ISSN: 2641-2039
DOI: 10.33552/GJES.2020.05.000625
Global Journal of Engineering Sciences
Iris Publishers

Review Article

Tendencies and Possible Application Model of the Domed Skylights in the Construction Sector

Egidijus Ruzgys* and Vladislavas Kutut

Vilnius Gediminas Technical University, Faculty of Civil Engineering, Lithuania

***Corresponding author:** Egidijus Ruzgys, Vilnius Gediminas Technical University, Faculty of Civil Engineering, Lithuania.

Received Date: June 15, 2020

Published Date: July 01, 2020

Summary

Domed skylights are the most actively used kind of skylight constructions. This article analyzes the main possibilities of domed skylights application, the latest world trends and perspectives are systemized and highlighted. The priority indicators of the efficiency are determined, a model of the possible use of domed skylights with a graphical 2D drawing after the expert survey is developed. The three-layer dome skylight model interconnects a set of characteristics and a complex of integrated technological solutions. In summary, proposals submitted for the representatives of the construction sector, i.e., businesses, building developers, designers and architects, and skylight manufacturers.

Keywords: Domed skylights; Opportunity model; Construction sector; Skylight trends

Introduction

There is an increasing focus on natural light entering premises and saving energy resources in the modern construction sector, as well as in the development of sustainable buildings. Skylight solutions are rapidly gaining popularity to ensure comfortable and safe working conditions, increase the amount of daylight entering the premises, perform ventilation, or smoke extraction function.

It is noticeable that too small of a skylight area often installed and filled for construction costs saving, which does not allow it to achieve the maximum desired efficiency. This shortcoming has the consequence of insufficient ventilation of the premises, limited light access that is offset by artificial lighting and additional ventilation, that have to be ensured by consuming significantly more electricity resources. Domed skylights are one of the most actively used kinds of skylight constructions installed in buildings, the applicability of which is studied in the scientific literature and could be more widely applied in practice.

Historically, daylight adjustment technologies were widely used in industrial buildings even before industrialization began. Initially, the glazing was quite primitive, but various skylight solutions were rapidly applied with modern glazing systems and designs. Combined with automatic lighting control, hybrid systems, optimal lighting can be achieved these days, taking into account all environmental conditions [1].

Skylight is a window built into a roof to allow light, according to the Cambridge Dictionary [2]. The scientific literature highlights these advantages of skylight: daylight has a positive effect on health and human well-being, induces comfort, stimulates visual system and attention, improves environmental conditions and increases productivity, helps ensure safety in production processes. Daylight also allows students to focus and improve their academic results by 25 percent, supermarkets with skylights can increase their sales up to 40 percent and increase energy savings as well (electricity

and heat), employees prefer natural light working places [3]. The conclusion that the primary function of a skylight is to ensure light transmission can be made and the possibilities of application are the main focus of this part of the article.

The Characteristics Overview of Domed Skylights

Domed Skylights not only function as a light-transmitting structure but are also used for ventilation or smoke extraction. Skylights can be operated manually, electrically, or pneumatically. They are installed in commercial, public (non-residential), apartment buildings, and other buildings, and perform different functions. Depending on the intended purpose, the construction of skylights differs, i.e., shapes, installation, and materials used — e.g., acrylic, chamber polycarbonate, or double-glazed unit [4].

The following main features of the functions performed by skylights can be distinguished based on the theoretical study:

- Ventilation – skylights affect the natural ventilation of the premises, and efficiency indicators can be achieved depending on their design and layout. According to E. Juodis [5], natural ventilation is when hot air rises, and cold air descends affected by gravitational and dynamic forces. The World Health Organization research shows that proper ventilation improves the emotional and physical well-being of people. People spend more than 90 percent of their time indoors, so fresh air enhances brain function. Fresh air ventilation is essential in public buildings where the learning process and various large gatherings of people take place where a lot of carbon dioxide is produced, which is detrimental to brain activity. Facilities like that have strict requirements that skylight manufacturers and installers must take into account [6].

