DOI:10.34918/87367

Sandra PRZEPIÓRKOWSKA[1], Aleksandra ŚLIWA[2], Jakub ŚWIDZIŃSKI[3]

7. MYCELIUM-BASED INSULATION MATERIALS AS AN ECOLOGICAL ALTERNATIVE TO MINERAL WOOL

7.1. Introduction

The main contributor to global energy consumption n and CO2 emissions are building industry and transport[4]. One of the measures taken to decarbonize the sector is the tightening of the legislation oriented toward reducing the energy inputs for heating and cooling the buildings[5]. To comply with these standards both during the design process for the new buildings and as a factor in improving energy efficiency within the existing ones, larger amounts of insulation materials or insulation materials with lower thermal conductivity parameters are used. The manufacturing of building insulation materials has a damaging effect on the environment, and they are expected to take hundreds of years to decompose. The pursuit of sustainable materials that can be easily disposed at the end of their life cycle may contribute to the improvement of the unfavorable ecological balance. Bio-based architectural materials and low-tech components, characterized by simple processing methods and possibilities of reuse or natural decomposition fit into the principles of sustainable development[6]. One of the encouraging ecological alternatives are mycelium-based materials. Considering the

[1] Silesian University of Technology, Faculty of Architecture, Department of Urban and Spatial Planning, Gliwice, e-mail: sandra.przepiorkowska@polsl.pl.
[2] Silesian University of Technology, Faculty of Architecture, Department of Residential and Public Architectural Design, Gliwice, e-mail: aleksandra.sliwa@polsl.pl.
[3] Silesian University of Technology, Faculty of Architecture, Department of Urban and Spatial Planning, Gliwice, e-mail: jakub.swidzinski@polsl.pl.
[4] United Nations Environment Programme: 2020 Global status report for buildings and construction: towards a zero-emission, efficient and resilient buildings and construction sector, Nairobi, 2020.
[5] DZ.U. 2020, poz. 2351: Rozporządzenie Ministra Rozwoju, Pracy i Technologii z dnia 21 grudnia 2020 r. zmieniające rozporządzenie w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie, 2020.
[6] Wasilewska A., Pietruszka B.: Materiały naturalne w ekobudownictwie, Przegląd Budowlany, 2017, Vol. 88, No. 10, pp. 50–53.

promising results of research on their properties[7] and the output of this paper, their implementation in construction would represent a shift toward the natural and sustainable materials that contribute to the reduction of the CO_2 emissions and lower the amount of construction sector waste production[8]. The integration of mycelium-based construction materials, exemplifies a futuristic approach to building infrastructure in smart cities, aligning with the principles of sustainable urban development.

7.2. Methodology and context of the study

The presented research is a continuation of the work on the application of mycelium-based sustainable materials in construction. The first phase culminated in a paper presented at the International Scientific Conference ACPS 2021: Architecture, City, People, Structure in 2021 on "Mycelium-based materials in architecture. A critical review". Previous analyses have shown that the conventional building material that most closely approximates the properties of mycelium-based materials are mineral and glass wools. This paper focuses on the possibility of implementing mycelium-based products in selected types of building partitions that involve various wools.

The aim of the research is to verify whether commercially available mycelium-based insulations may be applied as substitutes for conventional building materials. Due to the theoretical nature of the research, the next step is to implement the analysed solutions in practice in order to make appropriate measurements. At this stage, the intention of the authors is to provide a wider range of information on the potential applications of mycelium-derived organic materials.

In 2020, in Poland, 89.289 single-family houses were put into use, which is 97% of all newly constructed residential buildings, and for another 105.566 (out of 107.590 residential buildings overall) building permits were obtained[9]. Hence, for the purpose of this study, the partitions of a typical example of residential construction of a single--family building were analysed.

Past implementations using mycelium are primarily experimental exhibition displays, temporary buildings, and structures that do not directly alter building practices in Poland. Among the best known are the 2014 "Hi Fy" tower at the Museum of Modern Art in

[7] Mitchell J., Mautner A., Luenco S., Bismarck A., John S.: Engineered mycelium composite construction materials from fungal biorefineries: A critical review, Materials & Design, 2020, Vol. 187.
[8] Xing Y., Brewer M., El-Gharabawy H., Griffith G., Jones P.: Growing and testing mycelium bricks as building insulation materials. [In:] IOP Conference Series: Earth and Environmental Science, IOP Publishing, 2018, Vol. 121: 022032.
[9] GUS, Budownictwo w 2020 roku, Źródło danych GUS, 2020.

New York, the 2016 Shell Mycelium Pavillion as part of the Kochi-Muziris Biennale, the Growing Pavilion developed for Dutch Design Week in Eindhoven in 2019, and Circular Garden, an art installation that grew for Milan Design Week in 2019[10].

