1. PN-EN 1993-1-8 Eurocode 3 (2005) Design of Steel Structures. Part 1-8 Design of Joints. CEN. 2. Kozłowski A. Pisarek Z (2008) Resistance and stiffness of T-stub with four bolts. Archives of Civil Engineering Liv. 1: 167-191. 3. Krumm R (1991) Calculation of rigid face plate connections according to the DSTV/DASt Guidelines. Stahlbau 60: 4. Ungermann D, Schmidt B (2005) Moment resistance of bolted beam to column connections with four bolts in each row. Procc. of IV European Conference on Steel and Composite Structures, Eurosteel, Maastricht: 5. Polanski Z (1984) Planowanie doświadczalne w technice. PWN, Warsaw. (in Polish).

UDC 662.997

B.I. Piznak, V.M. Zhelykh, V.Z. Pashkevych
Lviv Polytechnic National University
Department of Heat and Gas Supply, and Ventilation

THE ECONOMIC EFFICIENCY OF THE USE OF POLYMERIC MATERIALS IN THE DESIGN OF SOLAR COLLECTORS

The results of the technical and economic analysis of the use of flat solar collector based on polymeric materials are given.

Key words: energy-savings, solar collector, polymeric materials, cellular polycarbonate plate.

Наведено результати техніко-економічного аналізу використання плоского сонячного колектора на основі полімерних матеріалів.

Ключові слова: енергозбереження, сонячний колектор, полімерні матеріали, стільникова полікарбонатна плита.

Timeliness

For the last centuries the demands for the energy quantity have increased in an unprecedented manner and the mankind is looking for additional energy sources. The increase in energy consumption occurs due to the constant population growth and the need for development and greater comfort.

Energy problem could be solved either by the sustainable use of the available natural energy sources, i. e. by conducting energy and resource saving policy or by using new alternative and renewable energy sources.

Most developed countries are involved in the implementation of alternative energy sources of sun, wind, flow, heat of the earth core etc. They cannot fully substitute oil, gas, coal or nuclear energy and have to be used along with the traditional energy sources. Moreover, they can have a crucial role in the regions with favorable climate conditions. The main reason restraining the development of renewable energy sources is the necessity of high capital expenditure.

Currently the most effective way for the development of the alternative energy is the usage of solar energy to obtain the heat. Transition to the solar energy prevents from the emission of carbon dioxide, carbon monoxide, sulfur dioxide, nitrous oxide and other pollutants into the atmosphere. The climate of Ukraine provides the possibility for the wide use of solar energy. The annual radiative solar flux at 1 m^2 of horizontal surface in the southern regions of Ukraine constitutes 1100-1380 kWh, and the duration of solar radiation comprises approximately 2000 hours per year [1]. Therefore, the conception of accelerated development of domestic solar installations to obtain heat energy is entirely appropriate. A number of solar heat supply engineering systems have been already developed and they are being developed now, however, they all have one mutual element which is a solar collector. The effectiveness of solar installation depends mainly on the right choice of the collector.

Simple and the cheapest way of solar energy usage is seasonal water heating for household needs in flat solar collectors. The correlation of their price and quality is acceptable; there are many possibilities for their wide installations. The technologies of effective water heating for household needs with the use of flat solar collectors (SC) have been well exploited and they are widely available at the market. Flat heliocollectors are most effectively used in sunny regions.

The aim of the research

To determine economic efficiency of solar collector made from transparent three-layered polycarbonate cellular plate with the given cost.

Analysis

Most flat SCs produced in the world are made of nonferrous metals, glass is used as a transparent coating (it is a hard and brittle material). Use of impact-resistant glass makes the production of solar collectors more expensive. Thus, the price of the systems with such collectors is high. Their disadvantages are low corrosion resistance, complicated production (during forming, bending, soldering or welding complex shaped products); considerable specific weight (approximately 20-30 kl/m^2). Moreover, influenced by thermal and corrosive deterioration of absorber selective covering, energy conversion efficiency of solar collector lowers. These processes depend on temperature conditions of collector operation. First and foremost, it is related to overheating of absorber as a result of different disorders of solar installation and also damages after corrosion**.** Structural improvements of collectors could be carried out using two approaches: search for new nonmetal materials and improvement of optothermal characteristics of the most important element “absorber- light transparent protective coating”.

