sciendo Ovidius University Annals Series: Civil Engineering, Year 25, 2023
DOI: 10.2478/ouacsce-2023-0007

Use of PIR/PUR sandwich panels as advanced materials in industrial constructions

Gabriela Drăghici, Cosmin Filip, Andrei - Cristian Panchici and Alexandru - Nicolae Bizu

***Abstract* – In the evolving field of construction, the use of advanced structural materials is becoming increasingly important. These innovative materials offer the potential to enhance structural strength, longevity and durability. The present study focuses on the analysis and comparison of two thermally insulating materials, specifically on Polyisocyanurate Foam (PIR) sandwich panels used in industrial construction.**

***Keywords* – advanced materials, heat transfer, industrial, sandwich panels.**

1. INTRODUCTION

Sandwich panels are a particularly important innovation in the multitude of building materials. These panels offer multiple advantages, contributing to the thermal and acoustic efficiency of industrial buildings, reducing energy costs and providing a comfortable working environment. Sandwich panels also provide protection against fire, thanks to the flame retardant materials used, limiting the spread of fire and minimising risks to life and property. They are also resistant to extreme temperature fluctuations, ensuring temperature stability in variable weather conditions, or separation of rooms with different temperatures (e.g. cold rooms).

These essential characteristics make sandwich panels an ideal choice in modern industrial steel construction, contributing significantly to the efficiency and safety of these vital structures in various industries. Their research and application is an area of increasing importance to construction professionals, given the benefits they bring in terms of performance, durability and sustainability in the evolving industrial environment.

2. THE MATERIAL CHARACTERISTICS

Sandwich panels are layered elements composed of lightweight materials with excellent insulating properties, surrounded by durable and resistant coatings. These materials are configured with a central core, which may consist of glass wool, polyurethane foam or extruded polystyrene foam, covered by outer layers of PVC, veneered plywood, aluminium or laminated sheet metal. [1]

In addition to this major advantage, sandwich panels have a number of benefits that make them suitable for outbuildings, industrial halls, warehouses, garages and similar types of construction. Compared to wood or other traditional materials for interior and exterior walls and roofs, sandwich panels are distinguished by their low weight, minimising the risk of structural damage. The thickness of these panels varies depending on the type, ranging from 30 to 200 millimetres for polystyrene or polyurethane foam versions and from 50 to 150 millimetres for mineral wool. [2] Standard dimensions, which vary by category and manufacturer, range from 2.00 to 14.00 metres in length and 1.40 to 2.00 metres in width.

In terms of thermal performance, PIR (Polyisocyanurate foam) or PUR (polyurethane foam) panels rank lower than basalt wool panels, but polystyrene panels are the most efficient in terms of heat transfer. In terms of sound insulation, polystyrene panels stand out as the best performing of the three categories, and in terms of fire resistance, basaltic mineral wool panels demonstrate superior fire retardant properties, with increased resistance to flame propagation and spread. [3]

Fig.1 Sandwich Panel [6]

3. CASE STUDY

This study was carried out on the use of Kingspan double skin steel faced sandwich panels, with a core made of QuadCore rigid foam, for insulating a freezer-type metal structure in a bakery factory.

The double-skin steel-faced sandwich panels are structured as composite elements, comprised of external and internal steel sheets, both of which are profiled, galvanized with a metallic coating, and finished with organic paint to ensure adequate corrosion resistance. These steel sheets enclose a rigid thermal insulating core material composed of polyisocyanurate foam.

The core material is manufactured utilizing Kingspan QuadCoreTM technology and forms a robust, firmly bonded intermediary layer between the steel faces. Additionally, it is worth noting that factory-applied sealing tapes may be present along the edges of the sandwich panels to enhance their overall performance. [4]

These sandwich panels hold a classification of low flammability, as per European standard EN 13501-1, attaining a reaction to fire classification of B-s1, d0.[5] This classification underscores their limited combustibility and their capacity to minimize the spread of fire, making them suitable for applications that require stringent fire safety measures.

It is important to note that, in order to achieve effective sealing of the entire structural assembly, silicone sealant need to be applied between the joints of the sandwich panels, and waterproof tape applied on vertical joints. This additional measure will incur extra cost but will ensure comprehensive sealing of the entire freezer building.