- Smoke extraction – one of the most common mistakes is improperly or no smoke extraction designed on the roof, which creates maintenance problems of the building [7]. The temperature of the smoke emitted during fire and combustion is higher than the ambient temperature, so the smoke spreads to colder places. The domed skylights result in more significant temperature differences, as well as air movement where the smoke travels outside through the skylight.

- The purpose of energy saving and lighting. In this case, the most important thing is to determine what shape the skylight should be to get the most natural light inside [8], and also it's opening direction/trajectory to achieve the maximum potentially natural light inside [9,10]. According to the Intergovernmental Panel on Climate Change, lighting energy consumption can be reduced by 75-90 percent [11].

- In case of evacuation systems must be designed for people to evacuate safely and avoid the harmful effects of smoke and to ensure the prevention of the potential risk [9]. The construction of a typical escape hatch consists of a base, a hinged top, and an opening mechanism. The emergency exit needs to be reliable so that it does not prevent you from leaving the premises.

The four primary functions of skylights should be considered in the context of the skylight installation proposal: the area of the room, the slope of the building roof, the intended purpose of the premises, the mounting height of the skylight, and other design requirements.

The Latest Trends and Prospects for Skylights in The Global Construction Market

Innovation in the real estate and construction sector also means changes in the skylight market. Growing requirements for building design solutions and maintenance, energy efficiency class, thermal efficiency, determine the need for additional skylight functionality. Therefore, it is clear that skylight manufacturers are investing in technological improvements through testing and introduction of new solutions.

According to global 2020-2025 forecasts, the rapid growth of the skylight market is expected, driven by the following key trends:

Increasing demand for daylight

Technological innovations will stimulate industry development, such as the widespread use of power-operated skylights that can track air quality, humidity, and temperature and automatically estimate when to open when fresh air is needed without any additional remote-control action. The segment of acrylic skylights should grow steadily, as this type of skylight is durable and resistant to environmental influences and shocks. Desire to reduce energy consumption should lead to daylight solutions in the commercial sector, as government regulation in this area is tightening, and requirements for buildings and their maintenance and renovation are increasing. The highest demand most likely is in North American and European regions, with 75 percent of the market share in 2019.

Growing importance of sustainability and reduction of the environmental impact

The modern construction sector is focused primarily on the construction of sustainable buildings and the pursuit of reducing environmental impact. In this context, the primary light source must be natural light, as it is a freely extractable form of energy. If the natural lighting system is well-designed and installed, it reduces electricity consumption [3].

Reduction of energy consumption in commercial and residential buildings

It is the European Union Directive 2010/31 / EU statutory for the energy performance of all new buildings must be zero by December the 31st 2020. Domed skylights are part of this trend and are, therefore, one of the most popular lighting, heat, and ventilation solutions for the A ++ class buildings [11]. The construction of new buildings and the popularity of green buildings in economically developed countries will expand the possibilities of adapting a skylight to achieve energy efficiency. The use of daylight devices is growing due to their efficient way of meeting sustainability stan-

dards. Skylight integrated photovoltaic systems are one of the most potential technologies due to their ability to simultaneously generate renewable solar energy, reduce heating or cooling costs.

Competition in the skylight market will remain fierce, with product design, quality, reliability, ancillary services, and price being the main criteria for customer choice manufacturers will need to invest in product development and innovations. Smart skylight technologies will contribute to the concept of smart homes - remote sensor-based control [12], automatically identified sunlight, humidity, temperature, and carbon dioxide levels to regulate skylight performance.

The popularity and the growing interest of green buildings are closely linked to the widespread use of skylight technologies that help achieve energy efficiency and encourage the entry of natural light into premises [13]. Home operators are striving to implement the principles of sustainable construction today more than ever. More and more smart devices are included in the "Energy Star" program in the USA, which means that products meet energy-saving standards and are marked with a star. Labeling can be applied to products for buildings, including skylights [14]. Representatives of the European Patent Office state solar energy to be a widely used method for buildings with renewable energy sources. Photovoltaic elements are assembled not only on roofs but also on facades and even in translucent modules such as windows and skylights [15,16].

