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TYPES OF ARCHITECTURAL GLASS TO IMPROVE THE ENERGY EFFICIENCY OF GLASS BUILDINGS

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ABSTRACT

The paper explores into key types of glass that are widely used in the construction of glass facades. The right combination of glass and glass structures at the design stage minimizes potential issues in operating the building, optimizes and improves its energy efficiency, as well as enhances visual and thermal comfort inside.

Key words: glass, glass facade, glazing systems, energy efficiency

INTRODUCTION

It is generally accepted that glass is a fragile material unable to withstand high forces. Despite this, it has found its broad application in modern architecture. Traditionally, glass has been used as the main element of window structures. It is also used for making of walls, roofs, and even floors. However, this material is becoming increasingly popular in decoration of facades. This aspect of the glass will be discussed in the paper.

The decision to apply glass in architecture came from multiple studies of its destruction processes. It resulted from the search for new technologies of strengthening, processing, and connection methods, with account for gravity and wind loads, energy efficiency, and other factors. Glass can take a variety of shapes, textures, colours and shades, and have different levels of transparency, thermal resistance, and mechanical durability. The wide range of glass properties allows builders to determine its optimal application in regions with different climate, social settings and needs. Furthermore, architects and designers can make use of the entire amplitude of features and advantages of glass to achieve impressive results in the search for aesthetic forms of glass buildings.

The glass allowed architects to fully express their fantasy in creating a unique image of the building, making extensive use of the properties of light and space (Figs 1 and 2). The nature of transparent glass is to let enough daylight into the room, create visual connections with the environment, and bring spatial infinity and fluidity to the room. No other material has such an instant visual effect. This material fully meets the desire of modern society for greater openness and frankness. In his book, "Cultures of Glass Architecture", the author noted that the presence or absence of glass in buildings will be the first sign of how safe a certain part of the city is (Elkadi, 2016).

Glass became popular in architecture for glazing of facades. The glass facade provides protection from external natural factors (wind, precipitation, temperature, and pressure); it maintains the optimal level of the building's thermal comfort, and, unlike the monolithic facade, it provides visual comfort and helps keep visual contact of the interior space with the outside (Sayed & Fikry, 2019).

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Fig. 1. Museum of The History of Polish Jews in Warsaw (ArchDaily, 2013)

Fig. 2. Hyatt Regency Business Hotel in Kyiv (OtpuskTime, 2022; Hyatt Corporation, 2022)

When designing a glass facade, it is important to choose the right combination of glass to optimize its benefits in terms of energy management, ensuring dynamic selectivity, thermal insulation and increased comfort, and minimizing potential problems such as condensation, etc. Glass used in construction must meet the requirements of thermal insulation, fire resistance, noise protection, safety of use, and anti-vandalism (Leśniak & Górka, 2020).

MATERIAL AND METHODS

The research methods used for writing this paper are based on the structural analysis and systematization of data from the scientific literature and publications, in paper and electronic formats, covering various aspects of using glass in modern architecture and the design of glass facades. They also include a comparative analysis of visual materials, which enables the selection of optimal options for glass facade systems using efficient glass types.

Structural analysis and data systematization helped identify key properties of glass required for high-quality operation of the glass building. They include the solidity of glass structure, its reliability, and energy efficiency. The obtained data allowed identifying five key glass types widely used in construction and architecture, such as sunscreen, thermal insulation, noise protection, self-cleaning, and tempered glass. Each type of glass has the appropriate set of biometric characteristics, which, when considered, will help to choose the optimal solution for the needs of a building.

Furthermore, the systematization of data from various scientific and practical sources contributed to highlighting the most optimal choices for energy-efficient facade solutions:

The study employed a number of graphical materials for comparative analysis, including illustrations of real objects with different types of glass, schemes of glass structures, and systems widely used in construction. The graphical material made it possible to better understand the technology of manufacturing certain types of glass, such as sunscreen, thermal insulation and self-cleaning glass types, as well as to see the difference in their practical application, functional concepts, and operation principles.

Thanks to the structural analysis, we compiled a list of the main types of glass designed to regulate the amount of solar energy inside the room.

RESULTS AND DISCUSSION

Contemporary research and technologies are aimed at maximizing the efficiency of glass in terms of light transmission, energy efficiency, and safety. The most important components that determine the bioclimatic needs of the glass facade are heating, air conditioning, and lighting.

