reached approximately 75 meters. For example, a 77-meter-high church named "Bolshoy Zlatoust" was built in Ekaterinburg (the capital of the region) in 1876. The church was designed by Russian architect Vasily E. Morgan in Russian-Byzantine style. This church was the highest building in the Urals at that time [1]. In 1982, upon an initiative of Boris N. Yeltsin, a 89-meter-high building for the Sverdlovsk Regional Committee of Communist Party of the Soviet Union, was built. This building, also known as a "White House" was designed in constructivist style. For more than 20 years (till 2000s) this building was the highest structure in Ekaterinburg [1].

Since the year 2000 more than sixty buildings higher than 75 meters have been built in Ekaterinburg. Of this number more than 10 buildings are higher than 100 meters and 2 building are higher than 150 meters.



Since the year 2006 a project of development of a business district "Ekaterinburg-City" located within the right-bank part of the city historical center is being actively implemented. The project includes four skyscrapers (named respectively: "Iset", "Yekaterina", "Tatischev", and "de Hennin") and some high-rise buildings.

The "Iset" tower is the highest building in the Urals region and one of the northernmost skyscrapers in the world [2]. The tower was built in 2016 as the first building of "Ekaterinburg-City" business complex. The height of the tower is 209 meters including 52 underground floors. Total area of the building is 70 600 square meters. The tower is a multipurpose building housing residential apartments at the upper floors, and shops and offices, restaurants, health care facilities, and an underground parking in the low-rise part of the building.

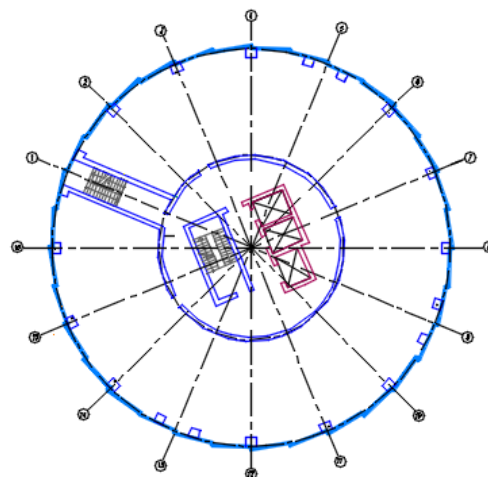
The incompleteness of Russian regulatory basis for designing high-rise buildings makes it necessary to carry-out a large amount of additional design and construction process. Local specialists were able to solve all complex problems that have arisen in the course of designing this high-rise building. In the process of the design and construction of the tower some innovative solutions were implemented that may be useful for designing other high-rise buildings in the future.

**2. Innovative solutions implemented in the design of Iset Tower**

First of all the architectural appearance of the tower should be mentioned. It is commonly known that the architecture of all high-rise buildings has a number of common features. In the present time these features mainly consist of modern streamline shapes which are not very expressive. On the other hand, the architectural appearance of every skyscraper bears not only aesthetic, but also an emotional function, and reflects the image of a district, a city, or a region, and in one way or the other is connected to the historical meaning of the construction site [3-6]. The architectural appearance of "Iset" tower (Figure. 1) is full of meaning for the citizens of Ekaterinburg. Innovative architectural solutions in the tower appearance include serrated shape of walling elements and an all-glass facade. Also the horizontal cross-section of the tower looks like a gear thus referring to the main industrial sector of the Urals region, the machine-building industry (Figure. 2).



**Figure 1.** "Iset" tower, visual appearance.



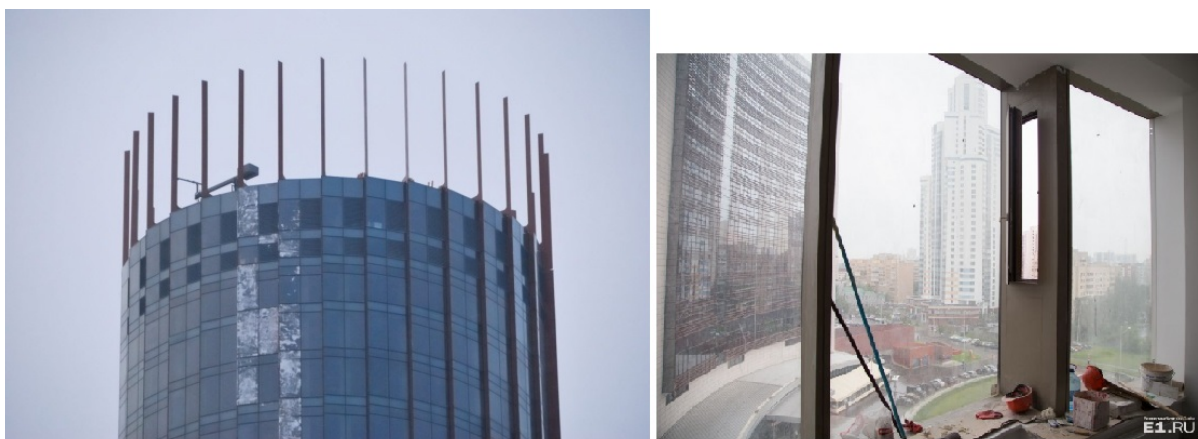
**Figure 2.** Plan of the bearing structures of typical floor of "Iset" tower.

