Architecture of medium- and multistoried residential buildings with steel framework

T V Shamaeva1, E S Zinkevich1

1 National Research Moscow State University of Civil Engineering (NRU MGSU), 26, Yaroslavskoye Shosse, Moscow, 129337, Russia

E-mail: ShamaevaTV@yandex.ru

Abstract. In this article, the object of research is multistoried buildings and medium-rise buildings with a steel framework as load-bearing structures, which have been built over the past 13 years. Advantages and disadvantages, characteristic features of the architectural design of these buildings have been specified. As a result of the work it has been revealed that architectural solutions depend directly on the structural solutions of the metal frame when the number of floors is from 3 to 21; the space-planning type is used as sectional and corridor, etc. A number of disadvantages have been identified such as: the choice of a structural system depends on the number of stories in the building; a narrow range of steel products is for the civil construction; there are no typical architectural units, etc. As for the advantages, there are various solutions for facade systems; short installation times are compared with the “all-season” construction; the load on the foundation from a metal frame is less than that from a monolithic one. There is a possibility of using prefabricated standard elements of the frame-modular construction of the building, adaptation of the building to another function. Galvanized steel structures have turned out to be more resistant to external factors.

1. Introduction

The steel framework is being used in buildings for various functions in modern design. We will consider the use of the steel frame in the residential construction of medium-and multi-stored buildings. We will identify the advantages and disadvantages of the steel-framework and will investigate feasibility of the design.

The percentage of steel frame buildings in our country does not exceed 15% of the total number of completed projects. For example, in Norway the percentage is 48%; in Sweden, the UK and the USA – 65-68% [1]. Mainly, this scale is achieved through the multi-stories housing construction. In the Russian design of residential buildings, the primacy is taken by the monolithic reinforced concrete construction. But the architectural solutions of residential buildings based on a steel frame are not inferior to monolithic ones.

Architectural solutions are directly related to the choice of the structural scheme of the steel framework. There are more than 10 structural frame schemes for the design of residential buildings on a metal framework, including for residential buildings. The most common frame is frame-tie, precast-monolithic. High-rise buildings are frequently frame-cable-stayed, frame systems with suspended floors, with reinforced concrete diaphragms and stiffeners, trusses and frames with a floor height shell. In the high-rise design, the possibilities of using steel frames are most fully revealed.
Let us determine which buildings are considered mid-rise and multi-storey. The classification of buildings by the number of storeys changes over time. Indicators of the number of floors increased with the general trend of increasing the height of buildings, development of design solutions, the technology of construction, development of new metal alloys. Today, in accordance with the norms, mid-rise buildings have 4-8 floors; multi-storey – 9 floors and more [2].

2. Materials and methods
An analysis of the architecture of residential buildings with a steel frame, built in Russia (7 pcs.), in the United States, Canada (6 pcs.) was illustrated by table 1.

The tasks were to determine the number of stories, space-planning type; characteristic features of the appearance of buildings. It is necessary to identify the disadvantages and advantages of using a steel frame in residential buildings over 4 floors, to raise the question of the feasibility of using a steel frame for residential multi-apartment buildings.

Table 1. Objects for analysis, part 1

| Russia                                                                 | USA, Canada                                           |
|-----------------------------------------------------------------------|-------------------------------------------------------|
| 1. “Moskovskiy” Residential complex, Yekaterinburg.                    | 1. Macallen Building, Boston, USA.                    |
| - Sectional.                                                          | - Corridor-type.                                      |
| - 25 floors.                                                          | - 14 floors.                                          |
| - Ventilated, suspended facade. Glass, panels.                        | - Ventilated, suspended façade.                       |
| - 2012.                                                               | - 2007.                                               |
| 2. Residential building for employees of the Ministry of Defense of RF. | 2. The Canopy Lofts, Lincoln, Nebraska, USA           |
| Murmansk, Murmansk region, Gadzhievo.                                  | - Sectional, corridor-type.                           |
| - Sectional (2 sections).                                             | - 6 floors.                                           |
| - 4 floors.                                                           | - Hinged panels, glass.                              |
| - Curtain facade. Ceramic granite tile.                               | - 2013.                                               |
| - 2015.                                                               |                                                       |
| 3. Residential complex "Fregat-Neo", Krasnoyarsk.                     | 3. Troy Boston, Boston, USA.                          |
| - Corridor-type, sectional.                                           | - Corridor-type.                                      |
| - 14-16 floors.                                                       | - 9-19 floors.                                        |
| - Ventilated, hinged facade. Glass, panels.                           | - Hinged panels, glass.                              |
| - 2015.                                                               | - 2015.                                               |
Table 2. Objects for analysis, part 2

| Object Description                                                                 | Sectional | Floors | Frame Material | Panel Material | Years |
|-----------------------------------------------------------------------------------|-----------|--------|----------------|----------------|-------|
| 4. Residential complex "River Park", Moscow, Nagatinsky Zaton.                     | -                     | 17-18  | Gas-concrete   | Ceramic granite panels on a steel frame. | 2017-2020 |
| 5. Residential neighborhood "Novomarusino", Novosibirsk.                          | -                     | 10     | Glass          | Hinged thermal panel. | 2017-2020 |
| 6. Residential complex «Tridesyatoe», Bogorodsk, Nizhny Novgorod region            | - Corridor-type       | 3-5    | Thermal panel «Rusteh+» | 2016-2017 |
| 7. Residential complex "Shakhtar", Chegdomyn, Khabarovsk Krai.                    | -                     | 4      | Thermal panel «Rusteh+» | 2016-2017 |