Heat transfer through the building material is quantified by the heat transfer coefficient or U coefficient, which is measured in $W \cdot m^{-2} \cdot K^{-1}$. The U coefficient is the rate of heat loss per square meter with a temperature difference of one Kelvin or degree Celsius between the interior and exterior environments separated by glass. Heat losses are also quantified in terms of thermal resistance, or R-values ($R = 1/U$ or $R = m^2k/w$). The U coefficient is a key parameter that affects the heat transfer through glass (Sayed & Fikry, 2019).

The amount of solar radiation passing through the building's facade is a function of the available radiation, area, orientation, and heat transfer peculiarities of the open facade. Solar power through glass can reach 85% of incident radiation. The thermal characteristics of a glass building are determined by its shading coefficient. The value indicates how much the glass insulates (shades) the interior when direct sunlight hits a panel or a window. This value ranges from 1.00 to 0.00. The lower the ranking, the less solar heat goes through the glass, and the greater the shading capacity. The higher the light transmittance of the glass used, the less artificial lighting is required (Sayed & Fikry, 2019).

Modern technologies for the design of glass facades provide for the use of such types of glass as sunglass, thermal insulation glass, noise-proof glass, self-cleaning glass, and tempered glass.

Sunglass is the glass with a special oxide coating that transmits less solar heat compared to regular

glass. The amount of daylight entering the room is not affected by this coating. The interior of the building remains well-lit and cool, even in hot climates. The sun glass also reduces the glare of natural light and creates a comfortable indoor atmosphere. There can be a laminated, tempered, and tinted sun glass (Desai, 2018; Guardian Glass, 2022).

Thermal insulation (low-emission) glass is a glass with a special coating that has a high level of sunlight transmission. At the same time, it has a high heat transfer resistance. In other words, it is a material that reflects heat inside due to its low thermal transmittance. In this way, the heat losses of the room can be reduced (Okonnyy Tsentr, 2016).

The extent to which low-emission glass reduces heat loss is measured by the U-value: the lower the U-value, the better the thermal insulation. The window U-value is a measurement of the rate of heat loss that indicates how well your windows retain valuable heat. It is expressed in $W \cdot m^{-2} \cdot K^{-1}$ (Sayed & Fikry, 2019).

Noise-proof glass is a soundproof laminated glass made of polyvinyl butyral. Such a glass has a layer of film with a special noise-absorbing viscoplastic structure, which contributes to reduced sound transmission. Soundproof glass inhibits the penetration of sound waves in the critical frequency range of the glass, regardless of whether it is a single or double-chamber glass unit. In a single-chamber glass unit, an air sound insulation index exceeding 50 dB is achieved (Saint-Gobain Building Glass, 2022).

Self-cleaning glass is regular glass, with a special transparent coating applied to its outer surface, which consists of photo-catalytic mineral material with a double action. First, daylight, under the influence of ultraviolet rays, causes the destruction of any organic pollution, and then rainwater, flowing evenly down the surface of the glass, washes away split organic dirt and mineral residues (FasadInfo, 2017; Sayed & Fikry, 2019).

Glazing with the lowest possible U-value, which is safe, anti-reflective and self-cleaning glasses, is used in the Innovative Center for Nutritional Sciences of the Warsaw University of Life Sciences (SGGW) project (Fornalczyk, 2019).

Tempered glass is a regular sheet glass obtained by heating to a temperature of 650–680°C, followed by rapid smooth cooling with cold air, on both sides. As a result of such processing, residual mechanical compression stress is formed in the surface layers of glass, which results in its increased mechanical strength, thermal stability and safety in case of destruction. Such glass has a high impact viscosity, which is why, when broken, it shatters into a lot of small pieces with blunt edges that will not cause any serious injuries (Tempered glass, 2022).

The second most popular modern facade systems widely used in architecture and construction are glass structures (Mehbud, 2022). Despite a number of disadvantages, such as the weight of glass structures, the fragility of the material, and the high cost, this glass facade looks attractive aesthetically and grants a feeling of openness. At the same time, glass facade systems provide a high level of energy efficiency for the building. The use of a properly selected type of glass and an appropriate design scheme reduces heat losses and makes glazing of facades more economical.

Further, I propose to consider the most optimal options for energy-efficient facade solutions.

Free-Sustainable Closed Cavity Facade (MFree-S+) is a dynamic closed-cavity facade system developed by Permasteelisa Group. The system consists of unified glass panels, 6–8 inches deep, similar to a standard double-glazed unit (DGU). The window blinds are protected in the cavity, and the supply of dry clean air under low pressure prevents the condensation and dust (Fig. 3). This provides the thermal advantage of an external shading device without high maintenance costs (Whole Building Design Guide, 2018).