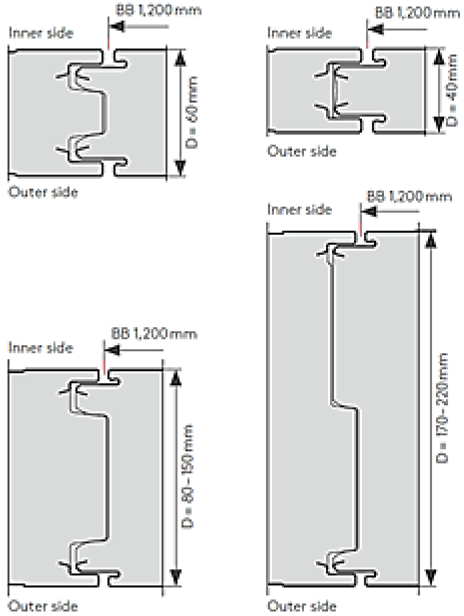

Fig. 2 Sandwich panel clamping system [6]

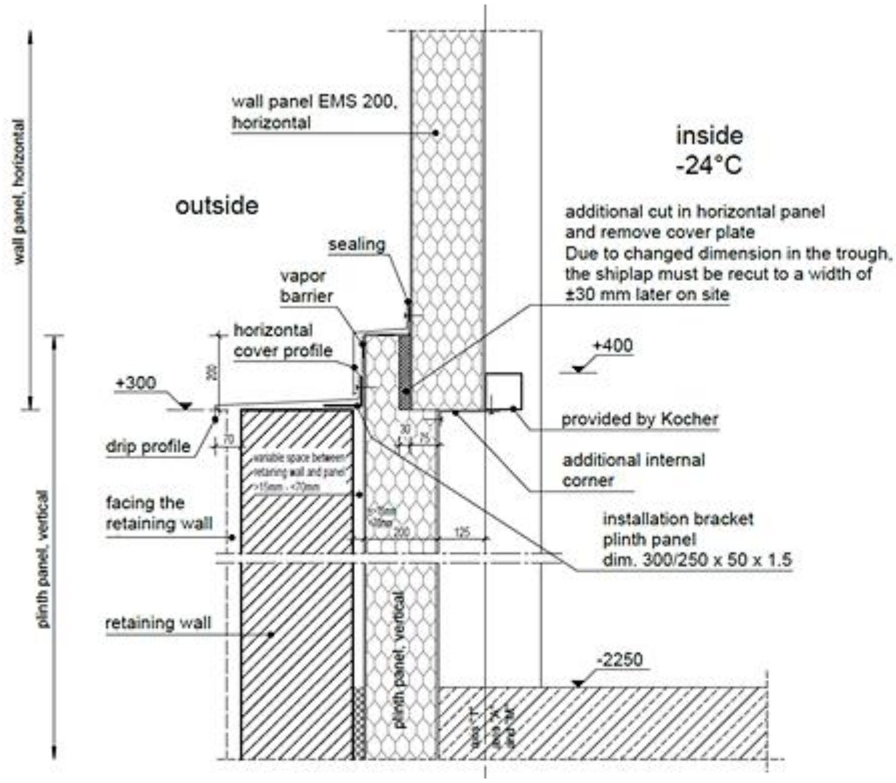

Fig. 3 Transition detail from skirting board to facade [7]

The complete sealing of the deposit was achieved by applying a special silicone, DOW-3145, which is resistant to very low temperatures and significant temperature variations (from -40 ^{0}C to +200 ^{0}C, according to the product data sheet).

This silicone was applied to the vertical and horizontal joints of the sandwich panels to ensure effective insulation and to maintain optimal indoor conditions, especially considering the large temperature differences between the indoor and outdoor environment, which can reach around ± 60 ^{0}Celsius (during summer).