Comparative analyses are based on data obtained from manufacturers: BIOHM (further referred to as “mycelium-based material (1)”), Mycellium.CO (further referred to as “mycelium-based material (2)”), Mushroom® Packaging (further referred to as “mycelium-based material (3)”), Grown.bio (further referred to as “mycelium-based material (4)”) and MOGU (further referred to as “mycelium-based material (5)”). The products range from indoor acoustic panels to fire and water-resistant panels suitable for outdoor applications. The aim of the research is to verify whether the available products can replace wool and to what extent.

7.3. Characteristics of mycelium-based materials

The physical properties of mycelium are dependent on a number of factors: species, substrate and substrate type, supplementary materials used, processing technology, growth conditions, and drying method[11]. After drying, mycelium acquires its final technical properties, its resistance to external influences such as water and fire, as well as a measurable and controllable hardness. Dried form also prevents from uncontrolled growth and allergic reactions that are caused by spores, which are inactivated. Due to a large number of variables, the final material properties must be determined on the basis of specific product data (Table 7.1). Previous research proves the possibility of using mycelium products in the construction industry, and the parameters meet or exceed widely used conventional materials, including synthetic[12].

[10] Przepiórkowska S., Śliwa A., Świdziński J.: Biomateriały przyszłości – grzybnia, Architektura murator, 2022, Vol. 03, pp. 84–89.
[11] Xing Y., Brewer M., El-Gharabawy H., Griffith G., Jones P.: Growing and testing mycelium bricks as building insulation materials. [In:] IOP Conference Series: Earth and Environmental Science, IOP Publishing, 2018, Vol. 121: 022032.
[12] Radziszewska-Zielina E.: Analiza porównawcza parametrów materiałów termoizolacyjnych, mających zastosowanie jako izolacja ścian zewnętrznych, Przegląd Budowlany, 2009, pp. 32–37.

Table 7.1

Technical parameters of mycelium-based materials and mineral wools *[13],**[14],***[15]

material		1	2	3	4	5	stone wool	glass wool
standard		UK	USA	USA	USA	EU	EU	EU
physical performance	density [kg/m³]	128	180 (ASTM C303)	120 (ASTM C303)	115,5 (AVANS)	180	40–200*	15–75*
physical performance	thermal conductivity [W/mK]	0,024 (LBU Labs)	0,059 (ASTM C518)	0,039 (ASTM C518)	0,058 (ASTM C155)	0,05 (UNI EN12664-2)	0.031–0.037 *	0.033–0.040 *
physical performance	compressive strength [MPa]	0,12 – 0,14	0,172 (ASTM C165)	0,124 (ASTM C165)	0,0021–0,046 (10% compress.) 0,49-1,79 (50% compress.) (ASTM D695)	0,01072 (UNI EN 826)	0,015 *	0,015–0,030*
physical performance	acoustic characteristics [NRC] (ISO 354)	data not avail.	0,53 at 2000Hz	data not avail.	data not avail.	0,4–0,6 at 2000 Hz (depending on shape)	0,9–1,15 at 1000 i 2000Hz (NRC) **	0,9–1,15 at 1000 i 2000Hz (NRC) **
fire performance	fire reaction (UNI EN 13501-1)	data not avail.	data not avail.	data not avail.	data not avail.	B-s1-d0	A1–A2 *	A1–A2*
fire performance	heat of combustion [MJ/kg] (EN ISO 1716)	16.36	data not avail.	data not avail.	data not avail.	data not avail.	18	11,54 MJ/kg ***
fire performance	flame spread [m²/m²] (ASTM E84)	data not avail.	18 class A	20 class A	20 class A	data not avail.	0 class A	≥0 class A
fire performance	smoke emission [m²/m²] (ASTM E84)	data not avail.	data not avail.	50	50	data not avail.	---------	max 25

[13] Radziszewska-Zielina E.: Analiza porównawcza parametrów materiałów termoizolacyjnych, mających zastosowanie jako izolacja ścian zewnętrznych, Przegląd Budowlany, 2009, pp. 32–37.

[14] Srivastava R.K., Dhabal R.L., Suman B. M., Saini A., Panchal P.: An estimation of correlation on thermo-acoustic properties of mineral wool, 2006.

