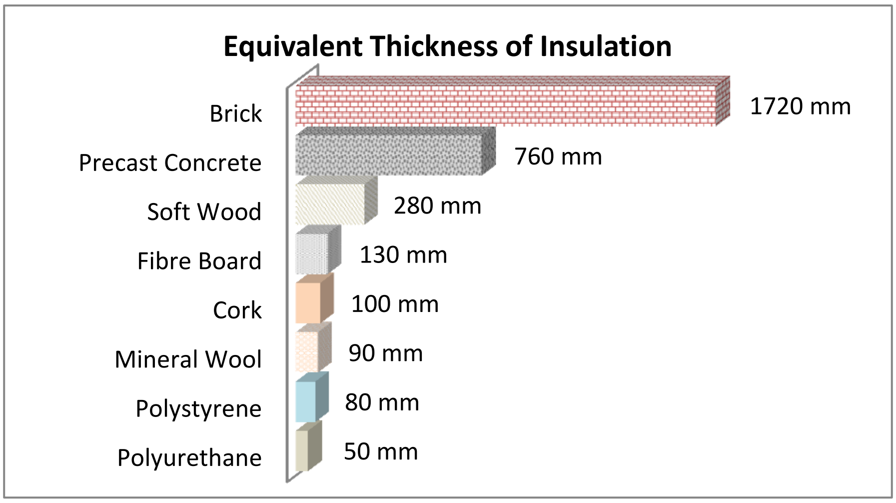
# Rigid Polyurethane Foams as an insulation material

The primary purpose of Insulation is to minimise temperature losses. In hot climates the primary purpose is to conserve cooling and to prevent atmospheric heat to ingress into the building. In cold climates it is to keep the warmth in and prevent it from dissipating into the outside cold. Heat always flows from warmer to colder areas.

Additionally, walls of large industrial and refrigerated buildings, cold stores, warehouses, exhibition and sports halls, schools and other large buildings are best constructed from components which provide thermal insulation while also meeting other technical requirements such as stability, inexpensive assembly, freedom from maintenance and easy disassembly and reconstruction.
By virtue of its microcellular closed cell construction and the presence of trapped insulant gases, Rigid Polyurethane foam provides the highest level of Insulation per unit thickness.




Polyurethanes are the single largest insulating material being used as the core material of load-bearing sandwich panels for refrigerated vehicles. The construction of the frame, floor and roof beams is particularly important in insulated containers and vehicles. In road transport, where jolting, impacts and vibrations lead to high strength requirements, the rigid polyurethane foam has to be extremely elastic to absorb these stresses in the long term. In addition to these mechanical requirements, rigid polyurethane foam must have high thermal insulation values and long-term stability with respect to thermal conductivity. The inward diffusion of water can be reliably prevented by using diffusion-resistant facings.

## Efficient Thermal Insulation to last a lifetime

The term rigid polyurethane foam (PUR/PIR) stands for a family of insulation materials that, in addition to polyurethane (PUR) also includes polyisocyanurate (PIR) rigid foam.
The excellent thermal insulation properties of closed-cell rigid polyurethane foam (PUR/PIR) are achieved today mainly with blowing agents such as pentane (hydrocarbon) or CO2. In addition to the low thermal conductivity, rigid polyurethane foam (PUR/PIR) is stable and durable. It will function for as long as the building stands and has a useful life beyond 50 years.
Thermal insulation with rigid polyurethane foam (PUR/PIR) conserves resources, saves energy and has no significant emission to the environment.

Rigid polyurethane foam (PUR/PIR) is the right investment for the future as it:

- is CFC Free
- offers optimal, long-life insulation with no drawbacks, maintenance or repairs
- enhances the value of property and the quality of life
- leads to large energy savings and reduced heating costs
- is cost-effective and easy to install

## Technical Properties of Rigid Polyurethane Foam

The properties of the insulation materials depend on their structure, the raw materials used and the manufacturing process. In the selection of a suitable thermal insulation material, the required thermal properties are of prime importance. For the functionality and safety of the building, other important criteria in the choice of insulation are mechanical strength, resistance to ageing, sound insulation properties, and resistance to moisture and fire.

Rigid polyurethane foam (PUR/PIR) insulation materials display excellent insulation characteristics. They have extremely low thermal conductivity values and can achieve optimal energy savings. The excellent mechanical strength values and exceptional durability of rigid polyurethane foam (PUR/PIR) fulfil all the requirements made of insulation materials used in the building industry.

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The thermal conductivity of rigid polyurethane foam (PUR/PIR) is dependent on:

- The cell gas used
- Density
- Temperature
- behaviour in the presence of water and moisture
- time of measurement

### The entrapment of Gases

Owing to the high closed-cell content of rigid polyurethane foam (PUR/PIR) (proportion of closed cells > 90 %), the blowing agents remain in the insulation material over the long term. Gas diffusion-tight facings reduce the cell-gas exchange with the surrounding air.

The thermal conductivity levels specified by the manufacturer are long-term values. These are based on an insulation material lifetime of at least 25 years, in practice the lifetime is expected to be greater than 60 years.