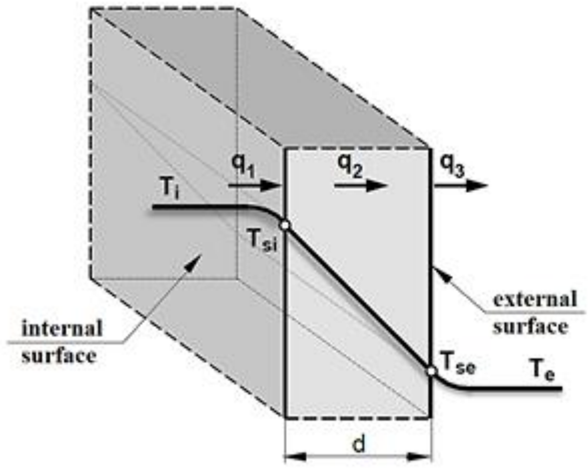

Fig. 4 Global heat transfer through a homogeneous element [9]

By means of the information provided both by the product data sheets and the literature, the values of thermal resistance and heat transfer coefficient can be determined considering the wall thickness **d** equal to 200 mm, coefficient of thermal conductivity **λ** equal to 0,0192 W/mK [4][8] as well as the following formulas:

$$R_0 = R_{si} + R + R_{se} = \frac{1}{\alpha_i} + \frac{d}{\lambda} + \frac{1}{\alpha_e} \quad (m^2K/W) \tag{1}$$

Where:

R_0 = total thermal resistance to heat transmission, in m^2K/W;
R_{si} = thermal resistance of the interior surface, in m^2K/W;
R = thermal resistance of element, with thickness "d", in m^2K/W;
R_{se} = thermal resistance of the exterior surface, in m^2K/W;
α_i = internal surface heat transfer coefficient, in W/m^2K;
d = thickness of the element, in m;
λ = coefficient of thermal conductivity, in W/mK;
α_e = external surface heat transfer coefficient, in W/m^2K.

According to C 107/3 - 2005, Table II the values of heat transfer coefficients at surfaces are equal to 8 and 12 W/m^2 K respectively [10]. Thus, having data for all the elements specified in Eq. (1), they can be replaced, resulting in:

$$R_0 = R_{si} + R + R_{se} = \frac{1}{8} + \frac{0,20}{0,0192} + \frac{1}{12} = 10,625 \ (m^2K/W) \tag{2}$$

By inverting the global thermal resistance R0 results the value of the global heat transfer coefficient U0 [11], as follows:

$$U_0 = \frac{1}{R_0} = \frac{1}{R_{si} + R + R_{se}} = \frac{1}{\frac{1}{\alpha_i} + \frac{d}{\lambda} + \frac{1}{\alpha_e}} = \frac{1}{10,625} = 0,0941 \ (W/m^2K) \tag{3}$$

Having established the overall thermal resistance (R_0) and the overall heat transfer coefficient (U_0), the focus will now shift towards the examination of an alternative type of sandwich panel which was initially proposed to be used. This comparative analysis aims to provide insights into the thermal performance of the alternative panel in relation to the previously investigated one.

The panels initially proposed for use are Stiferite RP1 panels, offered by Crown Cool SRL. These panels are made of rigid polyisocyanurate foam (PIR), caulked with Polytwin coating on both sides, and covered with plasterboard on one side.

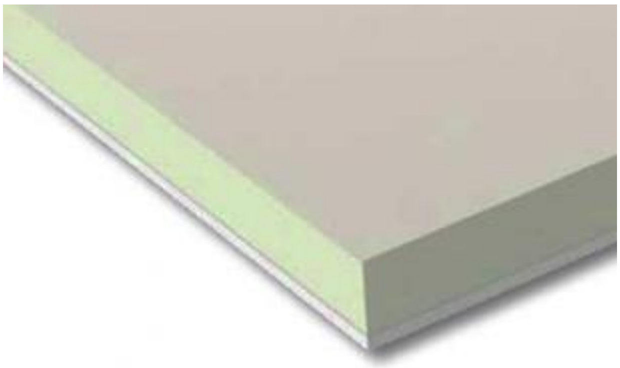

Fig. 5 Stiferite RP1 panel [13]

