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REVIEW ARTICLE

STUDY OF PROPERTIES OF MULTILAYER REFLECTIVE THERMAL INSULATION MATERIALS FOR IMPROVING ENERGY EFFICIENCY OF BUILDINGS

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Abstract. *The article examines the characteristics of multilayer reflective thermal insulation materials, which are increasingly used in the construction of energy-efficient buildings. These materials include highly reflective layers capable of reflecting up to 97% of thermal radiation and spacer elements that prevent dust accumulation and create stable air gaps, significantly improving their thermal insulation properties. The study investigates their ability to reduce heat transfer through a combination of reflection, convection, and conduction mechanisms, as well as their role in preventing condensation. The production of such materials is described as a technologically complex yet highly efficient process. The article reviews international standards, such as EN ISO 22097, and methods for measuring thermal insulation parameters, including the use of devices like the "guarded hot plate" and "hot box." Practical applications of multilayer materials in construction are analyzed, focusing on their use for insulating roofs, walls, and floors in both new buildings and renovation projects. The findings confirm the high efficiency of multilayer reflective thermal insulation in various climatic conditions. These materials help to reduce building overheating in summer, minimize heat loss in winter, improve indoor thermal comfort, and decrease energy consumption. Their use contributes to achieving the goals of sustainable construction, making them a key component of modern building practices.*

Keywords: *Multilayer reflective insulation, building energy efficiency, heat transfer, thermal conductivity, sustainable construction.*

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ШОЛУ МАҚАЛА

ҒИМАРАТТАРДЫҢ ЭНЕРГИЯ ТИІМДІЛІГІН АРТТЫРУ ҮШІН КӨПҚАБАТТЫ ШАҒЫЛЫСТЫРАТЫН ЖЫЛУ ОҚШАУЛАҒЫШ МАТЕРИАЛДАРДЫҢ ҚАСИЕТТЕРІН ЗЕРТТЕУ

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Аңдатпа. *Мақалада көпқабатты шағылдырғыш жылу оқшаулағыш материалдардың сипаттамалары қарастырылады, олар энергия тиімді ғимараттарды салуда кеңінен қолданылуда. Бұл материалдар жылу сәулеленудің 97%-на дейін шағылыстыратын жоғары шағылдырғыш қабаттарды және шаңның жиналуын болдырмайтын, тұрақты ауа саңылауларын қамтамасыз ететін бөлгіш элементтерді қамтиды, бұл олардың жылу оқшаулау қасиеттерін айтарлықтай жақсартады. Зерттеуде бұл материалдардың шағылдыру, конвекция және өткізгіштік механизмдерінің үйлесімі арқылы жылу өткізуді төмендету қабілеті, сондай-ақ конденсацияның пайда болуын болдырмаудағы рөлі талданады. Мұндай материалдарды өндіру технологиялық тұрғыдан күрделі, бірақ жоғары өнімді процесс ретінде сипатталады. Мақалада EN ISO 22097 сияқты халықаралық стандарттар және жылу оқшаулау параметрлерін өлшеу әдістері, соның ішінде «ыстық плита» және «ыстық қорап» құрылғыларын қолдану қарастырылады. Сондай-ақ, көпқабатты материалдарды құрылыс саласында - жаңа ғимараттарды оқшаулау және қолданыстағы ғимараттарды қайта құру үшін қолданудың практикалық аспектілері талданады. Алынған нәтижелер көпқабатты шағылдырғыш жылу оқшаулағыш материалдардың әртүрлі климаттық жағдайларда жоғары тиімділігін растайды. Бұл материалдар жазда ғимараттардың қызып кетуін азайтуға, қыста жылу шығынын барынша азайтуға, ішкі микроклиматты жақсартуға және энергия шығындарын қысқартуға көмектеседі. Оларды пайдалану тұрақты құрылыс мақсаттарына қол жеткізуге ықпал етеді және оларды заманауи құрылыс индустриясының маңызды элементіне* айналдырады.

Түйін сөздер: *Көпқабатты шағылдырғыш оқшаулау, ғимараттардың энергия тиімділігі, жылу өткізу, жылу өткізгіштік, тұрақты құрылыс.*

