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THE USE OF CONCRETE IN THE CONSTRUCTION OF SKYSCRAPERS

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Abstract

The construction of skyscrapers was started by the use of metal frames, which began in the USA at the end of the 19th century. Since then, buildings known as "Chicago structures" have spread widely around the world. For a long time, record heights were achieved only at the expense of using the unique properties of steel and improving construction technology. Despite many attempts in this direction, the use of concrete as the most common material in construction was almost impossible. The current situation changed radically after the discovery of the possibility of modifying concrete, i.e. giving it desired properties. The practical use of modified concrete has shown such advantages over steel that in recent years, almost all super-skyscrapers with a load-bearing core have been constructed with reinforced concrete.

Key words: Building, skyscraper, frame, steel, concrete, reinforced concrete.

Introduction

Fig. 1. The world's first concrete skyscraper

"Ingalls Building", built in 1903 in Cincinnati (USA), a 16-story, 64-meter-high building, is considered to be the world's first skyscraper built of reinforced concrete. Its construction, which lasted for 8 months, received a great response, because before that, a reinforced concrete building with a height of 6 floors had never been built anywhere. Therefore, the construction of the 15 X 30 m monolith in the plan was met with critic by the public and specialists. Most of them were sure that after replacing the supports, the building would not be able to withstand its own weight and would collapse. The building has survived undamaged and is one of the most important objects in the world (Fig. 1). After the construction of the "Ingalls Building", many similar buildings were built in different parts of the world, but their heights were always significantly lower than the steel skyscrapers. In 1971, the world's tallest reinforced concrete building, 218 meters high, was built in 1971 by Fazlur Rahman Khan, the engineer who developed the tubular structure technology. in Houston (USA) (Fig. 2).

Fig. 2. One Shell Place

The building's construction was the first example of a "tube-in-tube" structure, where the use of concrete instead of steel worked to great effect. In fact, concrete was widely used in the construction of skyscrapers after that. It should be noted that during this period, the construction of reinforced concrete television towers was already actively underway all over the world. The 540-meter-high Ostankino telemast, built in Moscow in 1967, whose concrete part is 385 meters, should be especially highlighted, and it is still considered the tallest building in Europe today (Fig. 3). In 1975, the construction of the 553 m high Toronto reinforced concrete telemast, which still holds the title of the tallest free-

standing structure in the world today, was completed (Fig. 4).
Despite the great achievements, the main task of scientists and engineers was to change a number of properties of concrete, i.e. to modify them. In addition, it was necessary to take into account that several types of concrete are needed to build even one building. One of the first examples of this was the 262 m high reinforced concrete 74-story "Water Tower Place" built in Chicago in 1976 (Fig. 5). To obtain the necessary properties of concrete, various superplasticizers and by-products of ferrosilicon production with a diameter of 100 nm are most often used. These spherical particles consist of 80-85% amorphous silicon dioxide (SiO_2). Plasticizers give the concrete mixture such flowability that it can be delivered at heights above 400 m using pumps and usually does not require additional liquefaction (vibration) during placing.

Fig.3. Ostankino Tele Tower

Fig. 4. Toronto Tele Tower

Fig.5. Water Tower Place

Main part

In the world, the most visible first example of the use of modified concrete is the 88-story, 451.9 m high Petronas Twin Towers built in 1998 in the capital of Malaysia, Kuala Lumpur. At the suggestion of the Prime Minister of Malaysia, the building was decided in the Islamic style and only local materials were used for construction. Because steel is not produced in Malaysia, a strong and yet plastic concrete was specially developed that the country could produce independently. As a result, the towers turned out to be twice as heavy, but the strength of concrete was not inferior to steel, and with the use of quartz additives, it reached 137 megapascals. The use of concrete created many other difficulties. Among them, due to the detection of low quality of concrete during the construction process, one of the built floors was completely dismantled and its arrangement was done again. During the geological survey of the ground, it was found that one side of the site selected for construction rested on rocky ground, and the other rested on soft limestones. This would cause one of the towers to collapse, so the construction site was moved 60 meters and placed entirely on soft ground. The existing foundation turned out to be very large and remains the largest foundation in the world by volume. Its construction technology is also unique.

Before the start of construction, the weak ground was strengthened by injecting cement at a depth of 160-162 meters. Drilled, 1.2 x 2.8 m, reinforced concrete barrettes were arranged from the bottom of the 4 m deep pit at a depth of 60 to 130 meters so that they were all placed in a uniform soil (Fig. 6). The shaft was then sunk another 25 m and the barret heads were combined into a 4.5 m high reinforced concrete slab-roastwork with a diameter of 53.7 m for each tower. 13,309 m3 of concrete was spent to prepare the foundation, which was continuously laid for 54 hours. The buildings, which held the title of the tallest in the world from 1998-2004, are distinguished not only by their colossal dimensions, but also by their structural complexity. The main load-bearing part of the tower consists of 16 main columns of reinforced concrete cylindrical shape. They are symmetrically distributed in the upward construction of the circular outline (Fig. 7). The bearing capacity of the columns made of high-strength concrete is calculated in such a way that even if three columns are out of order, the building remains stable. In addition, all other internal structural structures are based on them, due to which the spaces are limited and because of this, for example, it was necessary to arrange two-story elevator cabins. The safety of the towers (wind, seismic protection, fire resistance, means of evacuation, etc.) is additionally ensured by the roofed aerial steel bridge installed between them, which rests on gigantic joint girders at a height of 170 m. Its length is 58 meters, and its weight is 750 tons. It significantly weakens the vibrations caused in the towers during wind and earthquakes and acts as a kind of damper (Fig. 8).