[15] Półka M., Sulik P.: Analiza wybranych parametrów pożarowych wełny mineralnej i układów wełna mineralna-tynki cienkowarstwowe, Zeszyty Naukowe SGSP/Szkoła Główna Służby Pożarniczej, 2010, Vol. 40, pp. 99–111.

continue table 7.1

water reaction	water vapor permeation [dry cup] (ASTM E96)	data not avail.	30 permab.	30 permab.	data not avail.	data not avail.	---------	50
water reaction	moisture storage [m^3/m^3*100%] (ASTM C1498)	data not avail.	8 at 60% RH 12 at 80% RH	8 at 60% RH 12 at 80% RH	data not avail.	data not avail.	---------	water absorption by volume after long-term partial immersion ≤3%
other	compostability [days] (ASTM D6400)	data not avail.	35	30	data not avail.	data not avail.	>100 years	>100 years

Source: Data based on own research and interviews with designers and manufacturers of mycelium-based insulation conducted from March through May 2021 (submitted to publication via the ACPS conference).

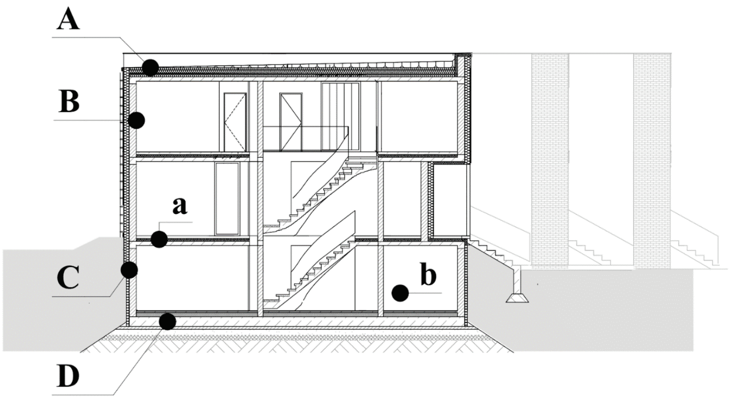
7.4. Potential for implementation

7.4.1. The scope of analysis

For the research, we have selected basic partitions in a single-family terraced building. The building is a part of an estate of 24 terraced houses completed in Gliwice in the year 2022. Completed buildings with an area of 150 m^2 on 3 floors meet the requirements for annual consumption of primary energy through the use of properly insulated partitions and application of the modern, energy-optimal installation solutions such as floor heating, heat pump system, mechanical ventilation with recuperation and recirculation. The appropriate scale and technology of the buildings and their typology allow an analysis of the building envelope in terms of the replacement of the insulation materials used with mycelium-based in order to cut down carbon footprint and decrease construction waste at the end of the building lifecycle. The investigated partitions are marked in Figure 7.1, and data on their thermal and fireproof requirements are presented in Table 7.2. The analysis assumes that the official guidelines contained in the regulations[16] for each building envelope are fulfilled. A detailed thermal diffusivity

[16] DZ. U. 2020, poz. 2351: Rozporządzenie Ministra Rozwoju, Pracy i Technologii z dnia 21 grudnia 2020 r.

analysis of the discussed partitions is also necessary, considering the significant consequences that may arise from moisture infiltration under unfavorable thermal--humidity conditions in the environment.



Exterior partitions: A – flat roof, B – exterior wall, C – basement wall, D – foundation slab

Interior partitions: a – inter – apartment party wall, b – inter – story floor

Fig. 7.1. Scheme of investigated partitions
Rys. 7.1. Schemat badanych przegród
Source: Author's scheme, 2022.

Table 7.2

Thermal and fireproof requirements of partitions

	heat transfer coefficient U [W/(m²K)]	fire resistance rating R – load bearing capacity [min] E – integrity [min] I – insulation [min]
exterior partitions		
flat roof	0,15	no requirements
exterior wall	0,20	no requirements
basement wall	no requirements	no requirements
foundation slab	0,30	no requirements
interior partitions		
inter-apartment party wall	1,00	REI60
inter-story floor	no requirements	no requirements

Source: Data based on Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie[17].

zmieniające rozporządzenie w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie, 2020.

[17] DZ. U. 2020, poz. 2351: Rozporządzenie Ministra Rozwoju, Pracy i Technologii z dnia 21 grudnia 2020 r. zmieniające rozporządzenie w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie, 2020.

7.4.2. External partitions

7.4.2.1. Flat roof

A typical solution was applied in the analysed building – a full flat roof based on a reinforced concrete slab, insulated with 20 cm mineral wool and with a sloping layer made of hard wool, the roof covering is an EPDM membrane (technical parameters presented in Table 7.3). In this partition, it is particularly important to maintain the highest level of airtightness and legally required thermal conductivity levels. In addition, the roof area should be suitable for servicing the roof of the building, which houses the air conditioning units, the air source heat pump and the solar panels.