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ОБЗОРНАЯ СТАТЬЯ

ИССЛЕДОВАНИЕ СВОЙСТВ МНОГОСЛОЙНЫХ ОТРАЖАЮЩИХ ТЕПЛОИЗОЛЯЦИОННЫХ МАТЕРИАЛОВ ДЛЯ ПОВЫШЕНИЯ ЭНЕРГОЭФФЕКТИВНОСТИ ЗДАНИЙ

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Аннотация. *В статье исследуются характеристики многослойных отражающих теплоизоляционных материалов, которые находят все большее применение в строительстве энергоэффективных зданий. Данные материалы включают высокоотражающие слои, отражающие до 97% теплового излучения, и разделительные элементы, предотвращающие скопление пыли и создающие стабильные воздушные зазоры, что значительно улучшает их теплоизоляционные свойства. Исследуется их способность снижать теплопередачу за счет комбинации механизмов отражения, конвекции и проводимости, а также их роль в предотвращении образования конденсата. Производство таких материалов описывается как технологически сложный, но высокопроизводительный процесс. В статье рассматриваются международные стандарты, такие как EN ISO 22097, и методы измерения теплоизоляционных параметров, включая использование устройств «горячая пластина» и «горячая коробка». Также анализируется практическое применение многослойных материалов в строительстве - для теплоизоляции крыш, стен и полов, как в новых зданиях, так и при реконструкции. Полученные результаты подтверждают высокую эффективность многослойной отражающей теплоизоляции в различных климатических условиях. Эти материалы помогают снизить перегрев зданий летом, минимизировать теплопотери зимой, улучшить внутренний микроклимат и сократить энергозатраты. Их применение способствует достижению целей устойчивого строительства, что делает их ключевым элементом современной строительной индустрии.*

Ключевые слова:. *Многослойная отражающая изоляция, энергоэффективность зданий, теплопередача, теплопроводность, устойчивое строительство.*

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest.

АЛҒЫС/ҚАРЖЫЛАНДЫРУ КӨЗІ

Зерттеу жеке қаржыландыру көздерін пайдалана отырып жүргізілді.

МҮДДЕЛЕР ҚАҚТЫҒЫСЫ

Авторлар мүдделер қақтығысы жоқ деп мәлімдейді.

БЛАГОДАРНОСТИ/ИСТОЧНИК ФИНАНСИРОВАНИЯ

Исследование проводилось с использованием частных источников финансирования.

КОНФЛИКТ ИНТЕРЕСОВ

Авторы заявляют, что конфликта интересов нет.

1 INTRODUCTION

Improving the energy efficiency of buildings and reducing energy consumption are among the key priorities outlined in Kazakhstan's state programs, such as the «Concept for the transition of the Republic of Kazakhstan to a Green Economy» and the State program for industrial and innovative development. These programs aim to reduce energy costs and promote the adoption of sustainable construction technologies that meet international environmental standards.

One of the effective tools for achieving these goals is the use of innovative thermal insulation materials. In particular, multilayer reflective thermal insulation materials demonstrate significant potential due to their ability to reduce heat loss through the reflection of thermal radiation and minimize heat transfer.

This article examines the characteristics of multilayer reflective thermal insulation materials, their structural features, and methods for their application in construction. The study aims to identify opportunities for improving building energy efficiency through the use of these materials, enhancing thermal protection, reducing energy costs, and lowering the carbon footprint.

Thus, the purpose of this work is to study the properties of multilayer reflective thermal insulation materials and to develop recommendations for their effective use in construction to improve building energy efficiency under the conditions of a sharply continental climate.

2 LITERATURE REVIEW

New thermal insulation materials are continually being developed globally, offering innovative solutions for energy efficiency. While the thermal properties of these new materials are often comparable to conventional ones, advancements focus on optimizing performance. Studies have highlighted that the thermal conductivity of air within the pores, voids, and loops of any material is 0.024 W/(m·K), with the overall material conductivity slightly higher due to its structural framework. However, materials achieving a thermal conductivity of 0.03 W/(m·K) are already within reach. Furthermore, incorporating gases with thermal conductivities of 0.012–0.013 W/(m·K) can enable materials to achieve conductivity values as low as 0.026 W/(m·K), even if a significant portion of the gas escapes during operation. These materials, often termed "future materials," are at the forefront of thermal insulation innovation, with technologies emerging to reduce thermal conductivity, thickness, and weight **(Gailius & Vėjelis, 2012).**

Multi-foil thermal insulation stands out as an advanced composite material for building applications. It consists of multiple thin foil layers made of low-emissivity materials, capable of reflecting significant portions of solar radiation. Between these foils, spacer layers of low-conductivity materials prevent dust accumulation and maintain consistent spacing. Common spacer materials include mineral, vegetable, or animal wool; metal-reinforced polyester layers; polyester wool; polyethylene foam; and air bubble films. Reflective layers are typically made from aluminum, capable of reflecting up to 97% of radiant heat due to its low emissivity (0.03–0.05) and high reflectivity (0.95–0.97). These features enable multi-foil insulation to retain heat efficiently by reflecting radiant energy, leading to improved U-values with thinner layers **(Pruteanu et al., 2011).**