ClimaGuard® offers a wide range of glass products that are adaptable to every home, taking into account different climatic conditions, aesthetic preferences, privacy, or energy saving needs. The glass provides thermal insulation and sun protection, while having a high level of light transmission in double-pane or triple-pane glass units (Guardian Glass, 2022).

Transparent photovoltaic (PV) glass is a glass used in construction to generate electricity using sunlight. It is made of layers of heat-treated safety glass that transmits as much natural light as regular architectural glass, and provides for a high level of thermal and sound insulation. However, unlike conventional

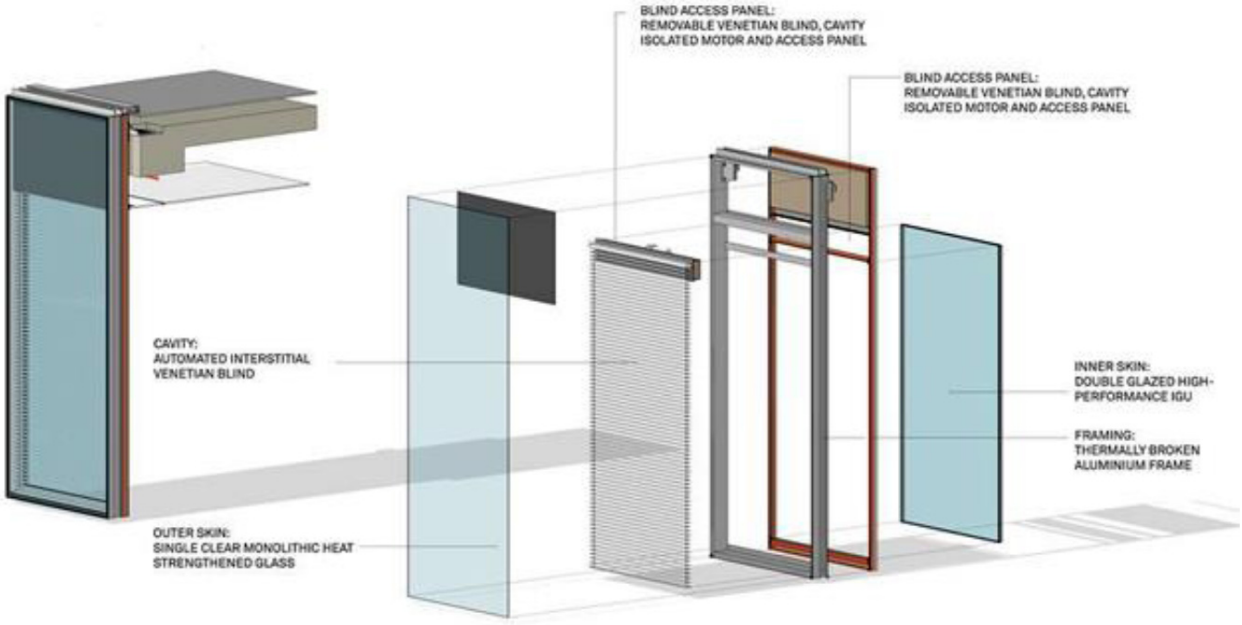

Fig. 3. Axonometric of facade components (Whole Building Design Guide, 2018)

glass, photovoltaic glass is able to generate free clean electricity from the sun, which allows buildings to significantly increase their energy efficiency, and reduce operational and maintenance costs (Onyx Solar Group LLC, 2022).

In line with energy efficiency, it should be noted that an important criterion for choosing glass structures in the construction of buildings is to prevent overheating of their interior space and ensure thermal comfort inside the premises. For this purpose, modern architecture uses facades with a system of double (or triple) glazing.

The best way to prevent solar radiation from exceeding the heating level of the room is to prevent the primary penetration of heat into the room. External shading devices are the most effective means of reducing the inflow of solar heat into a building with a high degree of glazing. In addition, by choosing a glass with an increased value of solar heat transfer, the absorption and reflection of heat can be adjusted to minimize its inflow inside the building.

This can be achieved by so-called spectrally selective glazing. Spectral selectivity means the ability of the glazing material to react differently to different wavelengths of solar energy. In other words, it can transmit visible light while rejecting unwanted invisible infrared heat. The characteristics of glass with a relatively high transmittance of visible light and a low solar heat coefficient highlight its capacity for selective glazing. Ideal spectral-selective glazing allows only that part of the solar energy that is useful for daylight to pass through (Boake, Harrison, Collins, Chatham & Lee, 2003).