Table 7.3

Technical parameters of the flat roof with primary insulation material

partition	**material**	**thickness [m]**	**thermal conductivity [W/(mK)]**	**thermal resistance [(m^{2}K/W]**
flat roof	EPDM membrane (roofing)	-	0.130	0.012
	hard mineral stone wool (sloping layer)	0.05	0.040	5.000
	mineral stone wool with ventilation	0.20	0.037	5.405
	vapor proof membrane	-	0.170	0.001
	reinforced concrete	0.15	1.700	0.206
	cement-lime plaster	0.01	1.000	0.020
		0.41	U = 0.145 [W/(m^{2}K)]	

Source: Data calculated based on producer data from Table 3.1.

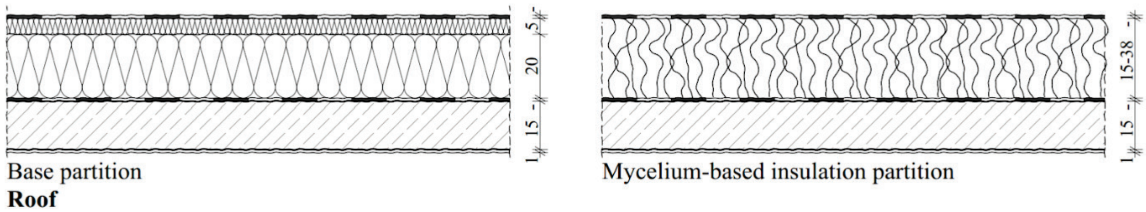


Fig. 7.2. Scheme of investigated partition
Rys. 7.2. Schemat badanej przegrody
Source: Author’s scheme, 2022.

Table 7.4

Technical performance of primary and alternative mycelium-based insulation materials

<table>
<tr><th colspan="2">material</th><th>thickness [m]</th><th>thermal conductivity [W/(mK)]</th><th>thermal resistance [(m²K/W]</th><th>partition U [W/(m²K)]</th><th>total partition thickness [m]</th></tr>
<tr><td colspan="2">hard mineral stone wool</td><td>0.05</td><td>0.040</td><td>5.000</td><td rowspan="2">0.145</td><td rowspan="2">0.41</td></tr>
<tr><td colspan="2">stone wool</td><td>0.20</td><td>0.037</td><td>5.405</td></tr>
<tr><td rowspan="5">mycelium-based materials</td><td>(1)</td><td>0.15</td><td>0.024</td><td>0.833</td><td>0.15</td><td>0.31</td></tr>
<tr><td>(2)</td><td>0.38</td><td>0.059</td><td>0.847</td><td>0.15</td><td>0.54</td></tr>
<tr><td>(3)</td><td>0.25</td><td>0.039</td><td>1.026</td><td>0.15</td><td>0.41</td></tr>
<tr><td>(4)</td><td>0.38</td><td>0.058</td><td>0.862</td><td>0.15</td><td>0.54</td></tr>
<tr><td>(5)</td><td>0.32</td><td>0.05</td><td>1.000</td><td>0.15</td><td>0.48</td></tr>
</table>

Source: Data calculated based on producer data from Table 3.1.

With the tested mycelium-based materials, the thickness of the applied partitions vary from 31 cm to 54 cm (Figure 7.2, Table 7.4). The disadvantage of the solution is a significant increase in the weight of insulation, which must be taken into account when designing the building structure. There are also doubts concerning the connection of the insulation with the roof water insulation, which require additional verification.

Mycelium is thus suitable for roofs not prone to flooding, i.e. inverted flat roofs (green, terrace). It is not suitable for inverted flat roofs due to the danger of biological corrosion as the waterproofing layer is embedded below the thermal insulation layer. Mycelium can be also used in a solid roof covered with roofing membrane. A combination of different types of roofing materials that are normally used with wools (i.e., e.g., surface felt and underlayment or single-ply roofing felt or PVC, FPO, TPO, or EPDM membrane) is to be further investigated. There are anticipated pest issues in partitions containing mycelium; as it is a natural insulating material, an additional separation layer may be required to protect against pests. Another of the concerns related to the roof envelope is biological corrosion in the case of application of insulation in terrace roof, slotted ventilated roof, and ducted ventilated roof.

7.4.2.2. Exterior wall

Exterior wall in the building is a three-layer masonry wall. The main bearing structure consists of 25 cm wide ceramic blocks and is insulated by hard stone wool. The final layer is clinker tile, glued to the insulation. Thermal transmittance of the partition is U = 0,17 [W/m^{2}K)] which is more than enough to comply with requirements implemented by polish law in 2021 (Table 7.5). The official minimal requirement of thermal transmittance of the external wall is U≤ 0,2 [W/m^{2}K)] and this value is the basis for analysing the feasibility of using an alternative insulation bio-material.