The most commonly integrated solutions that complement skylights, reflecting the trends mentioned above and perspectives in the evolving, dynamic construction sector, are:

Solar panels: Universal skylights are equipped with solar panels to improve energy efficiency. They are also combined with air sensors that allow the skylight to close automatically when it starts to rain [17].

Dynamic shades: The added functionality and innovation of domed skylights are built-in blinds with a Bluetooth device that allows you to control the screens remotely so that you can adjust and stop the shades at any time. The mechanism can be set to respond automatically to the light intensity with a remote control or a smartphone app [18].

Sunlight controller: Civil engineering is using a device to ensure the absorption of solar energy resources. Depending on the location, longitude and latitude data are entered into the mechanism to control the skylights. The result is effective regulation controlling the movement by daylight time, indoor temperature [19].

Reviewing the most striking trends, we can state that the skylight market is undergoing rapid changes, driven by intense competition and growing consumers (clients) needs for new natural light access solutions. Leading to the continuous improvement of structural and skylight materials, the implementation of innovations to ensure the best possible conditions and offer the most efficient solutions.

The popularity of smart homes, green buildings, environmental sustainability ideas, enhanced requirements for the energy efficiency class of buildings will only increase the applicability of skylights in modern construction, and advanced energy-saving methods, the higher the natural light will become more relevant.

Expert Evaluation of the Dome Skylight Criteria

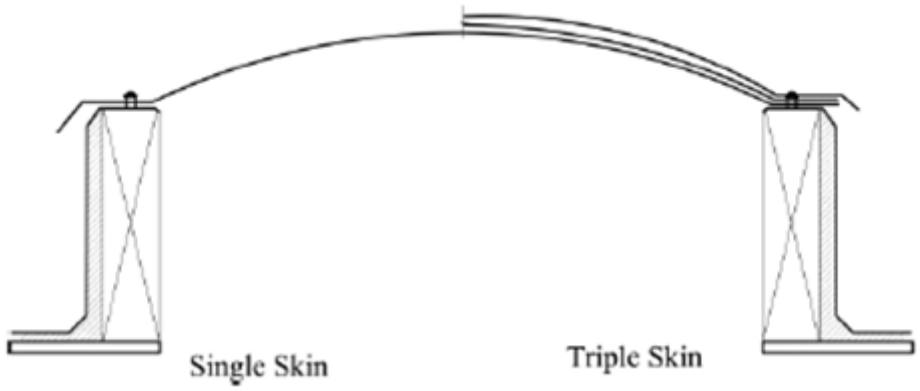

Figure 1: The cross-section of the domed skylight [20].

From a technological point of view, the dome of domed skylights can consist of one or several layers. The acrylic fiber material is selected in this case. The cross-section of the domed skylight (see Figure 1) shows that the skylight can be of several layers (matte, clear), each helps to create the desired effect - to increase or decrease (control) light transmission [20].

- The single-layer dome skylight is made of clear acrylic fiber. Typically, a single-layer dome is installed in industrial buildings and warehouses, suitable for unheated and open spaces. This type of dome has a high light transmittance (92 percent), but the

thermal insulation properties are weaker (5.6 W/m^{2}K). Sound insulation characteristics are lower compared to multilayer domes. The enclosure of this type of dome meets the requirements of the European directive and standards for the energy class. The shock resistance is equal to SB 800 J. In terms of climatic conditions resistance, and the single-layer dome withstands substantial temperature differences and precipitation well enough. The average price of a single-layer dome on the market is 166 Eur net of VAT.

- The two-layer skylight dome is made of two layers of clear acrylic fiber with an air gap between the layers, which strengthens the thermal insulation characteristics (3 W/m^{2}K) and sound insulation (24 dB). It has an excellent light transmission (84 percent). This dome is used for heated premises, commercial buildings, workshops, shopping, and logistics centers. The enclosure characteristics also meet the requirements of the standards, and resistance meets the SB 800 J. The double-layer dome withstands the effects of climatic conditions well. The average price of a two-layer dome on the market is 214 Eur net of VAT, which is slightly higher because more material is used in the production process.