Glass types with the ability to regulate the amount of solar energy inside the room are as follows:

- laminated glass – a transparent sheet of polymer clamped between two or more layers of glass to protect against ultraviolet rays and reduce noise vibration;
- insulating glass – glass layers are separated by a sealed dry air or gas space for thermal insulation and condensation control;
- coated glass – coated with a low-emission coating that reflects radiation;
- tinted glass – consists of minerals that stain the glass to absorb radiation;
- smart glazing is a unique solution in space management through instant opalescence control

(transparency and semi-transparency) and dynamic retro-projection of videos and images. It is an active glass that changes from semi-transparent to transparent under the influence of electric current, without changing the light transmission. The light transmission is practically the same in the transparent and semi-transparent states (Sayed & Fikry, 2019).

A new generation of sustainable glass facade solutions that delivers superior energy efficiency, enhanced living and working comfort with maximum natural daylight and multiple economic benefits. With the My Colour by Stratobel service from AGC (Asahi Glass Company), it is possible to create custom colours specifically tailored to the requirements of each project. Creating assemblies with anywhere from one to four coloured PVB interlayers offers thousands of possibilities (AGC Glass Europe, 2021).

Among the types of high-performance curtain walls, the Q-Air modular glass system of Trimo – one of Europe's leading companies – also stands out. The Q-Air is a unique unitized glass curtain wall system, which uses an innovative, multi-chamber insulating core that provides exceptional energy savings and living comfort. The Q-Air manages solar heat gain, thermal and light transmittance so perfectly that a full, panoramic transparent glazed area is achievable whilst fulfilling the building regulations for thermal insulation and total energy consumption of the building (Trimo d.o.o., 2017). This glass system presents energy saving reduction capabilities of 15–35 $kWh \cdot m^{-2}$. It is at least twice as high as that produced by traditional glass facades, indicating low values of thermal transmittance, according to technical standard EN ISO 12631:2012 (International Organization for Standardization [ISO], 2012), throughout the module, with $U_{cw} \geq 0.30\ W \cdot m^{-2} \cdot K^{-1}$, from a six-layered core (Mocerino, 2020).

Towards almost zero-energy buildings Qbiss Air is a unique single skin glass facade that offers all the performance and benefits of an active double skin facade. A premium unitized glass curtain wall system, Qbiss Air uses an innovative, multi-chamber insulating core, which delivers exceptional energy efficiency, living comfort, aesthetics and economic benefits. Qbiss Air is available in transparent, translucent and opaque glass options (Trimo d.o.o., 2015).

CONCLUSIONS

The correct choice of glass for glass facades should be made at the building's design stage. In the future, when operating the building, it will allow to regulate its heat energy, control ventilation, provide noise insulation, and improve visual comfort.

Improved coated architectural glass can optimize the daylight factor (DF), as well as help make the building more energy efficient by reducing the need for air conditioning, heating, and artificial lighting. These are significant factors that affect the comfort in the working or living environments of a glass house.

Glass selected for the construction of glass facades must meet all the technical requirements for solidity, reliability, energy efficiency, and have high-quality biometric characteristics. It should ensure optimum penetration of natural light inside the room, while preventing the glare on the working surfaces. Another important feature of high-quality glass is its ability to block ultraviolet rays to avoid overheating of the interior.

Glassmaking technologies keep evolving. The palette of glass units for construction is so wide that it will be difficult to choose the optimal solution without the appropriate research in the field. That is why it is important to follow the developments in systems and structures using different types of glass, as well as to analyse and compare their biometric properties.

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RODZAJE SZKŁA ARCHITEKTONICZNEGO STOSOWANE DO POPRAWY EFEKTYWNOŚCI ENERGETYCZNEJ BUDYNKÓW SZKLANYCH

STRESZCZENIE

W artykule omówiono główne rodzaje szkła znajdujące szerokie zastosowanie w budowie fasad szklanych. Prawidłowe połączenie szkła i konstrukcji szklanych na etapie projektowania minimalizuje potencjalne problemy eksploatacyjne budynku, optymalizuje i zwiększa jego efektywność energetyczną oraz promuje komfort wizualny i cieplny wewnątrz pomieszczenia.

Słowa kluczowe: szkło, fasada szklana, systemy szklenia, efektywność energetyczna