When using mycelium-based insulation, the width of the partition will increase in 3 cases, while it will decrease significantly if isolation 1 is used (Figure 7.3, Table 7.6). It is also important to pay attention to the mass of insulation, which for 1m^2 of partition insulated with wool is 15.6 kg while using alternative materials will increase even more than 3 times. For this reason, the technology of fixing should include additional mechanical elements securing the connection of thermal insulation with construction material.

Table 7.5

Technical parameters of the exterior wall with primary insulation material

partition	**material**	**thickness [m]**	**thermal conductivity [W/(mK)]**	**thermal resistance [(m^{2}K/W]**
exterior wall	clinker tile	0.02	1.000	0.020
	stone wool	0.20	0.040	5.000
	ceramic block	0.25	0.313	0.799
	cement-sand plaster	0.02	1.000	0.020
		0.49	U = 0.170 W/(m^{2}K)	

Source: Data based on the construction project.

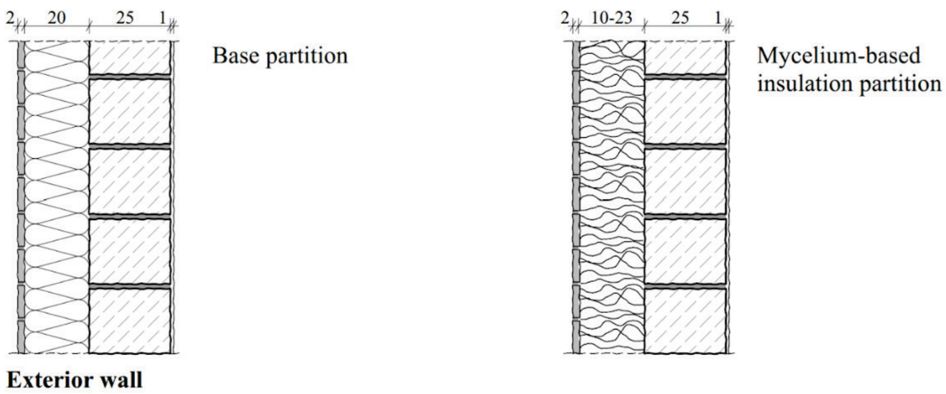


Fig. 7.3. Scheme of investigated partition
Rys. 7.3. Schemat badanej przegrody
Source: Author’s scheme, 2022.

Table 7.6

Technical performance of primary and alternative mycelium-based insulation materials

material		thickness [m]	thermal conductivity [W/(mK)]	thermal resistance [(m^2K/W]	partition U [W/(m^2K)]	total partition thickness [m]
stone wool		0.20	0.040	5.000	0.170	0.49
mycelium-based insulation	(1)	0.10	0.024	4.167	0.200	0.41
	(2)	0.23	0.059	3.898	0.200	0.57
	(3)	0.16	0.039	4.103	0.200	0.48
	(4)	0.23	0.058	3.966	0.200	0.57
	(5)	0.20	0.05	4.000	0.200	0.53

Source: Data calculated based on producer data from Table 3.1.

7.4.2.3. Basement wall

The basement wall is based on a reinforced concrete foundation slab, poured on site. Due to its location below ground level, the basement wall is additionally protected with vertical waterproofing. The main structure is insulated with a 10 cm layer of hard wool. A finishing layer of bucket foil was laid in order to additionally protect the wall against the pressure of the ground and to enable efficient draining of the rainwater. The required thermal transmittance coefficient of an underground wall is not specified in national regulations. Nevertheless, according to the construction standards, thermal insulation is necessary to prevent ground frost, so the coefficient for existing wall is at a level of U = 0.21 [W/m2*K], the performance of the investigated partition is specified in Table 7.7.

The use of alternative insulation materials, depending on the adopted solution, assuming the thermal parameters of the partition are maintained, will change the dimensions of the wall (Figure 7.4, Table 7.8). Due to the location, the width of underground wall layers is of secondary importance. Much more important issue is to ensure the tightness of walls exposed to rainwater and groundwater. It should be noted that, due to the substantial risk of moisture infiltration, discussed insulation applied in basement wall, may pose a greater risk compared to its application in other types of partitions. In case of a high level of underground water it is necessary to use additional waterproofing, which is the same way as in using mineral wool. The increased mass of mycelium-based insulation in comparison to stone wool in case of basement wall also does not play an important role as the ground protects the insulation against mechanical damage and possible tearing off of the layer.

Table 7.7
Technical parameters of the basement wall with primary insulation material

partition	material	thickness [m]	thermal conductivity [W/(mK)]	thermal resistance [(m²K/W]
basement wall	dimpled foil	0.02	0.018	0.001
	stone wool	0.10	0.036	**2.778**
	waterproof membrane	0.00	0.018	0.001
	concrete block (500 kg/m3)	0.25	0.135	1.852
	cement-sand plaster	0.02	1.000	0.020
		0.38	U = 0.210 W/(m²K)	

Source: Data based on the construction project.