3 MATERIALS AND METHODS

3.1 Material structure analysis

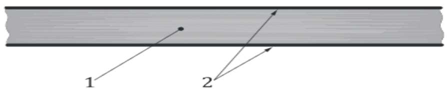
Reflective surfaces play a crucial role in improving the thermal efficiency of insulation products. They work by minimizing heat transfer caused by thermal radiation, particularly in materials that are partially or fully transparent to infrared radiation. Additionally, they help reduce radiant heat transfer across any air gaps present in the system. In some cases, these air gaps are integral to the insulation structure, while in others, the insulation is designed and installed to create deliberate air gaps between the reflective surfaces and the surrounding structure **(LST EN ISO 22097, 2023).**

Reflective multi-foil insulation is composed of multiple layers of thin metallic foils or metallized polymer films, each featuring a low emission coefficient for long-wave radiation. These layers are separated by spacer materials that maintain a consistent gap of 2–8 mm between the foils. Common spacer materials include closed-cell polymer foam, polyester wool, or bubble foil. Additional thin layers of polyethylene film or polyester fleece may also be incorporated to enhance performance. The total thickness of these multi-foil systems typically ranges from 10 to 30 mm. Due to the low emission properties of the reflective foils, the transmission of radiant heat through the material is significantly reduced, allowing for exceptional thermal performance, as claimed by many manufacturers.

Heat-reflective insulation, often a combination of aluminum foil and air bubble layers, creates voids that trap stable, motionless air, maximizing insulation effectiveness. Originally developed by NASA for lightweight, thin thermal systems adapted for astronaut suits, this technology has since found widespread application. Aluminum foil, known for its high heat-reflective properties, is widely used in specialized applications such as firefighter gear and building insulation. In Europe, heat-reflective insulation has been used effectively for over 40 years and accounts for about 8% of the thermal insulation market in France **(Tenpierik & Hasselaar, 2013).**

Reflective products are classified in 4 types. Examples of reflective insulations materials are given in **Figure 1,2.**

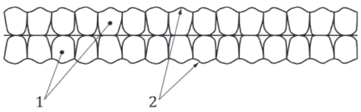
a) Type 1. It has a regular geometry with parallel faces.



1. insulation core
2. low enissivity surface or surfaces

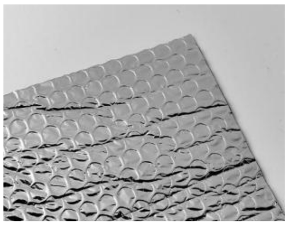
Insulation material of polymer foam (like PIR or EPS), glass woo (MWG) or rock wool (MWR) with on one or two sides a low-emissivity foil or coating.

b) Type 2. It has a regular geometry with parallel faces.



1. insulation core
2. low enissivity surface or surfaces

This product has a thickness of less than 2 mm and consist typically of a bubble foil with on one or sometimes two sides a metal foil or metallised polymer film with low emissivity, as a result increasing the thermal resistance of the adjoining air spaces; The product itself hardly has any thermal resistance.



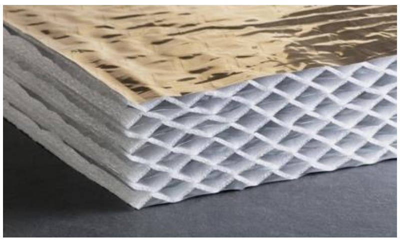
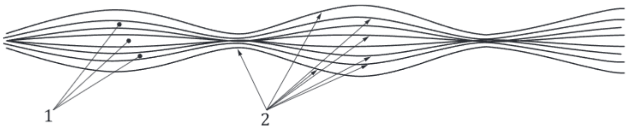


Figure 1 - Different types of reflective insulations a) type 1, b) type 2 **(Tenpierik & Hasselaar, 2013).**

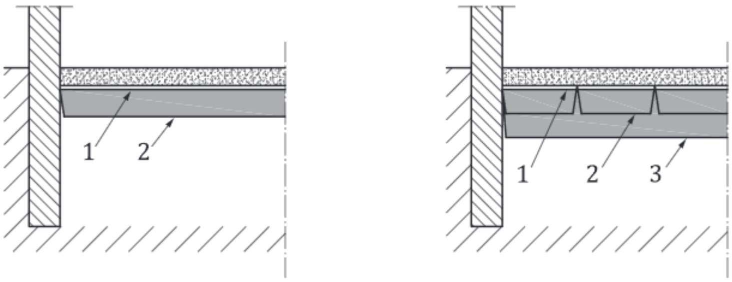
c) Type 3. It has irregular thickness geometry and does not have flat parallel faces



1. insulation core
2. low enissivity surface or surfaces

Multi-foil consisting of layers of metal foil or metallised polymer film, spacer material (for instance PE film of polyester fleece) and closed-cell polymer foam or polyester wool. In practice the number of layers varies between 5 and 20. The first and last layers consist of a (reinforced) coated aluminium foil.

d) Type 4. It is thin film or sheet, less than 2 mm thickness, using single or in multiple layers, which makes use of a low emissivity surface to increase the thermal resstance of adjacent or enclosed air spaces, but which has no significant thermal ressitance of its own.