- The three-layer skylight dome is made of three layers of acrylic fiber and has two air gaps. The transmission characteristics of this dome are lower (78 percent), but this technology has excellent thermal insulation characteristics (1.9 W/m^{2}K) and high sound insulation (25 dB). It meets the requirements for tightness and is also widely used in buildings of high energy efficiency class. This product is of high resistance, which corresponds to SB 1200 J. The three-layer dome has the highest strength to climatic conditions. The average price of a three-layer dome on the market is 270 Eur net of VAT and is the highest because of the high production process cost

- Different layered domed skylight distinguishes seven main evaluation criteria (see Table 1):

- Light transmission is measured in a percentage and evaluated by the maximum amount of daylight coming through the skylight layer. Conductivity characteristics of the material, position, and characteristics of the building, and the intensity of the sun affects the light transmission. Transparent polymeric, a glossy acrylic layer that has ultraviolet protection, is being measured as a glass substitute, known as the abbreviation PMMA in technical literature. The acrylic sheet is one of the most used materials for skylight systems. Manufacturers choose this material mainly for transparency, durability, weather resistance, lightness, and impact resistance reasons [4].

- Thermal conductivity is a type of heat exchange when the heat is transferred from the warmer parts of the body to the colder ones until the temperature equals. The smaller energy particles receive heat transferred from the higher energy particles. In general, this indicator is a material layer characteristic that conducts the heat. This means that a material with a lower thermal conductivity/transfer coefficient λ (measured by W/m^{2}K) has better insulating characteristics. Thermal conductivity is very closely related to the skylights ventilation when the ability to retain rather than transfer heat to the outside is more valued.

- Acoustic insulation are measures used to reduce sound and avoid noise. This parameter is called the sound level and measured by dB. The Construction Technical Regulation (CTR) specifies the sound insulation classes to ensure acoustic comfort, by labeling the sound insulation classes. The three selected alternatives show the difference of sound insulation of the layer of each type of dome [21].

- Enclosure a characteristic of the airtightness, which is very important in buildings, because it helps to maintain quality, and the maintenance of the object. The enclosure of buildings in Lithuania is regulated by the standard LST EN ISO 9972:2015 "Thermal characteristics of buildings. Determination of air permeability of buildings. Fan pressure difference method" [22]. This criterion depends on the class of the building, and accredited building enclosure testing laboratories can test the enclosure [11].

- Impact resistance is an impact compliance test of a high force or shock by a large soft body. Different values of application of the load are highlighted following the European Standard 1873:2005 (E), that is used in the assessment. In the case of the analysis, the single-layer and two-layer domes pass the 800 J test, and the three-layer dome is tested at 1200 J.

- Climatic change resistance is an evaluation of the weather conditions regarding the temperature, as well as heavy rain, hail, rainstorm, snow, or strong winds affecting the building through the skylights. The construction of the skylight and the dome layer must be climatic change resistance so that their heavily exposed fibers do not change their original factory technological characteristics.

- Price a monetary value of skylight established when sold to a customer. The market price is determined by supply and demand, in the present case, the price is a net of VAT, and the currency is the euro. The customer price of the skylight is calculated, having regard to the cost of production, the technology, and the raw materials and fabrics used. The average market value of the products is presented [23].

An expert group is set up to evaluate and compare alternatives. The evaluation involved seven skylights specialists (professionals in their field) - project and production managers, architects, whose projects include skylight implementation solutions. Experts completed a survey questionnaire and evaluated the indicators based on the characteristics of each layer of dome. According to experts, the significance of indicators is determined on a scale from 1 to 7, where 1 - not important at all, 2 – less significant, 3 - moderately important, 4 - fairly important, 5 - important, 6 - very important and 7 - critical. The expert judgment method is used to assign scores to performance indicators (see Table 2).

Table 1: List of alternatives for domed skylight layers and their characteristics (compiled by the author).

Domed skylights indicators	Unit	Alternatives		
		1-layer dome	2-layer dome	3-layer dome
Light transmission	%	92	84	78
Thermal conductivity	W/m2K	5,6	3	1,9
Acoustic insulation	dB	22	24	25
Enclosure	points	10	10	10
Impact resistance	J	800	800	1200
Climate change resistance	points	8	9	10
Price	Eur	166	214	270

Table 2: Expert-assessed criteria for domed skylight layers (compiled by the author).

