Metal structures as the basis of architectural design

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Abstracts The article is devoted to the role of metal structures in solving the architectural and artistic image of the facility. If earlier metal structures were associated with industrial facilities, facilities of engineering or transportation infrastructure, in modern architecture metal structures create an architectural image in absolutely any type of buildings and facilities. New technologies and changes in the metal itself contribute to the creation of memorable images. Four main techniques for using metal structures have been identified. The first technique is the traditional solution in the form of a load-bearing metal frame in the building structure, when all the metal is hidden. Most high-rise buildings in the world are built according to this scheme. The second technique is open metal structures, which are the main architectural details of facades and the entire architectural and planning solution, such as the Bird's Nest Stadium in Beijing. The third technique is when the metal itself serves more of a decorative function. The metal plasticity and the surface finishes versatility contribute to the creation of memorable images. The fourth technique is metal structures for large-span structures that work for both the interior space of the facility and its exterior perception.

Keywords: metal in architecture, metal structures, metal in interior, image in architecture, high-tech, diagrid

1 Introductions

The triad of materials: concrete, metal and glass allow to solve different architectural ideas. The modern tendency to form facades sometimes makes do with two materials: metal and glass. The trend was given a tangible boost by the high-tech style with the appearance of facilities such as the Centre Georges-Pompidou in Paris. Although, the diagonal metal links on the facade of the John Hancock Center skyscraper (1969) [1-3] in Chicago (Figure 1) appeared a little earlier.

Development of technologies are giving architects new possibilities in shaping the image of a building. There are a significant number of facilities where the metal structures themselves are the basis of the image. Such can be considered the Bird's Nest Stadium, built for the 2008 Olympics in Beijing (Figure 2) [4], the railway station in Kyoto (Figure 3), the International Forum in Tokyo (Figure 4), the Morpheus Hotel in Macau (architect Zaha Hadid) [5].

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Fig 1 John Hancock Center

Fig 2 Bird's Nest Stadium in Beijing
**Fig 3** Kyoto Railway Station

**Fig 4** Tokyo International Forum. Architect Rafael Vignoli
The ability of metal structures to cover large spans has a significant impact on the shaping of the interior space. In combination with metal plasticity and various light-transmitting materials, architects achieve expressive images of buildings and structures. Examples include the Olympic Stadium in Munich built for the 1972 Olympics, the square in front of the East Railway Station in Guangzhou (Figure 5) [6].

2 Materials and Methods

The author has analyzed the variety of facilities in different cities of the world, architectural expressiveness of which is achieved with the use of metal structures. The basic techniques of using the metal structures as the main idea of architectural image have been defined.

3 Results

The application of metal structures in architecture has four solution options. The first trend is more conservative and utilitarian, where metal structures fulfill a load-bearing role and are located in the structure of a building or facility without much influence on the architectural image. They are hidden.

The second trend is the opposite of the first, where metal structures come to the forefront and they shape the architectural image. Along with its load-bearing function, the metal structure is an important aesthetic form and architectural detail. Apart from the aforementioned stadium in Beijing, this is very typical of structures such as bridges. The architectural interpretation of the image of such structures as a bridge has been significantly transformed from the traditional view of such facilities. Examples are the bridges in Singapore (Figure 6) [7], Geneva (Figure 7), Tbilisi (Figure 8), and Moscow (Figure 9).
The third trend uses the plastic features of the metal and surface finishing options. These are the shiny plastic surfaces of the Guggenheim Museum in Bilbao or the "rusty" facades of Corten steel. The fourth trend is the solution of large-span structures. Sometimes even in the external perception of the facility metal structures may not be visible, but inside they can be the main accent of the interior.

In modern architecture, the second and fourth trends have acquired a larger-scale embodiment and these techniques are used by architects more and more often in the design of various types of buildings.

The third trend is used less frequently, when creating any important accent facilities.

The first trend has also undergone changes and above all it concerns the protection of the metal frame itself in various ways, for example against high temperatures. The need for such measures was confirmed by the unfortunate events with the WTC skyscrapers in New York on September 11, 2001.

The use of metal structures as the main architectural image is characteristic of the most diverse type of buildings and structures. Figure 10 shows a vertical load-bearing frame on the facade of a high-rise building in Tokyo. The exposed metal structures are in the same structure as the interior structural design, but they cope with the task to add individuality to the facility. As the load increases towards the lower floors, the frame becomes more massive.
The metal structures at the Hong Kong Design Institute (Figure 11) play an expressive role [8]. Four vertical towers connect the stylobate and the top two floors of the building. The vacant six-story space houses an escalator that takes you up to the main entrance. The diagonal, diamond-shaped structure of metal structures, which is called "diagrid", in addition to its main load-bearing function, contributes significantly to the solution of the building's image. The very principle of the diamond-shaped load-bearing frame was widely used by Russian engineer Vladimir Shukhov back in the early twentieth century [9].

The same technique with diamond-shaped metal links is used in the ArtScience Museum of Singapore. The imagery in the form of a peony flower is elevated 11 meters above the surface, for a total facility height of 80 meters. The facility hovers above the ground supported by dark colored columns and white diagrid structures (Figure 12).
The very pattern of diamond-shaped metal structures is quite popular in recent years. For example, in Norman Foster's work, these are the Hearst buildings in New York City, 30 St. Mary Axe in London.

Metal structures in the interiors of various facilities are mainly used to organize large-span facilities, when creating atrium spaces. For example, this is typical for airports, railway stations or stadiums and arenas.

An interesting space is formed for the above-ground subway station at Beijing Capital Airport (Figure 13).

Most buildings and facilities with exposed metal structures are categorized as high-tech style. The attitude to it among people is ambiguous. First of all, people are wary of the
excessive technogenicity, the coldness of metal, and associations with the industrial environment. It turns out that a combination of metal structures and natural surroundings is possible. An example of this is Gardens by the Bay in Singapore [10]. Here, metal trees are the base for the climbing plants (Figure 14).

The metal tree structures themselves organize the walking habitat within the park with a variety of perceptual points. For this purpose, they are connected to each other by suspended passages at different levels. The height of the structures reaches 50 meters. The engineering and technical purpose of the structures is that they collect solar energy and dissipate excess heat from the greenhouses nearby.

![Fig 14 Gardens by the Bay in Singapore](image)

A good combination of greenery and metal structures can be seen in the atrium of Seoul City Hall (Figure 15). The atrium, to the height of which the wall of greenery rises, is the main...
entrance and open public space. The decision made symbolizes the openness and accessibility of the city management for the citizens [11,12].

A spectacular technique has been used for a museum in Switzerland, the Zentrum Paul Klee in Bern (Figure 16) [13]. Waves of metal structures create an exhibition space and gradually sink into the ground until they disappear completely. The facility is very harmoniously incorporated into the environment.

![Fig 16 Metal structures of the Zentrum Paul Klee](image)

### 4 Discussion

Four main techniques of using metal structures in solving the architectural image of the facility are shown. Metal in the architecture of today is not only characteristic for industrial facilities or engineering structures as it was before, today it is used in absolutely all types of architectural facilities. Plasticity of metal and modern technologies allowed to significantly diversify architectural images of facilities, organization of environment and spaces.

The use of color in metal structures allows to achieve even greater effect in the perception of architectural design.

### 5 Conclusion

The study revealed that metal structures significantly affect the architectural image of the object. The plastic of the material allows you to openly demonstrate the design and present it as the main architectural element. The use of metal structures in the architectural image is typical for all types of buildings and structures. Large volumes of the introduction of metal structures in modern architecture determine the importance of research and prospects for the development of architectural activity.

### References