1, 2, 3 foil layers

Reflective foils and thermos cushions consist of air cushions of metallised polymer film; thermos cushions are a foldable insulation material in which one or two air layers are trapped.

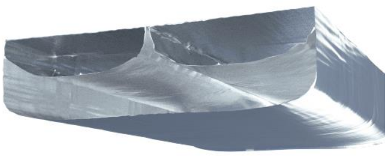


Figure 2 - Different types of reflective insulations c) type 3, d) type 4
(Tenpierik & Hasselaar, 2013).

Figure 3 - Manufacturing of multifoil insulation

3.3 Analysis of body transmission through material

Reflective thermal insulation operates based on a fundamentally different physical mechanism compared to conventional thermal insulation. It relies on highly reflective surfaces with low emissivity placed adjacent to air gaps to impede heat transfer into or out of a building. Unlike traditional insulation, where thermal resistance primarily depends on the thickness and thermal conductivity of the material, reflective insulation achieves its performance through the combination of low-emittance materials and airspaces, which play a critical role in its effectiveness **(Lee et al., 2016).**

Multilayer reflective insulation products are suitable for use in both cold and hot climate zones. In cold climates, these materials significantly reduce heat loss, while in hot climates, they mitigate overheating by reflecting radiant heat. However, the performance of radiant barrier systems varies throughout the year due to differences in climatic conditions and the direction of heat flow. During the summer, the primary mode of heat transfer is radiation from the roof to the conditioned space below. A radiant barrier installed in the attic can effectively block the majority of this radiant heat, which constitutes the largest component of total heat transfer. Conversely, in winter, heat transfer is primarily driven by convection due to buoyancy effects, as warm air rises from the conditioned space. Since radiation accounts for only a small portion of total heat flow in winter, the effectiveness of radiant barriers is reduced. Moreover, radiant barriers block solar heat gain during daytime in winter, which is counterproductive for heating needs, further limiting their performance during the colder season **Figure 4 (SuperFOIL Insulation, 2021)**.

Reflective thermal insulation not only reflects radiant heat but also reduces conduction and convection heat transfer. Materials with low thermal conductivity are incorporated to minimize heat flow between surfaces. Additionally, depending on the specific type and quality, some insulation products address other challenges, such as moisture accumulation, fire hazards, and noise reduction, making them versatile solutions for various building applications.

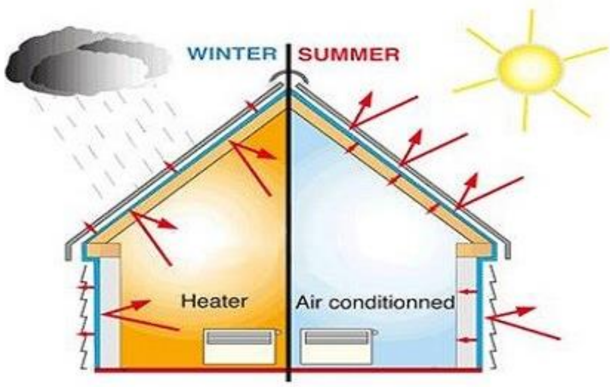


Figure 4 - The impact of reflective thermal insulation on heat loss of the building

3.4 Analysis of standards for determining the thermal properties of materials and practical measurements in the laboratory

The thermal performance of the reflective insulation products are determined according to the standard EN ISO 22097. This standard allows to determine the thermal resistance of reflective insulation products by few methods: guarded hot plate apparatus (Method A) according to the standards ISO 8302, EN 1946-2, EN 12664, EN 12667, heat flow meter apparatus (HFM) (Method B) - according to the standards ISO 8301, EN 1946-3, EN 12664, EN 12667, hot box apparatus (Method C) - according to the standards EN ISO 8990, EN 1946-4, Method D provides for measurement of surface emissivity and calculation of airspace thermal resistance **(LST EN ISO 22097, 2023).**

M. J. Tenpierik and E. Hasselaar **(Tenpierik & Hasselaar, 2013)** made a review of the methods of the determination of the thermal performance of the multilayer reflective insulation products and explained the main reasons for different results between methods: an existence of the air cavities and a ventilation type of them, a direction of the heat flow, a possibility to control environment conditions during the measurement, an air tightness of testing structure, an influence of thermal bridges.