The wall thickness **d** is equal to 200 mm and the coefficient of thermal conductivity **λ** is equal to 0,022 W/mK [12]. Thus, using the same principle as above, the following values result:

$$R_0 = R_{si} + R + R_{se} = \frac{1}{8} + \frac{0,20}{0,022} + \frac{1}{12} = 9,299 \ (m^2K/W) \tag{4}$$

$$U_0 = \frac{1}{R_0} = \frac{1}{9,299} = 0,107 \ (W/m^2K) \tag{5}$$

4. COST ANALYSIS BETWEEN THE TWO TYPES OF PANELS

Detailed cost analysis is a fundamental tool in assessing financial viability and guiding decisions towards a sustainable and cost-effective solution. By comparing the cost per square meter of material, assessing the cost of the adjacent parts needed to make the whole assembly, and analyzing the cost of labour to assemble the panels, this chapter provides a comprehensive overview of the economics involved in choosing between the two types of panels.

The importance of this analysis transcends immediate budgetary concerns and extends to a strategic approach to construction. Therefore, this chapter is a key point in the decision making process on the optimal material choice and serves not only as a guiding tool for immediate cost considerations, but also as a guide for construction decision making, ensuring that the financial aspects are correlated with the long-term perspectives and sustainability requirements of the project.

In the table below can be seen a price comparison for the materials used in the installation of the sandwich panels and the workmanship of the installers. It will be considered that both labour and adjacent parts necessary for the assembly of the panels will be of the same type, thus resulting in identical prices.

It should be noted that the prices are in line with the market situation at the time of writing (November 2023).

Table. 1. Cost per unit(s) of material(s)

Type of material	Unit of measure	Total quantity used	Price per unit of material [RON]		Total price for the panel type [RON]	
			King Span	Stiferite	King Span	Stiferite
Sandwich panel	(1 m^2)	10.460 (m^2)	350	260	3.661.000	2.719.600
Self-drilling screw	1 box (100 screws)	70 boxes	80		5.600	5.600
Silicone Ramsauer 125 Handwerk	1 tube (600 ml)	180 tubes	50		9.000	9.000
Cleaner Ramsauer 828	1 canister (1000 ml)	10 canisters	55		550	550
Cleaner Ramsauer 506	1 canister (5000 ml)	4 canisters	70		280	280
Waterproofing tape	1 roll (10 meters)	97 rolls	80		7.760	7.760
Workforce	(1 m^2)	10.460 (m^2)	80		836.800	836.800
Total price without TVA [RON]:					**4.520.990**	**3.579.590**
TVA					**19%**	
Total price with TVA [RON]:					**5.379.978**	**4.259.712**
Total price [Euros]:					**1.082.491**	**857.085**

The total cost for closing and sealing the industrial freezer structure, using KingSpan panels and other materials, is 5.379.978,00 RON (1.082.491,00 Euros), while for Stiferite panels it is equal to 3.579.590,00 RON (857.085,00 Euros), this results in a difference of 1.120.266,00 RON (225.406,00 Euros), which is in favor for the Stiferite system.

In addition to the cost, the lifetime of these materials is also taken into consideration. This lifetime may be found in the technical data sheet of the product or can be received directly from the supplier. The lifetime of Stiferite panels is approximately 40 to 60 years, while the lifetime of KingSpan panels is approximately 60 to 90 years. On the other hand, we are able to hypothesize that the two categories described above have an average lifespan of 50 and 75 years, respectively.

5. CONCLUSION

We thus conclude that the comparative analysis of the Kingspan QuadCore and CrownCool Stiferite sandwich panels provides significant insights into their insulating quality, purchase and installation costs in a building context.

Kingspan panels, with an overall heat transfer coefficient (U0) of 0,162 and an overall thermal resistance (R0) of 6,156, demonstrated outstanding thermal performance. These values suggest an enhanced ability to minimise temperature losses and provide effective thermal insulation. In contrast, CrownCool panels, with a U0 of 0,21 and an R0 of 4,75, showed a more modest insulating performance compared to Kingspan panels.

In order to achieve the project specifications, the decision between the two choices is influenced by this performance difference. Taking into account the financial aspects discussed in the previous chapter as well, the QuadCore ems-insulator panels from KingSpan, although more expensive at 1.082.491,00 Euros, offer a more dependable and superior solution than the CrownCool Stiferite panels, which come with a total cost of 857.085,00 Euros, for sealing and closing the industrial and multifunctional structure under study.