In the course of development of the architectural appearance of the tower the great attention was paid towards energy efficiency of the building. The saving of energy is one of the ways to reduce heating and air conditioning costs of a high-rise complex. There are numerous methods of saving

energy used in the design of different high-rises around the world. The most effective of these methods are those which provide for the energy efficiency of the whole building as early as at the concept development stage [8-9].

When designing the "Iset" tower architects aimed to create not just an energy efficient building but a "green" building. The term "green" means a building that is energy efficient and environmentally friendly at the same time, a building capable of ensuring highly-comfortable human environment. The most distinctive feature of the "green" buildings is the focus on the microclimate of human environment [10-14]. Design solutions adopted by the architects of the building included, first of all, positioning the tower relative the cardinal directions considering the existing buildings near the construction site.

The next important task was the selection of the external enclosure of the tower, i.e. facade materials. It was decided to use a silver-spray-coated glass to ensure high energy-efficiency and insolation resistance. Internal double-glass panels are made of shatterproof glass and their chambers are filled with argon in order to reduce energy losses in accommodation areas [7]. One of the state-of-art architectural solutions in the building design was to place ventilation windows on end faces of the serrated walls in order to reduce air conditioning costs. The design of the ventilation windows allows opening them even at the height of up to 200 meters with high wind loads (Figure. 3).



**Figure 3.** Ventilation windows in Iset tower enclosing structure.

Also a special air conditioning system including air cooling and heating facilities was provided for maintaining the required air parameters in the accommodation rooms and office areas. Air is supplied into the building ventilation system through special cleaning and decontaminating filters and heating facilities [11]. Besides that all rooms of the tower are equipped with a "smart house" system controlling temperature inside the room, floor heating systems, and air conditioning systems making it possible to create comfortable microclimate in every room.

Aside from solving the microclimate issues the architects and designers of "Iset" tower worked out a design solution for the interior layout of the building. A braced frame design was chosen in order to ensure rational use of internal area of the building. The design includes a central core formed by the walls of stairs and lift shaft, a cylindrical closed diaphragm around the shaft, solid reinforced concrete columns and beamless floors. This design allowed the architects to separate corridors, utility and lift rooms from accommodation areas without reducing living space [5].

Upon the completion of the architectural design of the tower, the development of detailed documentation for the bearing structures has started. The design of the bearing structures included several analyses, the most important of which were wind load effect calculations. Wind loading acting on a high-rise building was determined using two methods: numerical modeling methods and aerodynamic tunnel tests. When designing the Iset tower, the 1/380-scale model of the building was

aerodynamically tested by WACKER INGENIEURE (Germany). Due to the small scale of the model it became necessary to verify the distribution of wind loading on the external surface of tower using a mathematical model [16-17]. Numerical modeling was performed by the specialists of the "Civil Engineering and Architecture Institute of the Urals Federal University named after the first president of Russia B. N. Yeltsyn" using ANSYS software package[15]. Finite element modeling included the following stages:

- Selecting mathematical model and turbulence model;
- Creating domain;
- Building finite element mesh;
- Specifying boundary conditions.

The numerical simulation of the Iset tower was created using the numerical model of incompressible air flow on the basis of Reynolds equation (see below).

$$\rho \frac{dV}{dt} = -grad(p + \frac{2}{3}\mu_{\Sigma}divV) + 2Div(\mu_{\Sigma} \dot{S})$$

where:  $\rho$  - density;  $V$  - velocity;  $p$  - pressure;  $\mu_{\Sigma} = \mu + \mu_t$ ,  $\mu$  - molecular viscosity coefficient,  $\mu_t$  - turbulent viscosity coefficient;  $\dot{S}$  - velocity tensor.

As a model of turbulence the model SST (shear stress transport) has been chosen. The model effectively combines the stability and accuracy to the standard k- $\omega$ - model in the parietal areas and the effectiveness of the k-e model at a distance from the walls with a smooth transition between them (input expansion functions) [18-23].

Then, the building and its surroundings were put in a domain functionally similar to an aerodynamic tunnel (Figure 4) [19]. The following boundary conditions were set for the external walls of the domain depending on the air flow direction:

- OPENING: the flow is directed inside and outside the domain;
- INLET: the flow is directed inside the domain;
- OUTLET: the flow is directed outside the domain;
- WALL: roughness setting for low-height surrounding buildings, trees, etc;
- NLET: velocity distribution.

