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Technical Characteristics and Development Trend of Russian High-Rise Buildings

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Abstract. The article briefly describes the technical characteristics of Russian high-rise buildings. It presents an in-depth study and analysis of the historical background and the main problems of Russian high-rise buildings today and assesses the trends in the Russian high-rise construction industry. This study is based on an extensive review of the scientific literature, focusing on the historical development and technical characteristics of tall buildings in Russia, The current shortcomings and development prospects of high-rise buildings in Russia are analyzed, and the analogy and graphic methods. Within the framework of which goals and objectives were formulated, methods and means were selected, criteria for evaluating empirical information and analysis results were established. It is hoped that it can bring some reference to Russian high-rise construction, enhance the understanding of Chinese construction enterprises in Russia and research universities about Russian high-rise buildings, and lay the foundation for smooth development and research of construction projects.

Keywords. Russian high-rise buildings, high-rise building construction technology, construction control, Russian-Chinese relations, high-rise building development

1. Introduction

With the rapid development of urbanization and the increasing scarcity of land resources, high-rise buildings have become an important field of human development under the support of continuous progress in construction technology. In the post-industrial era, the service industry has received more and more attention, and various development trends such as administration and finance have led to a high demand for space to accommodate enterprises engaged in this field. The continuous increase in the price of construction land, especially commercial land, and certain conditions for the protection of urban historical buildings have greatly complicated the development of office buildings in the city. The natural advantages of high-rise buildings, thereby optimizing land use and forming mixed-use complexes, including not only offices, but also residences, hotels, retail and entertainment. In addition, these buildings are symbols of city and national prestige, high technological level and economic strength.

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the main problems of Russian high-rise buildings today and assesses the trends in the Russian high-rise construction industry. It is hoped that it can bring some reference to Russian high-rise construction, enhance the understanding of Chinese construction enterprises in Russia and research universities about Russian high-rise buildings, and lay the foundation for smooth development and research of construction projects.

2. Research Methods

This study is based on an extensive review of the scientific literature, focusing on the historical development and technical characteristics of tall buildings in Russia. The current shortcomings and development prospects of high-rise buildings in Russia are analyzed, and the analogy and graphic methods. Within the framework of which goals and objectives were formulated, methods and means were selected, criteria for evaluating empirical information and analysis results were established. To collect the information necessary for the analysis, the following sources were used: documentary information resources, regulatory documents, sources of professional reference information, publicly available information resources

High-rise buildings refer to buildings with more layers and higher heights, and their classification criteria vary from country to country and region to region. Super high-rise buildings are also called skyscrapers.

The Department of Economic and Social Affairs, UN classified high-rise buildings into four categories according to their height at International Conference on Tall Buildings in 1974.

9th to 16th floors (up to 50 meters).

17th to 25th floors (up to 75 meters).

26th to 40th floors (up to 100 meters).

Above the 40th floor (total building height of 100 meters or more, i.e. super high-rise buildings)

Buildings from the 5th to the 6th floor to the 14th to the 50th floor are designated as high-rise buildings in the Japanese Architectural Dictionary, and those above the 50th floor are considered super high-rise buildings.

China's "General Rules for Civil Building Design" (JG37-87) classifies residential buildings according to the number of floors as follows: the 1st to 3rd floors are low-rise; the 4th to 6th floors are multi-story; the 7th to 9th floors are mid-rise; the 10th floor and above are high-rise. Public buildings and comprehensive buildings with a total height of more than 24 meters are high-rises, but single-story buildings with a height of more than 24 meters are not considered high-rise buildings. Civil buildings over 100 meters are super high-rise buildings.

Since the Soviet era, a high-rise building in Russia is considered to be a building with a height of more than 75 meters or more than 25 stories. In the United States and Europe, buildings over 150 meters are considered skyscrapers. However, experts from the Council on Tall Buildings and the Urban Environment believe that the concept of "high-rise building" cannot be clearly defined and that buildings above a certain number of stories or heights would be considered tall. The starting height or the number of stories for high-rise buildings varies from country to country, and there are no absolute and strict standards [1].