One of such variants is a solar collector constructed on the basis of cellular multi-layered polycarbonate plates (fig. 1). The advantages of cellular polymeric constructions include:

1. Low specific weight – cellular polycarbonate is 16 times lighter than glass. It demands less costs for supporting structures.
2. High impact strength – being a tough polymer, polycarbonate 200 times stronger than glass. Polycarbonate panels do not break, do not crack, thus, they do not break into sharp fragments.
3. Low flammability, they do not burn in the open fire, do not facilitate its spread, they are not life-threatening during thermal destruction, and, to the contrary of other plastics, they do not release toxic substances.
4. High light transmission up to 86 % (fig. 20).
5. Wide range of temperature conditions in operation: from -40 °C to 120 °C.
6. Maximal thermal expansion at $\Delta T = 80$ ºC is 2,5 mm/m.
7. Cellular polycarbonate panels resist considerable wind and snow load, they are hail impact resistant.

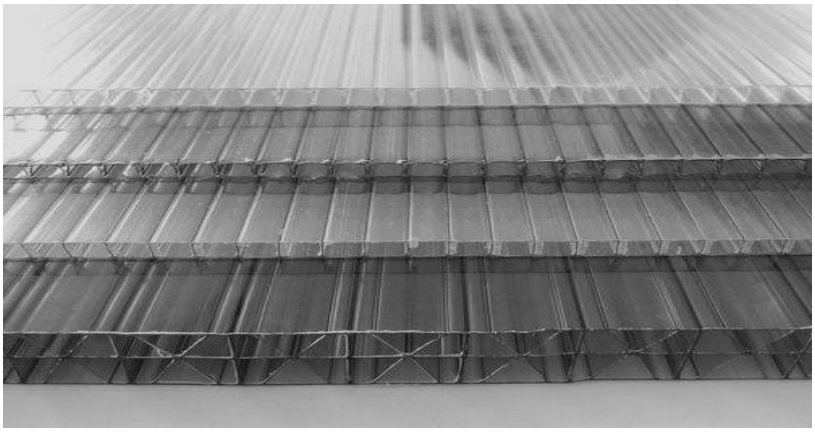

Fig. 1. Cellular polycarbonate plates

Polycarbonate is produced by the method of extrusion from the high quality raw material, which provides good physico-mechanical qualities and reasonable price. Air in the cavities between the layers of plate, “cells”, provides it with the high insulation qualities, and the edges of stiffness provide high structural strength of cellular polycarbonate.

Table 1

Physical characteristics of transparent cellular polycarbonate

Panel thickness, mm	4	6	8	10	16
Distance between the edges of stiffness, mm	5,7		11		20
Weigh, kl/m^2	0,8	1,3	1,5	1,7	2,7
Light transmission according to ASTM D1003 standards (with the fall of ray at the angle of 90^0)	86	86	85	85	76
Factor "C", according to ASTMC236 standard, W/m^2 ^{0}C	3,9	3,6	3,4	3,1	2,2

Cellular polycarbonate is resistant to UV radiation and it is distinguished with the high indicator of light transmission (fig. 2).

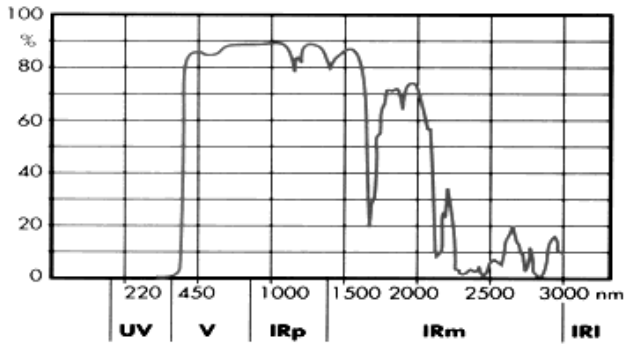

Fig. 2. Dependence of the light transmission of
polycarbonate sheet with the thickness of 6 mm from the length of the wave
UV – ultraviolet of 136- 400 nanometers; V – visible light of 400 -780 nanometers;
IRp – infrared light of 780-1400 nanometers; IRm – infrared light > 1400-3000 nanometers;
IRI – infrared light of 3000-1000000 nanometers

Such characteristics make polycarbonate satisfactory for designing solar collector. The solar collector structure on the basis of cellular three-layered polycarbonate plate was chosen for the analysis.

The solar collector consisted of solid three-layered cellular polycarbonate plate (fig. 3), the upper layer functioned as a translucent protective coating, the middle layer served as an absorber of solar energy, where the heating agent was circulating, the lower layer was meant for insulation. The pipelines were attached to the middle layer for supply and drainage of the heating agent.

