The Prospects of Application in Russia New Generation of Envelopes – Dynamic/Adaptive Facades

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Abstract Based on a review and analyses of new technologies and solutions of modern facade structures, a classification of a new generation of facades has been carried out. There are five main classes: “Bioclimatic” (or “green”) facades; “Energy” facades; facades - “Light concentrators”; "Scenic" (or "architectural") facades; "Dynamic" (or "adaptive") facades. Their distinctive features are given. The most typical examples of facades of various classes are considered. An assessment was made of the prospects for the use of a new generation facade in Russia.

1. Introduction

Windows are often called “the eyes of houses”, and the facades of buildings can be defined as “the face of the city”. Unfortunately, since the 1960s — since the start of the construction of the houses of the “mass series” (Khrushchevka) - the Soviet people have seen around, mostly gray, identical panel buildings. Frankly, even today - despite some exceptions - the Russian urban landscape is rather monotonous and dull. Psychologists, meanwhile, argue that many gray and uninteresting buildings have a very bad effect on a person - depriving him of initiative and hope.

Of course, the main function of the facades (external walling, envelopes) of buildings is protection from adverse climatic conditions. And the overwhelming part of the fences used in our country performs this function.

However, the explosive development of building and related technologies led to the emergence of a very large number of new facade solutions that were not possible earlier.

Modern architects use facades for creative display of rhythm, balance, proportions, experiments. It has become easier for them to ensure a balance between technology and aesthetics in their projects. Of course, it is necessary to take into account the engineering role of the facade (thermal protection and energy saving, natural lighting, ventilation, and sound insulation), but sometimes, following a beautiful design, our colleagues forget this.

Due to the huge variety of already executed projects of facades in many countries, we decided to introduce some classification of them, based on the main function embedded in them (as a rule, there have several such functions).

We offer five main classes of modern non-traditional facades:

1. "bioclimatic" (or "green") facades, in which the main idea is to protect the environment (use of plants [1], protection of buildings from smog [2], biogas production [3], rainwater use [4], etc.)
2. "energy" facades, in which the main function is to collect additional energy to ensure the operation of the building (photovoltaic panels of various modifications [5-10], the use of wind generators [5,6], the use of passive geothermal installations [10] and much more);
3. facades, which we called “light concentrators or hubs”, where the main function is the maximum and rational use of daylighting due to various modern innovative technical solutions [11-16];
4. “scenic” (or “architectural”) facades that are more intended to revitalize the urban environment through various optical or other solutions [17–22];
5. “dynamic” (or “adaptive”) facades, in which, by changing the appearance of the facade, the issues of microclimate regulation in the building’s premises are resolved (light conditions, local or general air conditioning and natural ventilation, many other tasks) [10, 23–31].

In this article we will give one or two examples of buildings, the facades of which we attributed to classes 1-4, and we will stop in more detail on the “dynamic” facades.

2. Bioclimatic facades
The most impressive passer-by is a vertical garden, made in accordance with the scheme developed by Patrick Blanc [32]. The garden consists of 3 main parts - a metal frame, PVC sheet with a thickness of 1 cm and a layer of artificial rot/felt using polyamide.

The frame with PVC mounted is installed on the wall with some relative, which provides additional heat and sound insulation of the premises, artificial felt is fastened to PVC. Its high capillarity ensures an even distribution of water. Plants are planted on this felt layer in the form of seeds, cuttings or already grown bushes - about thirty plants per square meter. Top watering and fertilizer automated. The weight of a vertical garden, including plants and a metal frame, is less than 30 kg per square meter. Thus, the vertical garden can be implemented on any wall, without restrictions on the size or height.

Of course, such an exotic (Fig. 1) in our climatic conditions is unlikely to be widely used - except in the Crimea and the Krasnodar Region. But in the southern regions of Europe such buildings appear more and more.

![Figure 1. Vertical garden (Spain, Madrid) [1].](image)

A much more interesting solution for Russian megalopolises characterized by high air pollution is a special facade that absorbs a significant amount of harmful impurities in the air [2].

Prosolve370e panels, designed by the German company Elegant Embellishments based on Alcoa technology created in 2011, were mounted on the building of the Torre de Especialidades Hospital
(Mexico City). The material contains titanium dioxide, which effectively purifies the air from toxins and other harmful substances.

![Figure 2. Hospital building Torre de Especialidades (Mexico City) [2].](image)

3. Energy facades
Buildings with such facades appear more and more with the further development of technology and increasing the efficiency of photovoltaic modules. Probably, this should be a separate review article.

Here we will give only one of the examples (perhaps, somewhat shocking) - the Museum of Contemporary Art Kunsthaus (Fig. 3) in the city of Graz (Austria) [7].

![Figure 3. Kunsthaus Museum of Contemporary Art (Graz, Austria) [7].](image)

The foundation of the building is a reinforced concrete structure, and the outer shell is acrylic panels with built-in photovoltaic elements, which allow producing enough energy to operate the museum. Of course, it is strange to see this in the center of the old city - but too many tourists, and - most importantly - the residents of the city like this building.
4. "Light Hubs (Concentrators)"
After a break in the late 1980s and 1990s, buildings began to appear in which the main idea of architects was to make the most of day light. This is due to both energy saving and its positive effect on the person. Among the many buildings we have chosen the newly built Art Museum of Ordos (Fig. 4) [14].

The surface of the building consists of polished curving metal louver panels that help the Ordos Museum to be resistant to the harsh desert climate and frequent sandstorms. The main light penetrates through the glass roof and spreads through the building using reflective walls, and the blinds provide natural ventilation as well.