3. Results.
In the course of the analysis, the following results were obtained:

- architectural solutions depend directly on the structural solutions of the metal frame. The formation of the architectural appearance of the facades is due to the "external" frame ("lattice facades"); the use of hinged facade systems; ventilation elevation systems; wall - "screen", curtain walls made of glass, panels, large stained-glass surfaces;
- the number of floors is from 3 to 21. In the Russian design of residential buildings with a steel frame, it is used in an equal ratio in buildings of medium height (3-5 floors) and in multi-stored buildings (10-18 floors). In foreign practice, multi-stored construction prevails (10-21 floors);
• the space-planning type is used in two versions: sectional and corridor. This is the advantage for sectional houses (90%). In Russian examples there is a tendency to create standard projects, in foreign examples - in individual design;
• elevations and appearance of buildings in foreign examples are not always aligned with the function of housing. At the same time, the appearance is more vivid, memorable, and the steel frame is visible in the appearance and in the interiors;
• the categorization of housing is different: from social, economy housing (RF), apartments to housing with increased comfort (mainly in foreign practice).

In the course of the research on this topic, additional results were obtained.

**Disadvantages of using a steel frame for residential buildings:**
• The choice of a structural system depends on the number of stories in the building; the higher the number of stories of the building, the more varied the choice of the structural system. For medium and high-rise buildings, frame, cased-frame systems are cost-effective. The frame creates restrictions on the layout of the building; therefore, it is mainly used in office and administrative buildings, in rare cases – in residential buildings [3]. It also creates a more rigid planning structure in comparison with a building made of monolithic reinforced concrete.
• At present there is a low level of unification of frame elements, the predominance of manual operations when creating the "frame" of nodes [3]; a narrow range of steel products for civil construction.
• There are no typical architectural units, design solutions in comparison with monolithic design.
• Metal prices have increased compared to previous years; the benefit from using a metal frame compared to reinforced concrete has decreased [3].
• High labor costs of highly professional assembly workers.
• To increase the fire resistance of structures, it is necessary to carry out structural protection of the load-bearing elements of the frame made of metal.

**The advantages consist in the following:**
• there are various solutions for facade systems;
• installation times are short compared to that of the monolithic construction;
• this is the “all-season” construction, independent from weather conditions in comparison with the monolithic construction;
• the load on the foundation from a metal frame is less than that from a monolithic one (above 25 floors, it is better to use a steel frame);
• there is a possibility of using prefabricated standard elements;
• the frame-modular construction of the building is possible, which is more suitable for the construction of social housing, hotels and dormitories;
• the building may be adapted for another function; there is a variability of the building with large spans. This allows you to create free spaces; at the same time, kitchens, bathrooms, toilets can be created as modular elements;
• galvanized steel structures are more resistant to external factors, but also more expensive.

**4. Discussions**
The question remained open: how many floors are there in a multi-stories building? The classification of buildings in terms of the number of stories in Russian standards is ambiguous.

There is a definition of a high-rise building. A high-rise building is the height of a residential building over 75 m [4], and the height of the building is determined by fire regulations. At the same time, the designers (especially for fire systems) have a concept of "high-rise" buildings, but there is no official definition. It is necessary to introduce clear limits on the number of floors for multi-stories buildings. There are rules for designing reinforced concrete frames for residential multi-stored buildings [5], but there are no rules and regulations for steel frames.
The feasibility of using a metal frame for apartment buildings is ambiguous in terms of architectural solutions. The conclusions are as follows:

- For residential buildings of medium stores (from 4 to 8 floors), it is more economical to use a steel frame with reinforced concrete floors. Most likely, these are economy class or social housing, as well as apartments, hotels and hostels. Facades are without bulk plastic. It is possible to use standard elements (for example, reinforced concrete floor slabs). The typical modular design is possible.

- For multi-stories buildings, the variability and choice of structural systems are higher. This is related to the possible variety of facade solutions. When using large-span structures, "free" spaces are created; there is an increase in various planning techniques, adaptation to different functions.

5. Conclusions
Much depends on the tasks set and on the capabilities of designers, builders, customers, climatic conditions, the raw material base and other factors. The design and construction of steel-framed apartment buildings deserve special attention and development in the future.

6. References
[1] Mironov V Iron arguments for and against steel construction. RBC+. [Electronic resource]. URL: https://plus.rbc.ru/news/
[2] SP 42.13330.2016 urban planning. Planning and development of urban and rural settlements. Updated version of SNiP 2.07.01-89* (with Changes №1, 2). Date of introduction 2017.07.01
[3] Razumova O V 2012 Principles of forming architectural buildings, structures and architectural complexes using steel frames Visnik Pridniprovskoi derzhavnoi Akademii budvinistva TA architekturi 1 pp 53–66
[4] SP 267.1325800.2016 High-rise Buildings and complexes. The rules of design. Date of introduction 2017.07.01
[5] SP 356.1325800.2017 Structures of frame reinforced concrete prefabricated multi-stories buildings. The rules of design.