Dome Skylight Criteria							
Experts	Light Transmission	Thermal Conductivity	Acoustic Insulation	Enclosure	Impact Resistance	Climatic Change Resistance	Price
Expert No. 1	6	5	2	7	3	1	4
Expert No. 2	7	5	3	6	2	1	4
Expert No. 3	6	5	3	7	1	2	5
Expert No. 4	6	5	1	7	3	2	4
Expert No. 5	5	6	2	7	3	1	4
Expert No. 6	7	5	3	6	2	1	4
Expert No. 7	6	4	3	7	1	3	5
Sum of evaluations $t_j = \sum_{k=1}^{r=8} t_{jk}$	43	35	17	47	15	11	30
The average value of the criteria $t_j = \frac{\sum_{k=1}^{r=8} t_{jk}}{r}$	6,14	5,00	2,43	6,71	2,14	1,57	4,29
The criteria ranking	2	3	5	1	6	7	4
Significance of the criteria $q_j = \frac{t_j}{\sum_{j=1}^{n=8} t_j}$	0,22	0,18	0,09	0,24	0,08	0,06	0,15

Once the experts have assessed the indicators, it is important to determine whether their views are consistent. The reliability of this assessment will be verified by calculating the concordance coefficient according to the following formula:

$$W = \frac{12.S}{r^2(n^3 - n)} \quad (1)$$

As the calculated value of the concordance coefficient W = 0,89 is close to one, this indicates that the opinions of the experts do not contradict each other.

Regarding the results of the significance of the criteria, a priority series of indicators for evaluating the efficiency of domed skylights is presented (see Figure 2).

The result analysis shows the enclosure to be the most important criteria for the dome layer of the skylight. It is noted that the tightness characteristics are especially relevant in all types of buildings. Experts pointed out that this is often one of the biggest problems encountered in the installation of skylight systems, so this indicator has been identified as a priority. Besides, tightness helps to ensure and maintain the quality characteristics of the building.

Light transmission is the second most important criteria - it reflects the essence of skylights and is a relevant parameter when choosing a skylight construction. It is important to note that light transmission does not only depend on the characteristics of acrylic fiber but is exposed to changing environmental conditions.

The third criteria identified by the group of experts is thermal conductivity. Depending on the context, this indicator can be interpreted in two ways. It essential to point out the ability of the skylight layer to retain rather than transfer heat to the outside. This feature was chosen because it is more relevant for skylight customers of the Lithuanian region climatic conditions. Price, acoustic insulation, impact resistance, and climatic change resistance indicators rank after the first highlighted ones.

Incorporation Options Model for Domed skylights

After the result analysis of theoretical and empirical research, incorporation of options model for domed skylights was developed, which is intended for construction business entities that manufacture skylight construction systems and for the interested building developers, designers, and architects.

The model for the manufacture and installation of skylights defines the main efficiency characteristics of domed skylights, which emerged during the expert and multi-criteria evaluation (see Figure 3). The best skylight dome layer alternative is the research identified priority characteristics of the skylight product, their significance, and the most rational choices. Graphic two-dimensional (2D) sunroof model is presented as the result of the latest trends and prospects of skylight us. The use of priority skylight design options by integrating technological solutions allows to offer an improved three-layer domed skylight.

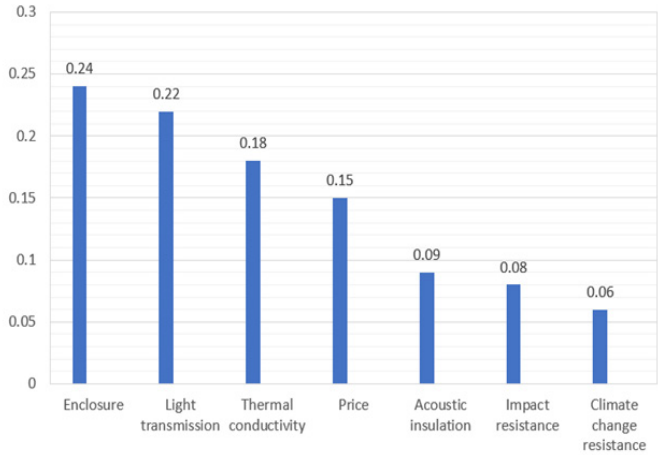

Figure 2: Priority order of evaluation indicators of dome layers (compiled by the author).

