Using of Solar Daylighting System to Decrease Electrical Energy Consumption in Chelyabinsk, Russia

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Abstract

The article gives information about construction of solar lightways, main structural elements and their purposes. It shows possibility of installation of solar daylighting systems in Chelyabinsk, Russia. Information about illumination in Chelyabinsk was given as well.

1. Introduction

Nowadays, reducing consumption of fossil fuels, heightening the effectiveness of using energy, energy saving, implementing of renewable energy sources are the most significant issues for almost every country in the world, including Russia. Some of the widespread methods of solving above mentioned issues are: operating hours of electrical equipment decrease, adoption of scientific achievements and new technologies that allows consuming less energy.

2. General information about daylighting systems

In general, residential users consume about 10-20% of total amount of electrical energy consumption on lighting in Russia. To create energy-efficient lighting in dwellings, office buildings, factories and special constructions, it was suggested to use solar daylighting systems. Operating principle of those systems is based on concentrating, reflecting, refracting and transmitting of light from the outside of the building to the inside consumer. We suppose that using of solar daylighting systems will show more effectiveness in northern latitudes due to the fact this lighting systems let the beams of solar light to pass from the upper position of a building, when windows allows to get light only from one side of a building. Solar lightways give more amount of light than usual skylight in the roof. As well it is known that the 10-inch solar tube produces up to 3750 lumens and the 14-inch solar tube produces up to 6500 lumens [1].

Premises that have no technical feasibility to have windows (for example, inner rooms, hallways, basements, subways, underground walkways, tunnels, etc.), rooms remoted from the roof and having insufficient illumination from its windows, high-cube premises (station houses, airports, storehouses), premises with explosive risk (in some cases, because solar tubes produce less heat than usual bulbs) are the most suitable for using daylighting systems.

Main advantages of using those systems as a source of light are reducing electricity costs (in daytime), high color-reproduction quality (in comparison with artificial lights), simplicity of using, and salutiferous effect on human health.

3. Information about illumination in Chelyabinsk, Russia

We conducted research in field of solar energy potential, solar irradiation estimate (per hour on a mean day for every moth in a year) possible energy produce by the certain photovoltaic module (PVM) in Chelyabinsk, Russia; results are given in [2]. Illumination in Chelyabinsk for a mean sunny day of July (I7), August (I8), September (I9), October (I10), November (I11) and December (I8) was determined experimentally. Results are included in table 1. Position of Chelyabinsk is 55°09′17″N 61°22′33″E, it is situated in South Ural Mountain Range. Average annual solar radiation intensity is 1200 kW/m² in this area. We obtain results that show opportunity of implementing PVM and solar daylighting systems in Chelyabinsk.

Table 1 - Illumination in Chelyabinsk for a mean sunny day

Time	5:00	6:00	7:00	8:00	9:00	10:00
I7, klx	0,04	5,8	14,7	23,1	34,4	58,7
I8, klx	-	0,06	0,14	12,8	21,6	38,2
I9, klx	-	-	0,06	5,76	18,6	36,4
I10, klx	-	-	-	1,1	10,2	20,3
I11, klx	-	-	-	-	0,02	0,3

Table 1 (continuation) - Illumination in Chelyabinsk for a mean sunny day

Time	11:00	12:00	13:00	14:00	15:00	16:00
I7, klx	73	80,7	89,6	86	91,8	76,5
I8, klx	56,8	77,3	76,7	70,4	64,5	56,2
I9, klx	52,4	64,2	73,1	71,7	63,8	54,2
I10, klx	29,5	48,3	45,7	37,4	32,6	27,3
I11, klx	6,8	17,4	21,2	18,4	9,2	5,3

Table 1 (continuation) - Illumination in Chelyabinsk for a mean sunny day

Time	17:00	18:00	19:00	20:00	21:00	22:00
I7, klx	65	44,3	29,4	17,5	6,1	0,9
I8, klx	46,7	36,7	20,5	8,8	0,96	-
I9, klx	35,6	25,5	12,3	0,7	-	-
I10, klx	15,8	6,8	0,9	-	-	-
I11, klx	0,6	0,06	-	-	-	-

4. Calculation of energy consumption by usual lighting system

Average energy consumption by lighting system of one-storeyed house if using compact fluorescent lamp (CFL) is about 1000 kW·h per year; if using light-emitting-diode lamp (LEDL) is about 550 kW·h per year. Total electrical energy consumption is approximately 9000 kW·h per year.

Average energy consumption by lighting system of stairwells in multistory building if using incandescent electric lamps (60 W each) is about 1750 kW·h per year; if using light-emitting-diode lamp (LEDL) is about 320 kW·h per year. Total electrical energy consumption is approximately 9000 kW·h per year.