High-rise buildings in Russia can be traced back to churches, which enjoyed a Byzantine architectural tradition where buildings were designed with circular domes,

rectangular bases, white stone and pleasing to the eye. From 1475 to 1479, Russia built the Dormition Cathedral in the Moscow Kremlin (figure 1), with a height of 55 meters, and in the early 16th century, Russia built Ivan the Great Bell-Tower (figure 2). In the 1600s, the Bell-Tower was extended by one story to a height of 81 meters, making it the tallest building in Russia at that time.

Figure 1. Dormition Cathedral, Moscow.

Figure 2. Ivan the Great Bell Tower, Moscow.

After the victory of the October Revolution at the beginning of the 20th century, the Communist Party of the Soviet Union led the people to start a large-scale socialist construction, which promoted the development of social productivity and led to a great increase in overall national power. It made the Soviet Union the second largest economy in the world after the United States. After the victory in World War II, the world landscape underwent a new change. Moscow became the capital of the world's proletariat and still stands after four years of war. The Soviet Union began building many new high-rise buildings in Moscow, considered a symbol of the growing strength of the socialist system. The Soviet Union was leading the socialist camp and modeled on other socialist countries. If the main outline of the city before the revolution was the church, the high-rise buildings that began to be built after the revolution symbolized the triumph of the working people. In the mid-twentieth century, a long-term master plan for the development of Moscow was approved. In this plan, Moscow planned to build many high-rise buildings (figure 3), whose appearance was intended to "celebrate the ideal social order of communism" and to be majestic, symmetrical and luxurious [2]. Until 1990, the main building of Lomonosov Moscow State University was the tallest in Europe and, even today, the tallest academic building in the world (table 1).

Figure 3. Seven Sisters (Moscow).

Table 1. Stalin's High-rises information.

Name	Architects	Construction started	Construction completed	Absolute Height (m)	Floors	Use
Moscow State University main building	Lev Rudnev	1949	1953	240	36	University
Hotel Ukraina	Arkady Mordvinov, Vyacheslav Oltarzhevsky	1947	1957	206	34	Hotel, Residential
Ministry of Foreign Affairs main building	Vladimir Gelfreykh, Adolf Minkus	1948	1953	172	27	Governmenta
Leningradskaya Hotel	Leonid Polyakov[ru]	1949	1954	136	26	Hotel
Kotelnicheskaya Embankment Building	Dmitry Chechulin, LeonidRostkovskiy [ru]	1947	1952	176	25	Residential, Commercia
Kudrinskaya Square Building	Mikhail Posokhin[ru], Ashot Mndoyants[ru]	1950	1954	176	22	Residential
Red Gates Administrative Building	Alexey Dushkin	1947	1953	138	24	Residential, Governmental

With Stalin's death, the Soviet authorities' enthusiasm for skyscrapers subsided: Nikita Khrushchev, the succeeding general secretary, focused on the construction of residential buildings, which came to be known as the Khrushchev buildings. Of course, high-rise buildings are still being built, but no one has set the goal of catching up with the West in this area.

Moscow's high-rise boom began in the 2000s. The Council on Tall Buildings and Urban Habitat (CTBUH) statistics show that there are 51 tall buildings over 150 meters in Russia as of 2021 (table 2), with 15 projects under construction, of which the tallest building is located in Lakhta Center in St. Petersburg with a height of 462 meters, which is currently the tallest building in Europe and has won several awards including the CTBUH Award of Excellence for Best Tall Building 400 meters and above in 2021, the European Award of Excellence for Best Tall Building in 2021, and the Architecture Award of Excellence in 2021. In addition, it is one of the five most environmentally friendly super high-rise buildings in the world [3].

Table 2. Ranking of high-rise buildings over 200 meters in Russia in 2021.