The advantages offered by both the quality of the material and the increased life span are the main factors in the design and execution of this type of structure.

The possibility of further analysis on these materials can be explored by determining the corrected specific thermal resistance, verifying thermal stability and assessing condensation resistance. These aspects are essential pillars in gaining an in-depth understanding of the thermal performance of thermal insulation materials.

In addition, performing the analyses under various environmental conditions is an essential dimension of the research, as varying environments can influence the durability and performance of materials. By addressing these factors analytically, a comprehensive framework is developed that favours an informed and adaptable selection of thermal insulation materials according to the specific requirements of each project or context.

5. ACKNOWLEDGMENTS

We thank Adrian Crivăț, site manager from SSAB-AG S.A., for providing us with plans, approvals, technical sheets and lists of quantities related to the structure. We thank Tudorache Grigoras, site engineer from SSAB-AG S.A., for providing us with detailed plans for joints and assembly, as well as for the price lists of the materials studied.

6. REFERENCES

[1] Y.C. Wang, A. Foster. (2017). *Experimental and numerical study of temperature developments in PIR core sandwich panels with joint*. Fire Safety Journal. (pp 2-3). https://doi.org/10.1016/j.firesaf.2017.03.003

[2] Woodhead Publishing Series. (2013). *Developments in Fiber-Reinforced Polymer (FRP) Composites for Civil Engineering*, https://www.sciencedirect.com/science/article/pii/B9780857092342500221
[3] Ding, K. W., Wang, G., & Yin, W. Y. (2013). *Application of Composite Sandwich Panels in Construction Engineering. Applied Mechanics and Materials.* https://doi.org/10.4028/www.scientific.net/amm.291-294.1172
[4] Kingspan GmbH. (2020). *Double skin steel faced sandwich panels with a core made of QuadCore rigid foam*, EPD-KSP-20200140-IBD1-EN
[5] SR EN 13501-1:2019. *Fire classification of construction products and building elements.* Part 1: Classification using results of reaction-to-fire tests.
[6] Datasheet of *Ems-Isolier QuadCore EM*
[7] A. Verkerk. (2022). *Detail wall panel, exterial corner & vertical joints.* (Drawing no. 7010). Revision no. 02. [Architectural drawing]. Retrieved from SSAB AG S.A.
[8] Kingspan quality test report no. L1-20-067
[9] D. Ștefănescu. (2012). *Manual de proiectare higrotermică a clădirilor.* (pp 58) Iași: Editura Societății Academice.
[10] Ministerul Dezvoltării, Lucrărilor Publice Și Administrației. (2005). *Normativ privind calculul termotehnic al elementelor de construcţie ale clădirilor (indicativ C 107 – 2005).* Consultat la 05.11.2023, la adresa https://bit.ly/47uduu0
[11] D. Ștefănescu. (2012). *Manual de proiectare higrotermică a clădirilor.* (pp 62) Iași: Editura Societății Academice
[12] Datasheet of *CT2RP1XXX Panou sandwich termoizolant PIR*
[13] https://tcromania.com/en/ventilation-systems/panels--/rp1-sandwich-panel/

Note:

Gabriela Draghici – PhD. Eng., Lecturer, Ovidius University of Constanta, Bd. Mamaia nr. 124, 900356-Constanta, Romania (corresponding author to provide phone: +40-241-619040; fax: +40-241-618372; (e-mail: draghici.gabriela@univ-ovidius.ro)

Cosmin Filip – PhD. Eng., Lecturer, Ovidius University of Constanta, Bd. Mamaia nr. 124, 900356-Constanta, Romania (e-mail: filip.cosmin@univ-ovidius.ro)

Andrei – Cristian Panchici – PhD student, Technical University of Civil Engineering of Bucharest, Bd. Lacul Tei, nr. 124, Romania (e-mail: andrei-cristian.panchici@phd.utcb.ro)

Alexandru Nicolae Bizu– PhD student, Gh. Asachi Technical University of Iasi, Str. Prof. dr. docent Dimitrie Mangeron , nr. 67, corp T, Romania (e-mail: bizu.alexandru@gmail.com)