So, if we need to get illumination of about 300 lx in a room of one-storey dwelling, it is possible to use solar lightways in daytime, so, for example, it would decrease energy consumption by lighting system up to 438 kW·h per year (from 1000 kW·h per year). If we are considering house, that has its own energy produce (from PVM, wind turbines, etc.) we would also have benefits while using solar tubes: we need less energy to consume, so we can have less amount of storage batteries, bigger surplus of energy, decrease of current load (it prolongs operating life of wires).

5. Design and key elements of solar lightway

Design of solar lightway must provide safety while using it (absence of fire outbreaks and overheating, it should contain no fragile parts), effectiveness,

appropriate illumination intensity for a human, protection against environmental exposure. Key elements of solar lightway are shown on fig.1.

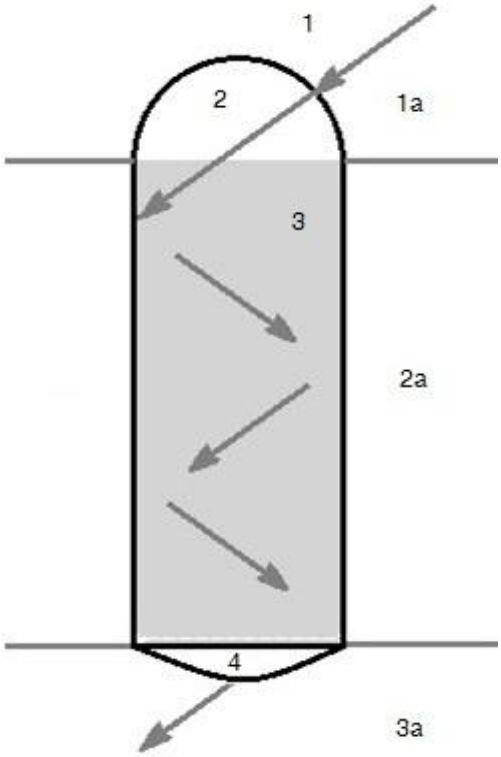

Fig.1 Design of solar lightway: 1 – solar beam; 2 – receiving part placed outside the building (1a); 3 – tube (2a) with reflecting coating for passing solar light; 4 – device for diffusing light in the ceiling of the room, which is receiving the light.

Receiving part (2) can be a hemispheric lens, or be flat and made of transparent polymer or special glued glass. Matter, receiving part is made of, have to provide bump resistance, luminous transmittance, concentrate solar beams (if needed), minimal reverberation of rays from its surface, UV protection.

Solar tubes can be sited on roof, go through the attic, inner rooms together with electrical and heating networks and plumb of the building.

The inequalities in a surface of solar beams transmitting tube are needed to provide safety of solar lightways usage. They are going to prevent possible overheating inside of the tube (for example, when sun sets or rises, its beams go to the surface angularly and it may cause its concentrating on some points of the tube's surface and come to overheating or fire of these points. Parallel course of beams is preferable in solar tube because it allows to prevent overheating, possible fire outbreak and to receive even light beam in the room. To receive parallel light beam we can use Fresnel lens as a receiving part.

Tube can be made of soft material (using polymer material; sheeting, etc.) or of solid material that keeps rigid die (metal, solid polymers, etc). Main properties of tube's material are: light weight, ability not to impose too much load on construction, to keep defined shape, not to have logjams (when using soft materials), too sharp angles (except as otherwise provided by building structure), because it would distort or preclude path of illumination rays. Reflecting coating can be applied on the inside of the tube by polishing (if tube was made of metal), spattering, lamination, galvanizing or anodizing.

Diffuser section should have light regulation and to act as a décor in a room. Main characteristics of it are strength, luminous transmittance, minimal reverberation of rays from its surface, decent diffusion of light beam for comfortable perception of human's eye.

Obtained illumination, spectral wavelengths of light beam in the room, maximal length that light can be passed from outside to the inside (while saving certain illumination) are principal characteristics of solar tube. Matters that solar tube is made of (such as receiving part material, way of mirroring of the inner tube, etc.), geographical and climatic aspects of the installation location are the most influencing factors.

6. Conclusion

Theoretical and laboratory investigations showed us reasonability of using solar tubes of certain type in aid of lighting of premises in northern latitudes. However, we need to conduct more research in field of depending effectiveness of solar tube on way of mirroring of the inner tube, material tube is made of, of the different installation location, influence of using different types of lenses as a receiving part, amount and quality of received light beam depending on spectral wavelength of source.

7. References

[1] www.odl.com
[2] Fil N.S. Solar irradiation estimate in Chelyabinsk, Russia. Nauka I studia, NR 21 (89) 2013.