	Building Name	City	Completion	Height	Floors	Material	Function
1	Lakhta Center	St. Petersburg (RU)	2019	462 m	87	composite	office
2	Federation Tower	Moscow (RU)	2016	373.7 m	93	concrete	residential / office
3	OKO - Residential Tower	Moscow (RU)	2015	354.2 m	90	concrete	residential / serviced apartments / hotel
4	NEVA TOWERS 2	Moscow (RU)	2020	345 m	79	concrete	residential
5	Mercury City Tower	Moscow (RU)	2013	338.8 m	75	concrete	residential / office

6	Eurasia Tower	Moscow (RU)	2015	308.9 m	72	composite	residential / hotel / office
7	Capital City Moscow Tower	Moscow (RU)	2010	301.8 m	76	concrete	residential
8	NEVA TOWERS 1	Moscow (RU)	2020	297 m	65	concrete	residential / office
9	Naberezhnaya Tower Block C	Moscow (RU)	2007	268.4 m	61	composite	office
10	Triumph Palace	Moscow (RU)	2005	264.1 m	61	concrete	hotel / residential
11	Capital City St. Petersburg Tower	Moscow (RU)	2010	257.2 m	65	concrete	residential
12	Evolution Tower	Moscow (RU)	2015	246 m	55	concrete	office
13	Federation Tower - Zapad Tower	Moscow (RU)	2008	242.5 m	63	concrete	residential / office
14	Imperia Tower	Moscow (RU)	2011	238.7 m	61	concrete	residential / hotel / office
15	OKO - Office Tower	Moscow (RU)	2015	224.5 m	46	concrete	office
16	House on Mosfilmovskaya Tower A	Moscow (RU)	2012	213.3 m	53	concrete	residential
17	Iset Tower	Yekaterinburg (RU)	2015	209 m	52	concrete	residential

In Russia, unlike in other countries, a high-rise building is usually defined as a building with a height of more than 75 m or 25 stories and above.

The continuous development of building materials and construction technologies has led to an increase in the speed and height of high-rise construction projects in Russia. A large number of valuable lessons have been learned from continuous practice.

The Moscow International Business Center (figure 4) is a typical example of the use of new technologies in high-rise buildings [4]. The complex has 13 objects, almost all of which were built with the application of new materials and innovative building technologies of the time.

Figure 4. Moscow International Business Center, Moscow.

The most famous of them is Mercury City Tower (figure 5), with its 338.8 m height and unique appearance. The continuous panoramic glazing is a modular system of energy-efficient, high-strength tinted double-glazed windows applied [1].

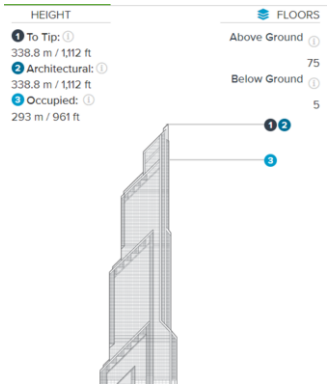

Figure 5. Mercury City Tower.

During the construction, the project applied prestressed concrete technology (figure 6). The use of prestressing reduces the weight and increases the strength of the structure, and reduces the amount of concrete used. In addition, it utilized a universal formwork design and self-lifting guard panels for working at height.

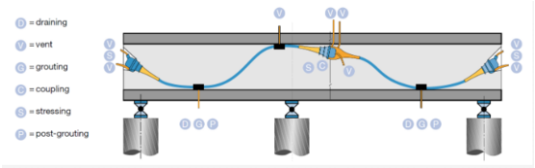

Figure 6. Prestressed system elements with clutches.

A total of 14,000 cubic meters of concrete was consumed to pour the foundation for the Russian Federation Tower (figure 7). The building's stability is ensured by a solid concrete core with a 1.4-meter bottom wall and 25 edge columns from the foundation to the top floor. Each of the 25-30 floors of the Federal Tower is equipped with outrigger floors made of high-strength steel to provide additional stability to the building.