In practice the most often used multilayer reflective insulation (product Type 3 according to EN ISO 22097), is investigated using the hot box apparatus. The hot box is expensive and complex equipment that is usually used by accredited or notified laboratories, or by the scientific institutions. However, the standard EN ISO 22097 does not specify the procedure and requirements for installation and fixing of multilayer reflective insulation products in the opening of the hot box surround panel when measuring their thermal resistance. The standard EN ISO 22097 draws attention on the similarity of emissivity's values of reflective insulation product's surfaces and tape's surfaces, which stuck the thermocouples on the reflective surface. However, there is not clearly identified, how much these values can vary and what influence this difference has for final measurement result of thermal resistance. The difference between emissivity values of the reflective insulation product's surfaces and tape's surfaces can lead to significant impact on the measured thermal resistance of the reflective insulation product, because heat transfer through such insulation products takes place also by convection and radiation, which are dependent on the temperature difference and emissivity of surfaces.

The research on the multilayer reflective insulation products is constantly performed in Building Physics Laboratory of KTU. The long-term measurement practice showed that the quality of specimens' preparation works, the installation procedure of testing specimens into orifice or surround panel of the GHB and the attaching of thermocouples on specimens' surfaces have a significant influence on the final measurement result of specimen's thermal resistance. The measurement practice of the reflective insulation products in the laboratory also revealed a few significant factors, which have influence on the thermal resistance measurement result for these products:

- for maintaining the exact thickness of the specimens, it is necessary to use a frame with known dimensions and materials' thermal properties;
- then should be evaluated the effect of such the frame on the overall measurement result;
- the thermal resistance of air gaps should be calculated according to the standard procedure;
- the influence of difference between emissivity values of reflective insulation product's surface and surface of tapes, which stuck the thermocouples on the reflective surface on accuracy of thermal resistance measurement result should be determined.

Consequently, the design of multilayer reflective products, searching for the best combinations of product dimensions, materials and surface emissions finding the most optimal parameters, manufacturing of the products executing the created design and the procedure of measurement of thermal properties are equally important for the development of multilayer products **(Stonkuvienė et al., 2022).**

The hot box method is one of the most reliable ways to determine the thermal properties of building envelopes or fragments under laboratory conditions. The hot box is a laboratory device designed to replicate the normal boundary conditions between a sample and two different environments. This apparatus consists of the hot and cold chambers at different temperatures between which a sample is placed. Scheme of climate chamber „Hot box“ (GHB) is shown in **Figure 5.**

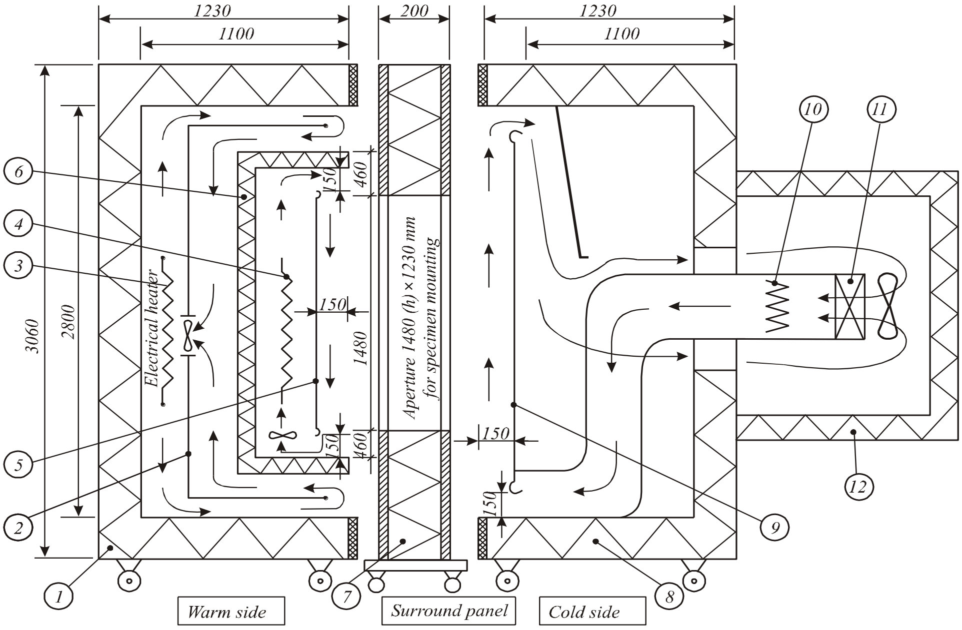


Figure 5 - Scheme of climate chamber Hot box

1. Warm side guard box:
- internal dimensions 2800 × 2800 × 1100 mm;
- wall thickness 130 mm, total thermal resistance about 3 m2·K/W.
2. Guard air flows deflecting screen.
3. Electrical heater, power 660 W, controlled according to a set point temperature in metering box(6).
4. Electrical heater of metering box, power control from 13W to 660 W.
5. Warm side baffler (of metering box) with surface and air temperature sensors.
6. Metering box - internal dimensions 2400 × 2400 × 360 mm.
7. Surround panel: 200 mm thick, core material EPS polystyrene (faced with 3 mm thick cellular PVC plastic sheet on either side), thermal resistance about 6 m2·K/W, 1484 x 1234 mm aperture for specimen mounting.
8. Cold side box:
- internal dimensions 2800 × 2800 × 1100 mm;
- wall thickness 130 mm, total thermal resistance about 3 m2·K/W.
9. Cold side baffler with surface and air temperature sensors.
10. Cold side box controlled
11. Cold side controlled cooling air unit, max. cooling power up to 3 kW.
12. Cold side air cooling box with 5 speed motor fan. electrical heater, max. power 2 kW **(Liu et al., 2023).**