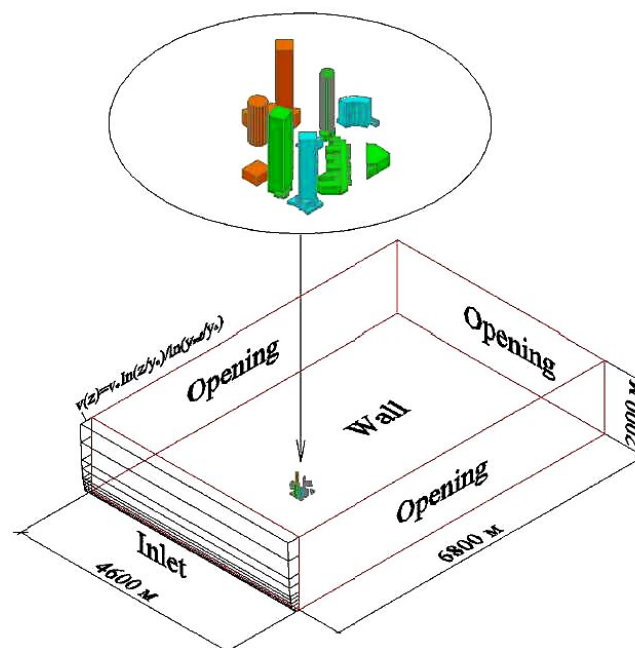
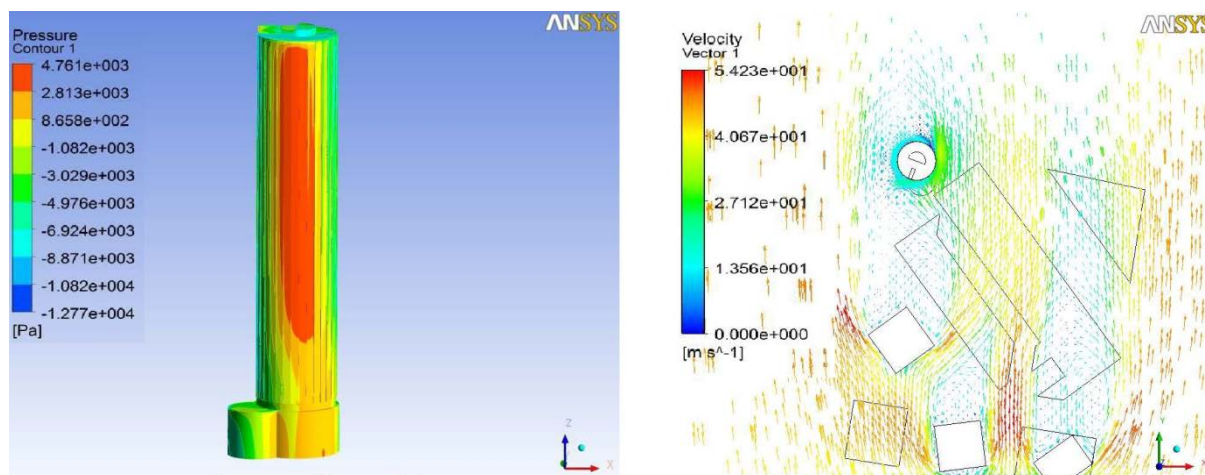


Figure 4. Domain.

In the result of calculation, the wind pressure distribution over the building height and distribution of wind flow speeds were determined (Figure 5). The results showed that the values obtained by numerical modeling are close to the values obtained experimentally.



**Figure 5.** Distribution of wind pressure over the height of building and distribution of wind flow speeds.

Besides the innovations in design, there also were some innovative solutions involved in the construction of the building. First of all the concrete mix composition was developed especially for this project. The development was carried out by the specialists of UMMC (Ural Mining and Metallurgical Company) together with St.-Petersburg university and consultants from Germany. A batching plant and a laboratory were built at the site due to colossal quantities of concrete required and stringent requirements to the quality of concrete: it was necessary to pour approx. 10 000 m<sup>3</sup> in three days in low temperature conditions (up to -20°C). A concrete mix grade B60 with low cement content was developed especially for the project and became the first concrete of this type ever used in Yekaterinburg. The setting temperature of the new mix was reduced due to low cement content, addition of fly ash, and a complex of additives including plasticizer, decelerator, and highly-active suspension of a mineral component. The second innovation was using a self-climbing system for the construction of the building core: six separate platforms with independent hydraulic systems for each lift shaft. The use of self-lifting forms and a self-climbing crane allowed reducing the time of construction as well as achieving prominent vertical accuracy of the building.

### 3. Conclusion

The construction of high-rise building in Ekaterinburg shows a tendency towards multifunctional complexes housing accommodation, retail and office areas instead of separate residential buildings. One of such complexes in the Urals region is "Iset" tower. In the process of the design and construction of the tower some innovative solutions were implemented, and these solutions, with no doubt, will be used in the future projects. The design process included the analysis of effects of harmful factors acting on the building frame including the wind loads. The analysis consisted of a computer simulation performed using ANSYS software package and experimental testing in a wind tunnel. The results of the analysis were used in the design of bearing and enveloping structures as well as the natural ventilation system of the building.

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