Insulation materials –

Properties

# Abstract

In this learning unit the properties of different insulation materials are described, basic terms are explained and assessment methods presented.

# Objectives

**On completing this unit students are able to …**

* Name the most important physical properties of insulation materials
* Explain the most essential terms and name the respective units
* Explain the different properties of insulation materials
* Explain the importance of the U value and additional properties of insulation materials with regard to wall structures
* List the most important aspects with regard to disposal, work safety and processing of insulation materials

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# What physical properties do insulation materials have?

To compare and evaluate different insulation materials, one needs to know their physical properties.

Depending on their

* thermal conductivity,
* heat transfer coefficient,
* fire-resistance rating,
* vapour diffusion resistance,
* specific heat capacity,
* soundproofing, and
* dimensional stability,

insulation materials can be used in differing areas of application.

## Thermal conductivity (λ value)

**Thermal conductivity** (unit = W/mK) is a material constant and **indicates how well a material transports heat**. It measures the amount of heat conducted per hour through a material 1 m thick over an area of 1 m2, if the difference between the air temperatures on both sides is 1 Kelvin.

A material’s **thermal conductivity** mainly **depends on its bulk density, temperature, pore or fibre structure, and moisture content**, because water has a high thermal conductivity and porous building materials tend to absorb water. Thermal conductivity is thus a temperature-dependent material constant.

**Rule of thumb**

The less the λ value, the better the material insulates.

## Heat transfer coefficient (U value)

The **heat transfer coefficient** (unit = W/m2K) **refers to a structure** and **indicates the heat flow through a standard cross-section over an area of 1 m2 per unit of time** if the difference between the air temperatures on both sides is 1 Kelvin.

 **U = 0.49 W/m2K U = 0.33 W/m2K U = 0.25 W/m2K**

Figure 1: U values at different insulation thicknesses (source: Dipl.-Kfm. Tobias Weißgerber, Marketing, ft Fenster & TürenForm GmbH, adapted)

**In contrast to thermal conductivity, the thicknesses of the respective building component are included in this calculation.** This makes the U value particularly important for comparing different structures. **It is not a material-specific value, like the λ value**, but is calculated from the thermal conductivity of the material (λ value) and the thickness of the insulation layer; so it always depends on the structure selected.

**Rule of thumb**

The smaller the U values (of building components), the lower the heating energy consumption (of the room enveloped by these building components).

## Fire-resistance rating

Insulation materials’ **fire resistance** is classified as per EN 13 501-1. The main **criteria** are **flammability, flame propagation, and heat released**. **Seven fire-resistance classes** are distinguished, with another seven for floors.

|  |  |
| --- | --- |
| **Class** | **Requirement** |
| **F** | Products whose resistance to fire cannot be determined or which cannot be classified in any of classes A1, A2, B, C, D, E. |
| **E** | Products capable of resisting a small flame attack without substantial flame propagation for a short time. |
| **D** | Products satisfying the criteria for class E and capable of resisting a small flame attack without substantial flame propagation for a longer time. In addition, they are also capable of withstanding thermal attack by a single burning item with sufficiently delayed and limited release of heat. |
| **C** | As class D, but satisfying more stringent requirements. In addition, under thermal attack by a single burning item these products exhibit limited lateral flame propagation. |
| **B** | As class C, but satisfying more stringent requirements. |
| **A2** | Satisfying the same criteria as class B for the SBI-test to EN 13823. In addition, in a full-scale fire these products do not significantly contribute to the fire load and the spread of the fire. |
| **A1** | Class A1 products do not contribute to the fire load and the spread of the fire at any stage, including a full-scale fire. For that reason they are assumed to be capable of satisfying all requirements of all lower classes automatically. |

Table 1: Fire-resistance classes to EN 13 501-1

## Vapour diffusion resistance (µ)

The **vapour diffusion resistance** is an **indicator of how far water vapour is hindered in diffusing within a material**. It is a dimensionless figure that shows how much greater a given material’s resistance is than that of a stationary layer of air of the same thickness. For a stationary layer of air, µ = 1.

**Rule of thumb**

An insulation material with a low µ value is called vapour permeable. In a vapour permeable structure water that has penetrated the insulation material can easily escape. The higher the µ value, the less vapour permeable the insulation material is. Thus it can less easily absorb moisture and transfer it to layers behind.

**Especially insulation materials made from natural fibres have low vapour diffusion resistance** and thus very good diffusion properties. Insulation materials obtained from plants or animals can usually absorb more water than other products without their insulation properties deteriorating much. They thus help to even out humidity indoors.

## Specific heat capacity (c)

The **specific heat capacity** (unit = J/kgK) is the **amount of heat needed to change the temperature of 1 kg of a material by 1 Kelvin**.

**Rule of thumb**

A material with a high specific heat capacity can store heat well, because a large amount of heat is needed to change the temperature of the substance.

The **specific heat capacity of an insulation material mainly affects a balanced temperature profile in buildings**, for example when differences between day and night temperatures are evened out.

## Soundproofing

Structures should not only protect from heat and cold; they should also reduce sound transmission, for example between an external sound source and residents indoors. Sound is defined as vibrations and their diffusion within an elastic body. The function of an insulated building component is to restrict this diffusion.

**A distinction is made between**

* airborne soundproofing and
* impact soundproofing.

sound transmission

sound reflection

sound event

sound absorption

Figure 2: Path of sound when it hits a body (source: Rockfon, adapted)

The airborne soundproofing provided by a building component is indicated by the Weighted Sound Reduction Index Rw (unit = dB, decibel). To arrive at this value, the contour of the measured sound reduction indices is fitted to a standardized reference contour. The Weighted Sound Reduction Index is then the value of this fitted contour at a frequency of 500 Hz.