3.5 Analysis of the use of materials in building projects

Multifoil insulation effectively reduces heat transfer through all three mechanisms: conduction, convection, and radiation. By utilizing low-emissivity foil layers, the transfer of heat via radiation is minimized. The thermal layers further inhibit conduction, while multifoil insulation acts as an air barrier, controlling air leakage. This air leakage control is crucial for enhancing energy efficiency and mitigating heat transfer caused by convection.

The reflective properties of foil layers make multifoil insulation highly versatile, suitable for use in various building components such as roofs, walls, and floors. It can be applied independently in single or dual configurations or combined with traditional non-reflective insulation materials. This

flexibility allows multifoil insulation to be utilized across diverse construction projects, from new developments to renovations, meeting U-value requirements efficiently.
Multifoil insulation can be installed externally by wrapping it around the building as a protective envelope to block air transfer or internally in applications such as cavity walls, floors, pitched roofs, and angled ceilings. Reflective insulation is most effective when integrated during the construction phase, as retrofitting can be challenging. A minimum air gap of 25 mm between the reflective side and adjacent materials is essential to maintain thermal performance; without this gap, the insulation loses its thermal efficacy. The orientation of the reflective surface is critical: downward for roofs, upward under floors, and inward for walls **(Kou et al., 2020).**

For roofs, reflective insulation should be installed at a downward angle to minimize dust accumulation, which can diminish its reflective properties. When used under floors or above ceilings and joists, precautions are necessary due to the foil's electrical conductivity, requiring non-conductive fasteners for safe installation.

Foil-faced insulation also provides excellent fire performance. It is fully non-combustible, and the aluminum foil enhances safety by offering additional fire protection, making it a reliable choice for modern construction practices.

4 RESULTS AND DISCUSSION

4.1 Roof/Ceiling

The roof is a critical element of a building's envelope, as it is highly exposed and significantly impacted by solar radiation. It plays a major role in a building's overall thermal performance, accounting for substantial heat gain and loss. With rising energy costs and the increasing demand for energy efficiency, reducing heat gain during hot summers and minimizing heat loss during cold winters has become imperative.

Thermal insulation serves as an effective passive solution to mitigate heat transfer through the roof. Its primary function is to slow or prevent the transfer of heat via convection, conduction, and radiation. The choice of appropriate insulation depends on several factors, including climatic conditions, architectural constraints, cost, durability, ease of installation, material availability, the predominant mode of heat transfer, and the overall performance of the insulation.

An example of roof insulation using reflective materials is illustrated in **Figure 6.** The R-value for such a roof system, incorporating standard boundary resistances, typically falls within the range of 1.7 to 2.1 m²·K/W.

Given the diverse properties of insulation materials, their selection and installation should adhere strictly to the manufacturer’s guidelines to ensure optimal performance.

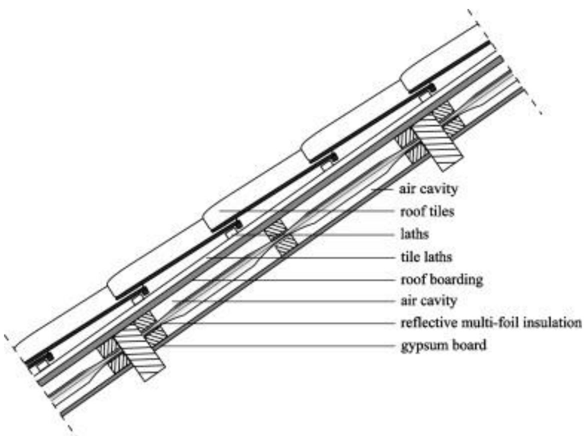


Figure 6 - Example of a roof construction with reflective multi-foil insulation **(Tenpierik & Hasselaar, 2013).**

4.2 Wall

In existing buildings, the potential to enhance the thermal performance of external walls depends largely on the structural characteristics of the wall. In many cases, the viable options are limited to applying insulation either to the external surface or internally on the inner side of the wall.

The type of construction - whether it involves traditional block or brick, steel, or timber framing - plays a significant role in determining the appropriate insulation approach. External wall insulation is a widely used solution for solid walls and is often the only feasible option when internal insulation would lead to a substantial reduction in usable floor space.