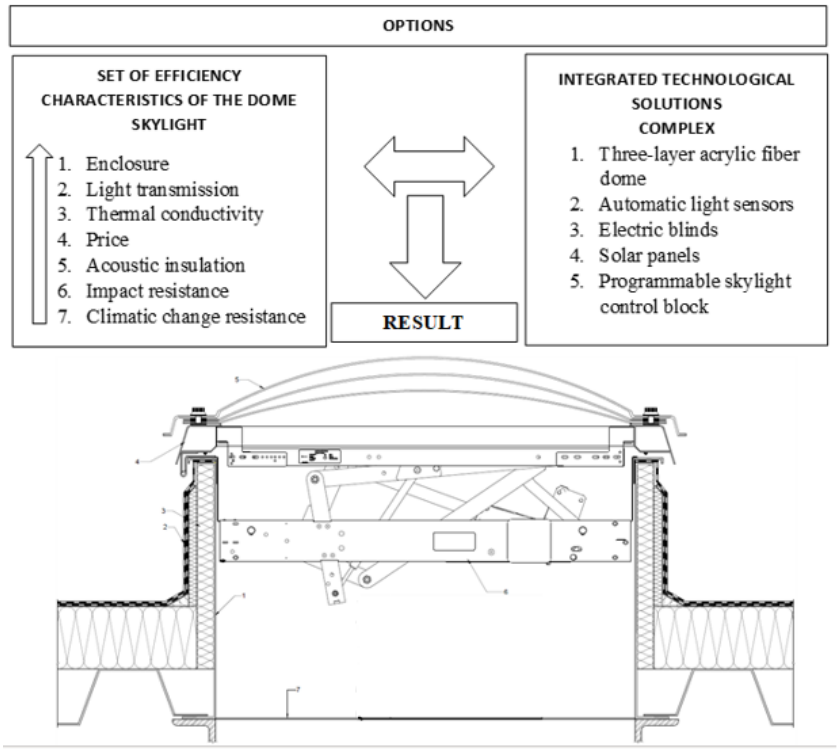

Figure 3: 1. Skylight base; 2. Roofing; 3. Insulation material; 4. Skylight frame; 5. Three-layer acrylic dome with a photovoltaic system; 6. Skylight electric drives; 7. Electric binds.

The first part of the skylight options model consists of a set of efficiency characteristics composed of seven key indicators of skylight dome evaluation. According to the experts, the criteria are prioritized. The essential factor in choosing the skylight is the enclosure. Since the best alternative of the domed skylight is the three-layer acrylic fiber technology, we can affirm the airtightness characteristics to be reliable.

Light transmission characteristics meet the norms, and the intensity can be adjusted with additional functions, in which case two options are recommended: a particular material-coated top layer of acrylic, which can darken in the presence of intense sunlight or, conversely, lighten. Another option is electrically operated blinds that can be adjusted with the sunroof control panel or programmed to work automatically according to set parameters.

Thermal conductivity is the third desired feature of construction market experts. One of the most important tasks is to ensure the energy efficiency of buildings to minimize heat loss. Therefore, in this domed skylight model, special attention is paid to the upper part of the structure, which consists of a three-layer acrylic dome of the highest thermal insulation characteristics.