The Weighted Normalized Impact Sound Pressure Level Lw,n (unit = dB, decibel) – relevant to floor structures – is calculated in a similar way and specified for impact soundproofing.

**Background on thermal insulation and soundproofing**

To achieve good thermal insulation and soundproofing at the same time one must take the entire structure into account, because individual component layers may have contrary material properties. In general low density with plenty of air pockets makes for good thermal insulation. On the other hand good soundproofing is achieved by high density. Where differing component layers alternate, this may be of particular advantage with respect to mechanical vibration and impact sound, e.g. for floating floor screeds. In special cases relatively dense insulation materials may be desirable (e.g. calcium silicate panels, straw bales, reed panels, softwood fibre panels).

## Dimensional stability

Especially for insulation panels and mats, dimensional stability (e.g. under the influence of pressure and temperature) is very important, because these products are prefabricated. But loose-fill and injected insulation materials also need some degree of stability, since voids in the insulation layer make a big difference to the insulation effect.

# How can insulation materials be assessed in terms of ecology and health?

To be able to compare insulation materials, one needs to know what other aspects are relevant apart from physical properties. A good first impression is given by the **Life Cycle Assessment of a product**. Apart from this, insulation materials can be evaluated in terms of **how they can be disposed** of after use and what **health effects** they have.

## Life Cycle Assessment (LCA)

A Life Cycle Assessment is a comprehensive evaluation based on as many environmental effects as possible (including potential effects). It is important to consider the whole life cycle of a product – “from the cradle to the grave”.

The **Life Cycle Assessment** of an insulation material also includes such **factors as useful life, availability of raw materials, resource consumption during production, and health effects during production, processing and usage**. One of the most important aspects, though, is the **structure’s energy consumption throughout its useful life**, since (when all is said and done) insulation materials are intended to save energy.

**Background on Life Cycle Assessment**

The assessment should include the amount of energy consumed in providing the insulation material or the entire structure. For this, **primary energy consumption** over the whole life cycle is considered, **covering processes of production, transport and processing**. The **disposal or re-use** of the product **after use** must also be taken into account.

If the structure is planned correctly, insulation materials save the same amount of energy in their first months (up to at most two years) of use as is necessary to produce and dispose of them. In other words they pay for themselves in energy terms within this time.

## Disposal

People often neglect the issue of disposal when choosing an insulation material, but waste from the construction sector accounts for a very high percentage of total waste.

## Health aspects

The insulation material selected may have health effects during both the building phase and actual use.

**Fibre insulation materials can emit respirable fibre dust** – particulates which can infiltrate into the lung. This applies for example to renovating structures incorporating older glass or rock wool products. In general, when fibre materials are installed or removed, skin, eyes and mucous membranes can be irritated unless adequate precautionary measures are taken. This is why **protection against dust** is absolutely necessary.

**Fire protection is an essential part of health protection.** Materials have to be installed in such a way that occupants’ safety is ensured in case of fire. Apart from the **immediate fire hazard** and the spreading of the fire, **combustion gases** are the key issue here. Almost all materials, including all organic materials such as insulation foams and biogenous materials, emit hazardous substances in such cases. The proportion of toxic components in the combustion products varies, but carbon monoxide, which in particular develops when these construction materials smoulder, is often responsible for lethal pollution.

Apart from this, **plant and animal-derived insulation materials** are generally well tolerated and almost harmless in terms of health. When cellulose, hemp, flax and cotton are installed or removed, though, harmful dust may accumulate. **If flame retardants or insect repellents are added, their health effects have to be taken into account.**

# Processing insulation materials

Mineral, fossil-based, plant or animal-derived materials can be used as insulation materials. They are available as insulation mats or felts, insulation panels or bales, or as loose-fill or injected materials. In addition there are some special solid insulation materials (vacuum insulation panels, aerogels) which cannot be clearly classified as mineral or fossil-based.

Using plant or animal-derived insulation materials may have ecological advantages, especially if the raw materials are available locally and if energy consumption for production, transport and disposal is relatively low.

**The following generally applies to processing insulation materials:**

**While the various components (mats, panels, etc.) are stored on the building site, they must be protected from moisture, direct sunlight, contamination of any kind and damage.**

**For practically all insulation materials the rule is that only well-matched system components are to be used.**

**Before** a start can be made on **installing insulation panels**, the **substrate** **must be prepared** in line with current regulations, **all plumbing work must have been completed**, and all breaches must have been made in line with the state of the art.

**It is essential that the substrate is dry, free from dust and grease, intact (cohesive) and flat.** In the case of interior insulation, existing wallpaper, old paintwork, panels, etc. must be removed entirely. Any mouldy plaster or salt efflorescence must be tracked down and removed entirely.

**The substrate is inspected visually, and tested by wiping, scratching, moistening and tapping; flatness and cohesion are also tested.** For example, in a wipe test the surface is wiped with a cloth or by hand to check whether the surface is shedding chalky dust. The scratch test shows if the substrate is intact (cohesive), and tapping shows whether there are cavities.

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Published by:

e-genius – Verein zur Förderung und Entwicklung offener Bildungsmaterialien im technisch-naturwissenschaftlichen Bereich

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August 2015

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| --- | --- | --- | --- | --- |
| This learning unit was funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. |  |  |  |  |
| The basis for this learning unit was developed within a project of „Building of Tomorrow“.  |  |  |  |  |

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