![Art Museum of Ordos](image)

Figure 4. Art Museum of Ordos [14] (China).

5. “Stage” (“architectural”) facades
Such facades are used for various reasons - to diversify the urban environment, to provide the reporting of any information, and, as it seems to us - sometimes architects just pranks their hooliganism. But it is also allowed in boring urban spaces.

Among many examples, we chose the building of Eskenazi Hospital (Indianapolis, USA) [20].

An original approach based on the optical effect was used in this building: the illusion of mobility (in fact, a fixed one) of the facade is created during the movement of pedestrians or car trips. To achieve the desired effect, panels of different sizes were used, each of which was bent at a certain angle. The selected color scheme was fairly simple: one side of the panels was painted in golden yellow, and the other in dark blue. But thanks to the angles of inclination of the surfaces and the reflection of light, an illusion of various shades is created, which makes the spectrum of colors much more diverse (Fig. 5).
6. "Dynamic" ("adaptive") facades

We would like to dwell on this type of facades, since (in our opinion) it is the one that shows the greatest need and possibility in the near future to move from the ideology of “protecting the premises from environmental exposure” to the ideology of “using indoor environment”. Fortunately, more such projects and already implemented objects appear. Some of them are listed below.

In the project “The Gate Residence” [10] (Egypt) it is supposed to use a lot of new products. In particular - the so-called: windcatchers, vertically positioned devices that will distribute airflow in the desired direction; passive geothermal installations for cooling and/or heating the building; innovative solar photovoltaic cells that can convert the ultraviolet part of the solar radiation into electricity (they are installed instead of ordinary glass and placed on top of them); water-heating glass-metal pipes powered by solar energy; vertical wind turbines; vertical gardens. And this project looks very impressive (Fig. 6).

Built in 2014, the SDU Campus Kolding building (Kolding, Denmark) [30] is one of the most prominent examples of dynamic facades (Fig. 7).
Figure 7. SDU Campus Kolding building (Kolding, Denmark) [30].

About 1600 triangular perforated steel blinds are installed on the facade, so that they can regulate the flow of natural light into the premises, depending on its intensity. The entire system is equipped with sensors that continuously measure the ambient light and temperatures in the rooms and control the blinds with the help of small engines. When the shutters are closed, they are exactly along the facade. In the half-open state, they break the plane of the wall, giving the building additional expressiveness. Thus, the Kolding campus building is equipped with a sun protection system that adapts to specific climatic conditions.

The exhibition hall of Kiefer Technic is located in Steiermark (Austria) [27] (Fig. 8).

Figure 8. The building of the company Kiefer Technic (Steiermark, Austria) [27].
The operation of the dynamic facade is carried out using electronic controls inside the building, which can individually control each of the 54 engines inside the facade. This is a simple technology that does not include any type of regulation depending on the readings of the sensors of climatic conditions, but responds only to the use of input data from people in the building. The facade itself functions as a shading device, but gives users the ability to control the angle of the panel and the amount of light transmitted into the interior.

During the design and construction of the Al Bahr Towers in the UAE [23] (Fig. 9), the goal was set - to create in these extreme conditions a favorable indoor microclimate without large power consumption.

![Figure 9](image)

**Figure 9.** Fragment of the facade of the Al Bahr Tower in the UAE [23].

For the solution of the task, moving gratings were created. Kinetic elements are designed in such a way that they change their position depending on the time of day and the movement of the sun. This grid construction creates the effect of a double shell and as if envelops the building. The gigantic shielding facade consists of more than 1000 mobile elements and has a direct analogy with the facade of the Jean Nouvel Institute of Arabic Culture [15].

Strings of movable panels regulate the climate of office premises, and, at the same time, form geometric shapes that give the building additional artistic expression. As a prototype of the design, traditional Arabic Mashrabiya openwork lattices were used, letting in light but not allowing the air to get very hot inside the room.

The facades of the RMIT design school building (Melbourne, Australia) [24] are made of thousands of small sandblasted glass circles, each of which is attached to the central bar (fig.10). Depending on the humidity and temperature inside the building, these rods automatically rotate to facilitate (or block) the flow of air through the facade.
Currently, a lot of new technical solutions for building envelopes are being developed, which in the coming years will be "on the façades": the kinetic membrane "FLARE" [29], thermo-bimetallic louvered grilles [25], Saber membrane, working as an air conditioner with zero energy consumption [26], much more. In fact, we live in an era when not only the appearance of buildings, but also ideological approaches to their operation and maintaining the parameters of the indoor microclimate change dramatically in traditionally conservative construction.

Of course, the cost of such facades is higher (sometimes significantly higher!) than standard ones. And some of them will never pay off due to energy saving and other innovations incorporated in them (the authors of “stage” façades did not set themselves such a goal). The main thing in them is the creation of a comfortable and interesting environment and full-scale testing of technological innovations.

In our country, the appearance of new buildings (even typical ones) is also changing for the better, but, unfortunately, it is based - for the most part - on already long-thought-out and repeatedly worked out solutions at home and abroad. No, very good architects, engineers, and designers work in Russia. And purely visually, you can mark many new buildings. But there are practically no “pioneer” technological solutions.

This is connected, in our opinion, with the notion sitting in our subcortex - “the payback period of capital expenditures”. For most of the examples above, it exceeds all the ideas of investors and officials "about good and evil." That is why we are very skeptical about the possibilities and prospects for the emergence in Russia of truly breakthrough technologies in construction and, accordingly, a new generation of facades.

No, there are new ideas among our scientists - but all this so far, as they say, “done on the knee”, practically nothing comes to practical implementation.

Although, we really want to hope that we are wrong.
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