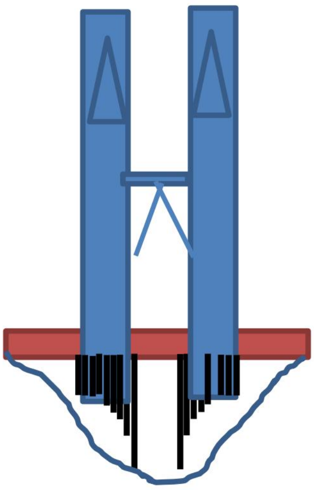

Fig. 6. Laying the foundations of the Petronas Towers

This construction was the first to reveal the versatile and unlimited possibilities of modified concrete. Also the advantages it has compared to steel. After that, concrete was actively used in skyscrapers along with steel.Due to the lower deformability of modified concrete, it has become possible to implement projects for the construction of higher skyscrapers compared to steel.

Fig. 7. Tower construction process

Fig. 8. Petronas Towers

In 2004, the construction of the world's first over 500-meter skyscraper "Taipei 101", which was the world's tallest building until 2007, was completed in Taiwan. The main bearing part of the building is represented by 36 columns, of which 8 main columns are made of 70 MPa concrete. The foundation is equipped with 380 pieces of reinforced concrete beams buried 80 m deep in the ground. The diameter is 1.5 m, and the carrying capacity of each is 1000-1300 tons. The construction of the bamboo stem structure consists of 8 interlocking blocks in height. Such a structure and a 660-ton spherical damper hanging between floors 87-91 ensure its high reliability in a place characterized by strong storms and earthquakes (Fig. 9).

Fig.9. Taipei 101

A good example of the use of modern concrete is the construction of the world's tallest building and structure "Burj Khalifa" (828 m), which was completed in 2010. Reinforced concrete was used to build its supporting core. 30,000 tons of steel and more than 250,000 m3 of concrete of various types and strengths were spent on the entire building. Its carrier core is built in the form of a three-pointed star and spirals upward. The central, six-sided section of reinforced concrete forms the main axis of the building, which resists horizontal loads much better than steel. Reinforced concrete made it possible to arrange monolithic diaphragms on each branch of the core. Their combination creates a spider-like network and gives special stability to the entire structural system in case of wind and dynamic loads (Fig. 10). The foundation of Burj Khalifa (Fig. 10) is a 3.7 m high reinforced concrete slab resting on hanging girders. 12,500 m3 of C50 grade concrete was used for its construction. 1.5 m in diameter and an average length of 43 m, the total number of deep f deep foundation was 194 pieces. Based on the mass of the building, the estimated load on each roof corresponds to 6600 tons. Therefore, the grade of concrete used for the construction of deep foundation was even higher and was C60. Also, higher grade modified concretes were used in the construction of reinforced concrete load-bearing core, walls and roof slabs. Due to the location of the facility in very hot climatic conditions, all types of concrete used during construction were made of temperature resistant additives. Other measures were taken to neutralize the effects of the heat. For example, the concreting process was mostly carried out at night, and ice was always added to the mixture during their placement (Fig.10).

Fig.10. Burj Khalifa

In 2012, the largest building by mass in the world "Abraj Al-Bayt" was built with concrete in Mecca (Saudi Arabia) (Fig. 12). Its main tower is similar to the famous Big Ben in London, but it is 6.3 times higher (601 m). In Kuala Lumpur (Malaysia), the super-skyscraper "Merdeka 118", which is still mainly built with concrete, reached its design height in 2022 (678.9m) and is the second tallest building in the world.

Fig. 11. Abraj al-Bayt

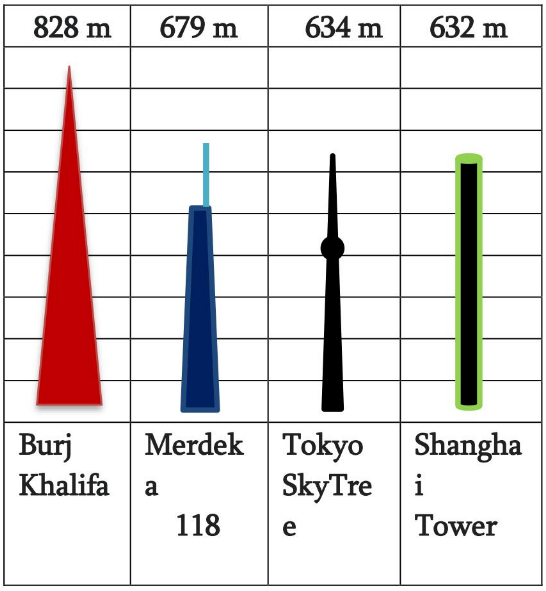

Fig. 12. Higher buildings Worlds

It must be noted that the supporting core of the first four tallest structures and buildings in the world (Burj Khalifa, Merdeka 118, Tokyo's New TV Tower and Shanghai Tower) is reinforced concrete (Fig. 12). All skyscrapers under construction are also being built using new types of concrete. This indicates a number of advantages of concrete and even greater prospects for its use

Conclusions

1. After many years of using only steel in the construction of skyscrapers, in recent years concrete has gained a great advantage. Almost all new super-tall buildings are now made of reinforced concrete. This became possible after the modification of concrete, i.e. giving it the necessary properties. The advantage of using such concretes has already been proven by many unique facilities;
2. In addition to the fact that the core of reinforced concrete is less deformable than steel, concrete allows for a variety of construction solutions. In addition, concrete resists wind load much better and is more fire resistant.;
3. The first four places in the list of the tallest buildings and structures currently in the world are occupied by objects built with a reinforced concrete load-bearing core (Burj Khalifa, Merdeka 118, Tokyo's new TV tower and Shanghai Tower). Almost all new important buildings are constructed using concrete. This shows the great possibilities of modified concretes and the limitless prospects of their use in the construction of skyscrapers.

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