Regarding the practice of foreign countries and modern trends, a complex of technological solutions integrated into the skylight is proposed consisting of the following components:

- The three-layer acrylic fiber dome is the top part of the construction. This material not only ensures light transmission but also helps to retain heat. Besides, this type of dome has 25 dB sound insulation characteristics.
- Automatic light sensors make it possible to control the process of light entering the premises remotely by receiving a signal from programmed sensors. Typically, the light sensor is mounted on the ceiling indoors and is connected to the skylight mechanism responding according to the situation. The technology is applicable to reduce the amount of artificial light in the premises because the principle of operation of sensors allows achieving the light balance, i. e. to control the intensity of natural light and luminaires and to reduce electricity consumption.
- Electric blinds are built in blinds at the base of the skylight to restrict the flow of light into the premises or to dim them to the desired level. The blinds can also be wide opened when there is no need to limit the light source. The blinds can be controlled remotely using a control panel or a special app.
- Solar panels. More skylights are being combined on the roof with solar panels. Solar panels generate electricity that can also be used to operate automatic skylight mechanisms. This technological combination is especially common for high-energy class buildings, followers of modern, sustainable construction, dominated by natural light and renewable electricity sources in their projects.
- The programmable sunroof control unit is an automatic control unit that can control the electric drive and opening the skylight. Single skylight or segment installed can be operated together or individually, depending on the actions programmed. Regardless of the operation of this control unit system, the skylights open automatically in an emergency. On the screen in modern units, it is possible to instantly assess the condition of the skylight and the environment conditions according to the set parameters (e.g., room temperature, light intensity, blinds open/closed) and make appropriate decisions.

Domed skylight becomes intuitive when these technological solutions are integrated, as it can adapt to change and dynamic environmental conditions.

The two-dimensional drawing shows a three-layer acrylic dome skylight model illustrating application possibilities. Its purpose is to supplement and graphically visualize the described characteristics and technological elements. The construction of the skylight consists of:

1. Skylight base;
2. Roofing;
3. Insulation material;
4. Skylight frame;
5. Three-layer acrylic dome with a photovoltaic system;
6. Skylight electric drives;
7. Electric blinds.

Usually, the base of the skylight is of a galvanized metal sheet. The base is insulated with thermal insulation materials (rock wool, polyurethane - PIR, or foam - EPS) to ensure heat retention characteristics. Roofing is where a roof waterproofing material is applied to the base of the insulated skylight, which helps to ensure enclosure. A polyvinyl chloride (PVC) frame of the enclosure strengthening characteristics is placed on the upper part of the skylight base. An electric skylight drive is attached to said frame, the mechanism of which allows to control the skylight with a remote control or remotely, using a mobile app.

The frame of the skylight is installed with a rubber gasket, and the acrylic three-layer dome is affixed to the frame. Electric blinds are installed at the bottom of the sunroof base and are controlled using electricity generated by solar panels. The light sensor is not included in the drawing as it is mounted on the ceiling next to the skylight. The light-intensity sensor transmits signals to the control unit, which adjusts the sunroof for more or less natural light.

Besides, precipitation and wind sensors responding to climatic changing conditions can be installed to help the skylight to adapt, e.g., the skylight is closed during strong winds and heavy rainfall. The proposed three-layer domed skylight construction is quite uni-

versal. Still, when installed, it is essential to take into account the technical requirements of the project, location and purpose of the building, and the defined standards for sound insulation, impact resistance, thermal conductivity.

The recommended skylight model is most applicable in educational institutions, commercial and industrial buildings, i.e., supermarket, factories, warehouses, workshops, schools. A well-known and reliable dome construction is offered, with additional elements, taking into account today's most significant indicators of skylight evaluation, the need, relevance, and prospects of the construction industry.

The design of the intuitive three-layer skylight would attract attention among the representatives of the sustainable buildings who work with high-energy class projects. This trend will become more pronounced in 2021, as new building permits will be issued only for structures complying with A++ energy class. Consistent follow – up of the innovations of the skylight industry will allow us to meet the expectations of the participants of the construction sector, offering a skylight model that adapts to the environmental conditions, and will be equipped with intelligent technological solutions.