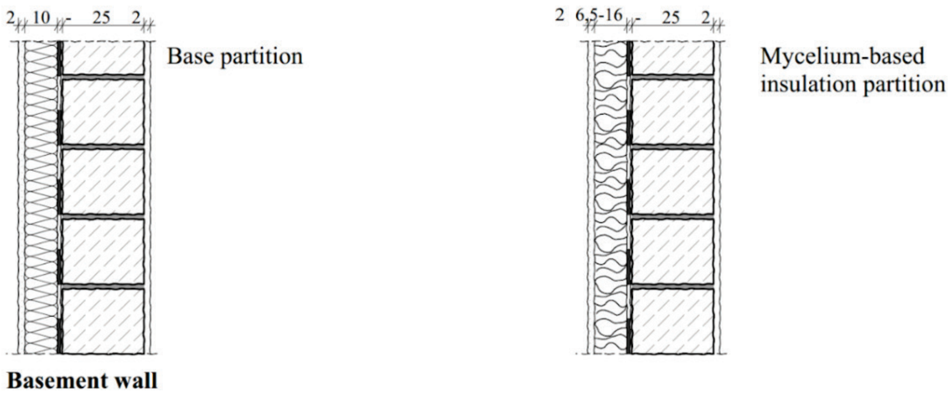


Fig. 7.4. Scheme of investigated partition
Rys. 7.4. Schemat badanej przegrody
Source: Author's scheme, 2022.

Table 7.8
Technical performance of primary and alternative mycelium-based insulation materials

material		thickness [m]	thermal conductivity [W/(mK)]	thermal resistance [(m²K/W)]	partition U [W/(m²K)]	total partition thickness [m]
stone wool		0.10	0.036	2.778	0.210	0.38
mycelium-based insulation	(1)	0.065	0.024	2.708	0.210	0.345
	(2)	0.16	0.059	2.712	0.210	0.44
	(3)	0.11	0.039	2.821	0.210	0.39
	(4)	0.16	0.058	2.759	0.210	0.44
	(5)	0.14	0.05	2.800	0.210	0.42

Source: Data calculated based on producer data from Table 3.1

7.4.2.4. Flooring on the foundation slab

Foundation thermal insulation is required to be waterproof and resistant to compression, so wools are not a common choice. There are, however, suitable stone wool based products for these applications which are suitable for use as thermal insulation under foundation slabs. In the considered example, the layered structure of the foundation slab includes insulation made of stone wool, meeting the criterion of thermal insulating capacity with layer thickness equal to 4 cm (Table 7.9). The primary thermal insulating material meets the following technical parameters which are important for this partition wall: density = 140 kg/m^3 and compressive strength at 10% relative strain ≥ 0.03 mPa. The tested substitute materials based on mycelium have comparable densities ranging from 115.5 (4) to 180 kg/m^3 (2 and 5).

Table 7.9

Technical parameters of the flooring on the foundation slab with primary insulation

partition	**material**	**thickness [m]**	**thermal conductivity [W/(mK)]**	**thermal resistance [(m^{2}K)/W]**
flooring on the foundation slab	floor ceramics	0.02	1.050	0.019
	concrete base	0.05	1.650	0.030
	vapour proof membrane	0.00	0.170	0.001
	stone wool	**0.04**	**0.039**	**1.026**
	reinforced concrete	0.35	1.700	0.206
	concrete	0.10	1.050	0.095
	sand	0.30	0.40	0.75
		0.86	**U=0.283** W/(m^{2}K)	

Source: Data based on the construction project.

As far as compressive strength is concerned, the materials (1,2,3 and 5) have properties with higher thermal parameters than those of stone wool; only mycelium--based insulation (4) is less resistant and may require reinforcement in this regard (in the case of humidity parameters, the opposite may be true). Due to their insulating properties, bio-materials correspond to the thermal resistance of stone wool while maintaining the same material thickness (3), slightly thicker – 5 cm (2, 4 and 5), and even a lower layer thickness of 2 cm for the material (1) - complete data is shown in Figure 7.5 and Table 7.10.