In retrofit scenarios, insulating the external wall is frequently the most practical solution. However, for new constructions, a combination of both external and internal insulation can be effectively implemented to achieve or even exceed the desired thermal performance.

An example, as shown in **Figure 7**, illustrates a timber frame wall incorporating both reflective multi-foil insulation and 60 mm of mineral fiber insulation. The R-value for this wall system, including standard boundary resistances, typically ranges between 3.7 and 4.1 m²·K/W.

Given the varying characteristics of insulation materials, their selection and installation should strictly follow the manufacturer's guidelines to ensure optimal performance and durability **(Zhong & Asad, 2021).**

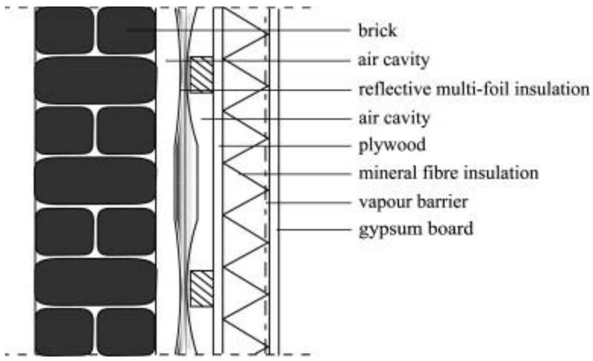


Figure 7 - Example of a timber frame wall with both reflective multi-foil insulation and mineral fibre insulation **(Tenpierik & Hasselaar, 2013).**

4.3 Floors

Insulating solid floors is essential for reducing heat loss and maintaining stable indoor temperatures. However, traditional insulation methods for solid floors often lead to a reduction in usable space due to limitations in floor depth. Adding a vapor-proof membrane can further complicate installation. If the insulation lacks vapor resistance, warm and moist air can degrade its thermal performance over time, potentially causing long-term damage to the building structure. An example of a solid floor insulated with reflective multi-foil materials is shown in **Figure 9.**

Suspended timber floors, common in older houses, consist of timber boards supported by joists just above the building's foundation. These floors are prone to significant heat loss, particularly if there are gaps between floorboards that allow draughts. Insulating suspended timber floors is strongly recommended due to their vulnerability to moisture and air leakage. Effective insulation and draught-proofing of these floors can improve thermal comfort and lead to noticeable reductions in energy costs. An example of a suspended timber floor insulated with reflective multi-foil materials is illustrated in **Figure 8 (Tape University, 2022).**

Given the diverse properties of insulation materials, their selection and installation should be performed in strict accordance with the manufacturer’s guidelines to ensure optimal functionality and durability.

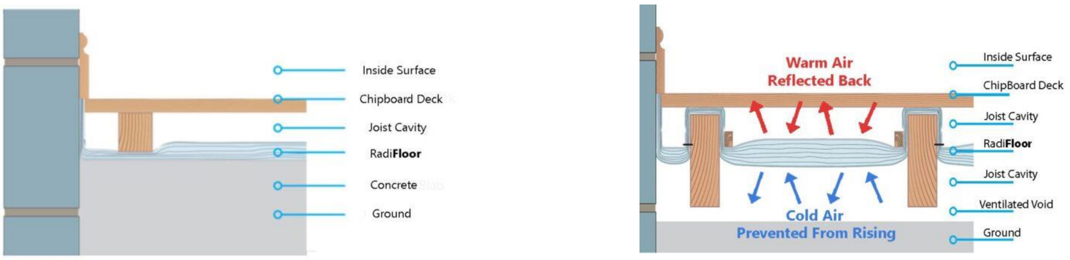


Figure 8 - Example of a suspended timber floors insulation with reflective multi-foil insulation

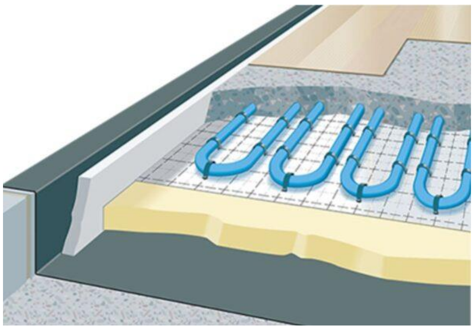


Figure 9 - Example of a solid floors insulation with reflective multi-foil

4.4 HVAC

Reflective foil insulation is also effective for insulating HVAC systems by wrapping ductwork to minimize radiant heat gain and loss. This helps enhance the performance of the HVAC system and improves overall energy efficiency in buildings. By reflecting radiant heat emitted by the ducts back onto their surface, reflective insulation maintains the temperature of the ductwork, thereby preserving the temperature of the air within the system. This improves the system's efficiency, enabling it to maintain the desired indoor temperature for extended periods without additional energy consumption**(Kravvaritis, 2011).**