Conclusion

Summarizing the overview of the characteristics of domed skylights, the trends of use, the experts evaluated efficiency criteria, the following conclusions can be drawn:

- The possibilities of using skylights are characterized by their purpose: 1) ventilation, which ensures natural ventilation and air circulation; 2) smoke extraction, that helps to ensure compliance with fire safety requirements; 3) energy-saving and lighting; 4) building evacuation;

- Recent trends review of skylight use (in 2019, European and US markets ranked 75 percent) reveals a strong correlation between changes in construction and the skylight sector. Global forecasts for 2020-2025 show that the skylight market will multiply, the main determinants of which will be the growing demand for lighting solutions, the increasing idea of a sustainable environment, and the desire to reduce electricity consumption;

- Technologies for the high energy efficiency skylights, such as photovoltaic systems, opening and darkening mechanisms using solar panels' energy generated, temperature, wind, precipitation and light sensors automatic remote control, will be dominating in new green building constructions;

- Tightness, light transmission, and thermal conductivity as the skylight assessment priority indicator were determined based on the results of the expert survey.

Incorporation options model for domed skylights is recommended combining main characteristics of the assessment of the efficiency of skylights and integrated technological solutions. A graphical two-dimensional skylight model illustrating the recommended design has been developed to visualize the model.

Incorporation options model for domed skylights is recommended for the representatives of the construction sector, having regard to new integrated technology solutions and efficiency criteria. Skylight manufacturers and installers are encouraged to regularly update their knowledge and put it into practice by improving skylight designs, focusing on enclosure and energy class.

Acknowledgment

None.

Conflict of Interest

No conflict of interest.

References

1. Mc Cowan B, Birleanu D, Hildt N (2003) Daylighting Application and Effectiveness in Industrial Facilities.
2. Meaning of skylight in English. Cambridge Dictionary. (2020).
3. (2017) Daylighting by rooflights. Recommendations for design to maximize the benefit of rooflights in buildings.
4. Al-Obaidi KM, Ismail M, Malek A, Rahman A (2014) A study of the impact of environmental loads that penetrate a passive skylight roofing system in Malaysian buildings. Frontiers of Architectural Research 3(2): 178-191.
5. Juodis E (1998) Vėdinimas. Vilnius: Technika.
6. Du T, Chen J (2017) Skylight Optimization Design Based on the Interior Ventilation in the Office Building in Cold Region. Mediterranean Green Buildings & Renewable Energy, 691-699.
7. Kiaulakis A, Vilutienė T, Migilinskas D (2018) Statinio informacinio modeliavimo taikymo efektyvumo vertinimo kriterijai ir atvejo analizė.
8. Luca F, Kurnicki J, Simson R (2016) Energy and daylighting performance design of skylights and clerestories in a large hall retail building.
9. Fu Q, Peng B, Chen L (2014) Performance-based Smoke Prevention and Extraction System Design for an Exhibition Center.Procedia Engineering, Volume 71: 544-551.
10. Acosta I, Navarro J, Sendra JJ (2013) Daylighting design with lightscoop skylights: Towards an optimization of shape under overcast sky conditions. Energy and Buildings 60: 232-238.
11. (2020) Energy efficiency.
12. (2020) Global Skylight Market Outlook and Forecast 2020-2025 - Growth of Green Building Activities, Incorporation of BIPV Skylights.
13. (2019) New Trends in Skylights.
14. Lee S, Soh J (2018) A Study on Mid- to Long-Term Development Directions for Energy Efficiency Management in the Age of the Fourth Industrial Revolution (1/3).
15. (2020) Building the future: Four innovation trends that are shaping green construction.
16. (2020) Sustainable technologies: Building a better future with "green" patents.
17. (2018) Trend Alert - Skylights Are Making a Comeback.
18. Khadke SK (2014) Home Appliances Control System Based On Android Smartphone. Journal of Electronics and Communication Engineering (IOSR-JECE) 9(3): 67-72.

19. Chen X (2018) The Exploration of Construction Technology and Innovation in Civil Engineering Construction.

20. Iqbal N (2015) Incorporation of useful daylight in luminous environment of RMG factories by effective use of skylights in context of Dhaka.

21. (2013) On the approval of the technical construction regulation STR 2.01.07: 2003 "Protection of the interior and exterior environment of buildings against noise".

22. (2015) Lithuanian Standardization Department. Thermal performance of buildings.

23. (2020) Energy Efficient Building Design.