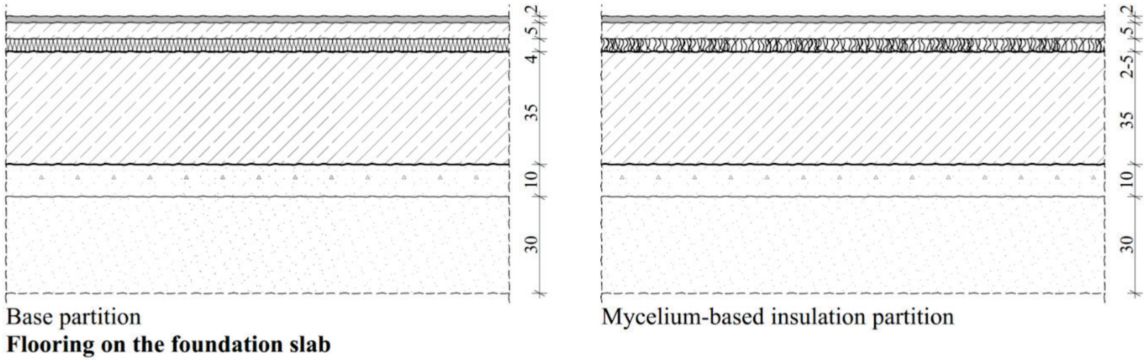


Fig. 7.5. Scheme of investigated partition
Rys. 7.5. Schemat badanej przegrody
Source: Author's scheme, 2022.

Table 7.10

Technical performance of primary and alternative mycelium-based insulation materials

material		thickness [m]	thermal conductivity [W/(mK)]	thermal resistance [(m²K)/W]	partition U [W/(m²K)]	total partition thickness [m]
stone wool		0.04	0.039	1.026	0.283	0.86
mycelium-based insulation	(1)	0.02	0.024	0.833	0.302	0.84
	(2)	0.05	0.059	0.847	0.300	0.87
	(3)	0.04	0.039	1.026	0.283	0.86
	(4)	0.05	0.058	0.862	0.299	0.87
	(5)	0.05	0.05	1.000	0,286	0.87

Source: Data calculated based on producer data from Table 3.1.

7.4.3. Interior partitions

7.4.3.1. Inter-apartment party wall with expansion joint

In the case of this estate of terraced houses, the partition wall between apartments also serves as a dilatation wall between the buildings. In this case, official guidelines specify that the heat transfer coefficient is U ≤ 1.0 [W/m2*K]. In addition, the key feature of such a partition is its fire load-bearing capacity, fire tightness and fire insulation, which must be at least 60 min. The partition is a wall built of 25 cm thick ceramic blocks on both sides, with a 5 cm wide dilatation on the full height of the wall, filled with mineral wool (Table 7.11).

The fireproofing requirement is fulfilled by a single layer of ceramic blocks. Similarly, as far as thermal parameters are concerned, the required permeability coefficient U ≤ 1.0 [W/m^{2}K] is met by a single layer of 25 cm hollow brick blocks with plaster on one side. The key distinguishing attribute of this wall is the occurrence of expansion joints, the width of which should be 5 cm between independent systems for structural reasons. This leads to the conclusion that the filling of the expansion joint is of little significance in terms of the legal requirements. However, the use of alternative bio-insulation will change the thermal performance of the compartment and significantly reduce the carbon footprint of the materials - the results of the survey are indicated in the Figure 7.6 and Table 7.12.

Table 7.11

Technical parameters of the inter-apartment party wall with expansion joint from primary insulation material

partition	**material**	**thickness [m]**	**thermal conductivity [W/(mK)]**	**thermal resistance [(m^{2}K/W]**
basement wall	cement-sand plaster	0.02	1.000	0.020
	ceramic block	0.25	0.313	0.799
	stone wool	**0.05**	**0.04**	**1.250**
	ceramic block	0.25	0.313	0.799
	cement-sand plaster	0.02	1.000	0.020
		0.59	**U = 0.320 W/(m^{2}K)**	

Source: Data based on the construction project.

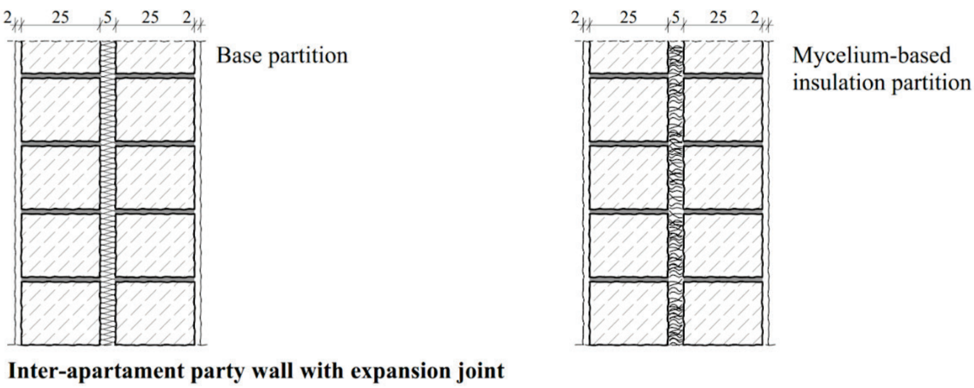


Fig. 7.6. Scheme of investigated partition
Rys. 7.6. Schemat badanej przegrody
Source: Author’s scheme, 2022.