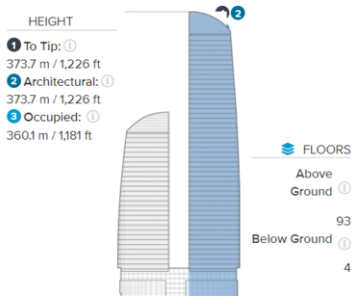

Figure 7. Federation Tower, Moscow.

In addition, the project uses a state-of-the-art glazing system developed by German and Chinese experts specifically for the Federal Building. The system's glass surface

reflects solar radiation and maintains the building's optimal temperature. This glass has thermal parameters close to those of brick walls [5]. At the time the project started applying this technology, it had not yet been used in any skyscraper in the world.

In 2018, a 462-meter-high "flame" "went up" at the Lakhta Center (figure 8) on the Gulf Coast of Finland. This large-scale project is considered one of the most complex and unique compared to other skyscrapers on the planet. The tower's architecture uses extensive BIM technology, as well as over 500,000 m^2 of glass on the building's façade.

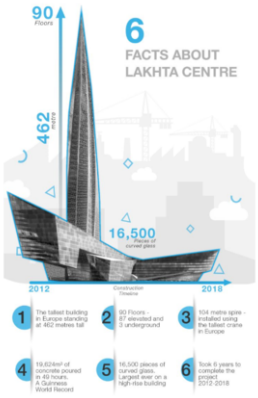

Figure 8. Lakhta Center, Saint Petersburg.

Construction of the Lakhta Center in St. Petersburg's Primorsky Krai began in 2012 (figure 9) and was completed in October 2018. It is the headquarters of Gazprom, and the building is shaped like a blazing flame, echoing the Gazprom logo. Upon completion of the project, Lakhta Center received several awards - 49 hours of continuous concrete pouring record, CTBUH 2021 award winners, one of the 5 most environmentally friendly super high-rise buildings in the world, etc.

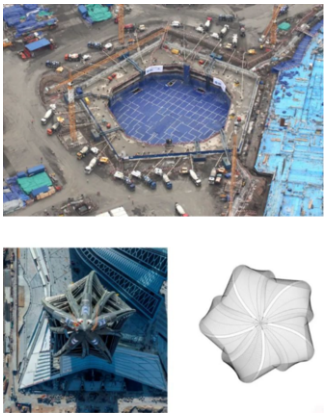

Figure 9. Concrete pouring site and aerial view.

British architect Tony Kettle of RMJM is the lead designer of the project (figure 10). This huge project involved 20,000 people from 18 countries. The façade consists of 16,505 individual panes of glass, most of which are rendered as beveled quadrants

with automatic blinds to improve energy conversion efficiency. The record height all-glass vertical frames provide maximum visual brightness and transparency spaces for the public flat stained glass windows. The energy-efficient glazing installed resulted in a 40 percent improvement in energy efficiency metrics. Lakhta Center also received LEED Platinum certification as one of the five greenest skyscrapers in the world. Installations such as elevator energy recovery, waste treatment systems, and coolers make the building superior in sustainability and very energy efficient and environmentally friendly.

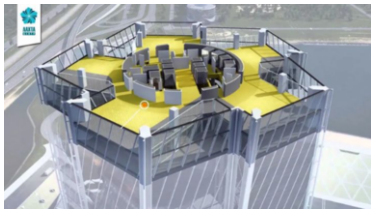

Figure 10. Lakhta BIM technical modeling renderings.

Lakhta Center is the world's northernmost giant skyscraper. No one has ever built such a building at the such latitude and in such a humid climate. For several months of the year, the 100-meter spire will be hidden in low clouds, making the surface of the facade icy and increasing the risk. Anti-icing measures are very important here. To avoid ice formation during the cold season, the facade of the Lakhta Center is equipped with piezoelectric sensors used in the aircraft industry. Their heating function will turn on automatically when ice forms on the exterior surfaces of the steel façade cladding.