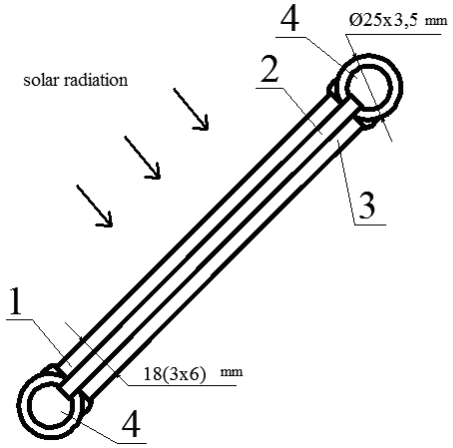

Fig. 3. Polymeric solar collector chart
1 – translucent protective coating, 2 – solar energy absorber,
3 – insulation, 4 – pipelines for supply and drainage of the heating agent

To determine the economic effect resulting from the usage of polymeric heliocollectors of the considered construction, two variants of solar hot water supply systems in a single-family detached home were compared.

Two variants of solar hot water supply systems in a single-family detached home were considered in the research:

– 1 variant – solar hot water supply systems in a single-family detached home on the basis of Vitosol 100-F flat solar collector by Viessman.

– 2 variant – solar hot water supply systems in a single-family detached home with flat solar collectors made of cellular three-layered polycarbonate sheets.

Schematic diagram of helioinstallation was similar for two variants, only a type of solar collector was changed.

The decisions have to be directed at the increase of the effectiveness of capital investments, they should facilitate reduction of labor intensively and time performance of construction and installation works, be oriented at sustainable use of all kinds of resources, improve productivity and quality of work, and also to meet the eco-friendly requirements. This should be supported with necessary technical and economic justification of these decisions.

The comparison was made with the given costs. The variant (i = 1,2) with fewer costs is considered to be more effective.

$$G_i = O_i + R_n \cdot E_i \quad (1)$$

where G_i – given costs of i variant, thousand hrn; O_i – operation costs of i variant, thousand hrn; R_n =0,12 – normalized ratio of economic effectiveness of capital investments; E_i – estimated cost of i variant, thousand hrn.

Annual operation costs are determined in such a way:

$$O_i = A_i + M_i + S_i + D_i \quad (2)$$

where A_i – amortization costs; M_i – maintenance costs; S_i – staff salary; D_i – other costs.

Amortization recoupment was assessed according to the existing norms. Average recoupment comprised 8 % of the estimated costs of C_i system:

$$A_i = 0,08 \cdot C_i \quad (3)$$

Maintenance costs depend on the variability of the system, aggressive environment etc. average maintenance costs make approximately 20 – 30 % of amortization costs:

$$M_i = (0,2…0,3) \cdot A_i \quad (4)$$

Other costs are related to management costs, lighting, health and safety etc., they were considered to make 30 % of the amount of amortization recoupment, maintenance costs and staff salary:

$$D_i = 0,3 \cdot (A_i + M_i + S_i) \quad (5)$$

Table 2

Comparison of two projects costs

	Existing SC Vitosol 100-F	Polymeric SC on the basis of three-layered polycarbonate plate
Estimated costs, thousand hrn	51,027	39,812
Amortization costs, thousand hrn	4,24	3,18
Maintenance costs, thousand hrn	0,848	0,954
Operation costs, thousand hrn	7,134	6,024
Given costs,thousand hrn	13,5	10,8

Economic effect resulting from more effective variant of design is determined as a difference of the given costs:

$$E = G_1 – G_2 = 13,5 – 10,8 = 2,7 \text{ thousand hrn.} \quad (6)$$

Conclusions

Hot water supply system on the basis of the developed polymeric solar collectors is more economically effective than the solar hot water supply system offered at the market, and the economic effect makes 2700 hrn/year.

1. Rekstad, J. Solar Collectors in plastic materials from Norway / J. Rekstad // SolarNor AS and General Electric Plastics, 1997. 2. Сухий М., Козлов Я., Сухий К., Бражник Ю., Бурмістр М., «Сонячні колектори на основі стільникових полікарбонатних пластиків» // Вопросы химии и химической технологии, – №1. – 2009. –С. 146–149. (on ua) 3. Желих В., Пізнак Б., Фечан А.: Патент на корисну модель № 55948 – Сонячний колектор. (on ua).