Table 7.12

Technical performance of primary and alternative mycelium-based insulation materials

material		thickness [m]	thermal conductivity [W/(mK)]	thermal resistance [(m²K)/W]	partition U [W/m²K)]	total partition thickness [m]
stone wool		0.05	0.036	1.250	0.320	0.59
mycelium-based insulation	(1)	0.05	0.024	2.083	0.250	0.59
	(2)	0.05	0.059	0.847	0.370	0.59
	(3)	0.05	0.039	1.282	0.320	0.59
	(4)	0.05	0.058	0.862	0.360	0.59
	(5)	0.05	0.05	1.000	0.350	0.59

Source: Data calculated based on producer data from Table 3.1.

7.4.3.2. Inter-storey floor

In the case under consideration, the inter-storey ceiling is located between heated rooms of the same temperature, so it does not require thermal insulation. The ceiling structure is a reinforced concrete slab with a 10 cm layer of mineral wool on it, in which mechanical ventilation ducts are led, so the thickness of the layer results from reasons independent of the thermal insulation parameter (Table 7.13).

Table 7.13

Technical performance of primary and alternative mycelium-based insulation materials

partition	material	thickness [m]	thermal conductivity [W/(mK)]	thermal resistance [(m²K)/W]
inter-story floor	wood flooring	0.02	0.180	0.111
	concrete base	0.08	1.650	0.048
	vapour proof membrane	0.00	1.000	0.002
	stone wool	0.10	0.039	2.564
	reinforced concrete	0.15	1.700	0.088
	concrete	0.10	1.050	0.095
	cement-sand plaster	0.01	1.000	0.010
		0.36	U=0.316 W/(m²K)	

Source: Data based on the construction project.

Due to the lack of requirements related to the thermal insulation parameter, the thickness of material alternatives based on mycelium was calculated with the assumption that the layer thickness equals 10 cm (Figure 7.7, Table 7.14).

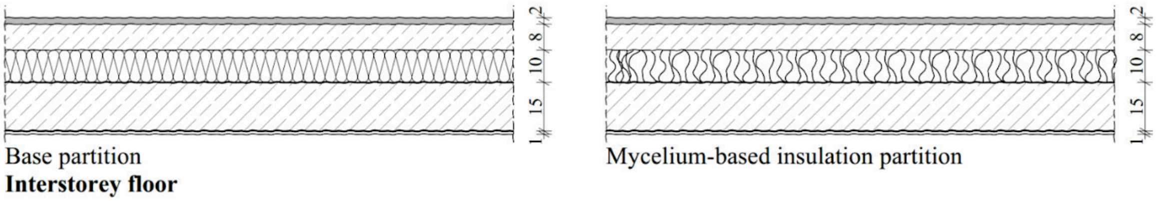


Fig. 7.7. Scheme of investigated partition
Rys. 7.7. Schemat badanej przegrody
Source: Author's scheme, 2022.

Table 7.14

Technical performance of primary and alternative mycelium-based insulation materials

Material		**thickness [m]**	**thermal conductivity [W/(mK)]**	**thermal resistance [(m²K)/W]**	**partition U [W/(m²K)]**	**total partition thickness [m]**
stone wool		0.10	0.039	2.564	0.316	0.36
mycelium-based insulation	(1)	0.10	0.024	4.167	0.210	0.36
	(2)	0.10	0.059	1.695	0.436	0.36
	(3)	0.10	0.039	2.564	0.316	0.36
	(4)	0.10	0.058	1.724	0.430	0.36
	(5)	0.10	0.05	2.000	0.385	0.36

Source: Data calculated based on producer data from Table 3.1.

7.5. Conclusions

The conducted analyses prove that in terms of thermal insulation parameter, ecological products based on mycelium can provide a substitute for conventional mineral wool insulation materials. Their performance often exceeds the relatively high insulating capacity of wools. The ability of mycelium panels to bond permanently with other materials, especially at high temperatures, is an issue that needs to be recognized and further investigated. In partitions not exposed to moisture, these materials can perform very well. As with mineral wools, the challenge is to maintain adequate compression resistance in horizontal partitions, but again, only one of the products may require further testing or reinforcement in the form of a substructure. An important parameter from the point of view of facade insulation may be the significant weight of mycelium-based materials requiring the development of an appropriate substructure. When implementing mycelium-based insulations, it is also crucial to evaluate project-specific conditions, with a particular focus on fire safety measures.