One of the primary advantages of reflective insulation is the cost savings it provides through enhanced energy efficiency. By allowing the HVAC system to heat or cool spaces more rapidly and maintain the target temperature, reflective insulation reduces energy usage, resulting in lower utility bills. Homeowners and business owners often report significant energy cost savings, particularly if the HVAC system was older or less efficient prior to the installation of reflective insulation. An example of HVAC system insulation utilizing reflective multi-foil materials is presented in **Figure 10.**

To ensure reflective insulation performs optimally, proper installation is critical. This includes maintaining air gaps and using specialized HVAC tape designed to withstand year-round unconditioned environments **(Insulation Less, 2022).**

Figure 10 - Example of a HVAC system insulation with reflective multi-foil **(Lee et al., 2016).**

5 CONCLUSIONS

In summary, it is crucial to remember that foil-faced insulation is one of the most modern forms of home insulation, serving dual functions. Its insulating core protects against cold, while its aluminum foil reflects heat back to its source. This ensures that the insulation is always effective and fulfills its purpose. The aluminum foil on the upper part of the insulation can, under specific conditions, act as a Vapor Control Layer (VCL) and provide additional protection against rodents, for whom the foil may be irritating.

The reflective technology integral to multi-layer insulation can assist in reducing thermal losses from buildings. Given this alternative approach to thermal performance, specifiers now need to consider surface emissivity and thermal resistance when specifying thermal insulation products.

REFERENCES

1. **Gailius, A., & Vėjelis, S.** (2012). Acoustic and Thermal Insulation Materials. Vilnius: Technika. eISBN: 978-609-457-395-8. https://doi.org/10.3846/1427-S Retrieved from: https://ru.scribd.com/document/440375946/1427-Gailius-Akustines-WEB
2. **Pruteanu, M., Radu, A., Ciobanu, A., & Iacob, A.** (2011). A closer examination of the thermal performance of multifoil insulations. ModTech International Conference - New Face of TMCR.
3. **Tenpierik, M. J., & Hasselaar, E.** (2013). Reflective multi-foil insulations for buildings: A review. Energy and Buildings, *56*, 233–243. https://doi.org/10.1016/j.enbuild.2012.10.003
4. **LST EN ISO 22097:2023.** Thermal insulation for buildings – Reflective insulation products – Determination of thermal performance [Standard]. Retrieved from: https://www.iso.org/standard/72538.html.
5. **TLX Insulation.** (22.12.2020). What is multifoil insulation? Retrieved from: https://tlxinsulation.co.uk/what-is-multifoil-insulation/
6. **Lee, S. W., Lim, C. H., & Bin Salleh, E. I.** (2016). Reflective thermal insulation systems in buildings: A review on radiant barrier and reflective insulation. Renewable and Sustainable Energy Reviews, 65, 643–661. https://doi.org/10.1016/j.rser.2016.07.002
7. **Stonkuvienė, A., Burlingis, A., Ramanauskas, J., & Banionis, K.** (2022). Determination of core thermal resistance errors of reflective multifoil insulation products measured in a hot box depending on evaluation accuracy of its low emissivity surfaces. Journal of Building Engineering, *59*, 105143. https://doi.org/10.1016/j.jobe.2022.105143
8. **SuperFOIL Insulation.** (2021). Retrieved from: https://www.superfoil.co.uk/applications/
9. **Tape University.** (2022). What are the benefits of reflective insulation for HVAC ductwork? Retrieved from: https://tapeuniversity.com/industry/hvac-industry/what-are-the-benefits-of-reflective-insulation-for-hvac-ductwork/.
10. **Insulation Less.** (2022). Reflective insulation. Retrieved from: https://www.insulation4less.com/reflective-insulation.
11. **Lee, M., Lee, K., & Seo, W.** (2012). Analyses on performances of heat and multilayer reflection insulators. Journal of Central South University, 19(6), 1645–1656. https://doi.org/10.1007/s11771-012-1188-x
12. **Kravvaritis, E. (2011).** Testing reflective insulation for improvement of buildings energy efficiency. *Open Engineering*, *1*(3), 346–352. https://doi.org/10.2478/s13531-011-0036-3
13. **Liu, B., Wang, Y., Rabczuk, T., Olofsson, T., & Lu, W.** (2023). Multi-scale modeling in thermal conductivity of Polyurethane incorporated with Phase Change Materials using Physics-Informed Neural Networks. Retrieved from:. https://arxiv.org/abs/2307.16785
14. **Kou, R., Zhong, Y., Wang, Q., Kim, J., Chen, R., & Qiao, Y.** (2020). Thermal Insulating Polymer-Air Multilayer for Window Energy Efficiency. Retrieved from: https://arxiv.org/abs/2005.14395
15. **Zhong, Y., & Asad, M. S.** (2021). Transparent planar solar absorber for winter thermal management. Retrieved from: https://arxiv.org/abs/2106.12008