The unique anti-icing system on the spire is designed to combat ice build-up on large metal surfaces (figure 11).

Equally unique is the façade maintenance system. It moves along a spiral track parallel to the façade shell to clean and repair stained glass or replace double-glazed windows. There, the track integrates active dynamic building lighting and anti-icing systems. Special sensors will monitor when local heating needs to be turned on in certain areas, such as where frost may occur during the cold season.

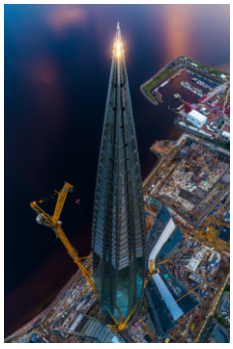

Figure 11. Lakhta spire anti-icing system.

While most of the building's space is office space, the Lakhta Center will also be home to a planetarium, a medical center and a performance hall. An amphitheater for 2,000 people and a green promenade with fountains, paths and benches are integrated

into the site. The observation deck is located at a height of 360 meters and the building's restaurant is the highest panoramic restaurant in Europe.

The tower is equipped with an active and intelligent double chain façade system with double height buffers. The valves of the automatically controlled beams at the corners of the buffer zone will open for ventilation in case of overheating. It is cooler and particularly suitable for plants: the temperature is between "inside" and "outside", but it can be freely adjusted if needed.

At present there are only 76 buildings in Russia with a height of more than 130m, of which 26 are under construction, 22 are waiting for investors and 28 projects are not yet implemented. These are absurd numbers for countries that have been developing in this direction for decades (USA, China, etc.). However, skyscrapers are already being built and the speed of development of technology, improvement of construction materials, engineering concepts, etc. is rapid.

In Russia, the development of high-rise buildings has also been slowed by the lack of a unified regulatory framework and research base to govern high-rise construction 30 years ago: the need to develop and obtain approved documents for each project has hindered the popularity and widespread development of high-rise buildings.

However, in recent years the government of Russia has introduced a series of new regulations (figure 12) that have actively contributed to the rapid development of the construction industry. One of the organizers of the 100+Foruv Russia is the Ministry of Construction of Russia. It serves as an effective official platform for exchanging experience and addressing barriers to high-rise construction, as well as domestic and international experience in high-rise technology and management [6].

Today Russia has a huge potential for the construction of multifunctional high-rise buildings. A vivid testimony to this is Russia's advanced experience in developing production technologies, including materials aimed at improving the overall safety of high-rise facilities. Cities such as Klimovsk and Sergeev towns near Moscow have implemented the local production of a new generation of fireproofing, insulation and thermal insulation materials, freeing themselves from dependence on imports [7].

Figure 12. Relevant federal policies and regulations.

3. Conclusion

After studying the history and current status of high-rise buildings in Russia, it should be pointed out that both in terms of construction experience and construction technology, Russia has its own uniqueness, and at the same time, the modern stage

The construction of skyscrapers shows the rapidly growing interest in skyscrapers in Russia, as well as the number of cities participating in the race. The experience of Moscow City shows that increasing the height of buildings is beneficial to maximize the public space of the city and pedestrians, including landscaping such as parking lots and city parks, saving land for public facilities construction, such as pedestrian streets and urban greening construction, Improve the urban environment and increase the happiness of the people.

Of course, Russia is also facing the imbalance of construction technology and supervision and management. The rapid development of building materials and construction technology has made high-rise buildings continue to climb to new heights. The lack of a corresponding modern supervision system and professional training is an obstacle to the current development of high-rise buildings in Russia.

Today, the Ministry of Construction of Russia is actively developing normative and methodological documents to compensate for ineffective and outdated documents in the field of high-rise construction. Together with the professional community in recent years, the department has developed rules for urban planning, design, and operation of high-rise buildings and complexes, which set out detailed requirements for the infrastructure and engineering systems of high-rise buildings.

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