**Influence of Density**

The amount of structural material increases as the density rises. This increases the share of heat conducted over the structural material. The increase in thermal conductivity, however, does not increase in proportion to the increase in density; the thermal conductivity of rigid polyurethane foam (PUR/PIR) changes little in the density range 30 to 100 kg/m³ relevant for building.

**Influence of Temperature**

The thermal conductivity of insulation materials decreases as the temperature falls. Temperature increases on the other hand result in a minimal increase in thermal conductivity. Thermal conductivity measurements are made under standardised conditions. That is why the measured values are converted to a mean temperature of 10°C. The minimal deviations in thermal conductivity for the building applications compared with the reference temperature of 10 °C are taken into account in the design value of thermal conductivity.

**Influence of Water and Moisture**

At a reference temperature of 25 °C, the thermal conductivity of water is $\lambda = 0.58$ W/(m·K). As the thermal conductivity of most common insulation materials ranges between 0.020 W/(m·K) and 0.050 W/(m·K), water absorption due to immersion in water leads to an increase in thermal conductivity. However, water absorption has only a small impact on the thermal conductivity of rigid polyurethane foam (PUR/PIR). Studies have shown that the increase in thermal conductivity of rigid polyurethane foam (PUR/PIR) expanded with pentane after 28-day immersion in water is negligible, amounting to around 0.0018 W/(m·K)

## Density

The density of rigid polyurethane foam (PUR/PIR) used for thermal insulation in buildings normally ranges between 30 kg/m³ and 45 kg/m³. However, it can reach 100 kg/m³ for some applications. For special applications that are subject to extreme mechanical loads, the density of the rigid polyurethane foam (PUR/PIR) can be increased to 700 kg/m³.

## Solid Content

Only a small portion of the rigid polyurethane foam volume consists of solid material. At a density of 40 kg/m³ usual in building applications, the solid plastic material makes up only 5% of the volume. This material forms a grid of cell struts and cell walls that can withstand mechanical loads due to its rigidity and anti-buckling properties.

## Compressive Strength

For many rigid polyurethane foam (PUR/PIR) applications, a compressive strength $\sigma_m$ or compressive stress $\sigma_{10}$ value of 100 kPa is sufficient. In some insulation applications, for example in flat roofing, flooring, ceilings or perimeter insulation, higher pressure loadings can occur.

## Tensile, Shear and Bending Strength

Depending on the density, the Tensile Stress values for PUR/PIR lie between 40 und 900 kPa. Depending on density, rigid polyurethane foam (PUR/PIR) insulation materials exhibit shear strengths between 120 and 450 kPa. The bending strength describes the behaviour under bending stress in certain application areas, such as plaster supports in wooden structures or bridging large open spans between the top chords in roofing constructions. The bending strength of composite elements with a, rigid polyurethane foam (PUR/PIR) core depends on the foam density and the facings used; the values lie between 250 and 1300 kPa.

## Presence of Water and Moisture

Insulation materials made of rigid polyurethane foam (PUR/PIR) do not absorb moisture from the air. Due to their closed cell structure, they do not absorb or transport water, i.e. there is no capillary action. For this reason, normal moisture in buildings does not lead to an increase in thermal conductivity. Water vapour diffusion cannot cause increased moisture levels in rigid polyurethane foam (PUR/PIR) insulation boards unless these have not been properly installed from a structural point of view, for example where vapour barriers are lacking, or due to air pockets or faulty seals in flat roofs.

## 28 Day water absorption test

In laboratory tests, in which rigid polyurethane foam (PUR/PIR) insulation boards are permanently surrounded by water, absorption of water can result through diffusion and condensation. In the 28-day immersion the absorption level measured in a 60 mm thick PUR/PIR insulation board (with mineral fleece facing, density 35 kg/m$^3$) is typically around 1.3 percent by volume.

## Thermal Expansion

Measurements taken on rigid polyurethane foam (PUR/PIR) insulation boards with flexible facings and densities of between 30 and 35 kg/m$^3$ yielded coefficients of thermal expansion of between 3 and 7 x $10^{-5} \cdot K^{-1}$. For rigid polyurethane foam (PUR/PIR) insulation boards without facings and with densities of between 30 and 60 kg/m$^3$ the linear coefficient of thermal expansion lies between 5 and 8 x $10^{-5} \cdot K^{-1}$. The coefficient of thermal expansion of insulation boards of higher density without facings is around 5 x $10^{-5} \cdot K^{-1}$. These values apply to boards or cut sections/mouldings that are not attached to a substrate or are not tautly mounted.

## Thermal Stability

Insulation materials made of rigid polyurethane foam (PUR/PIR) have a high level of thermal resistance and good dimensional stability properties. Depending on the density and facings, rigid polyurethane foam (PUR/PIR) insulation materials for building applications can be used long-term over a temperature range of – 30°C to +90°C. Rigid polyurethane foam (PUR/PIR) insulation materials can withstand temperatures of up to 250°C for short periods with no adverse effects.

Rigid polyurethane foam (PUR/PIR) with mineral fleece facings or without coatings is resistant to hot bitumen and can be used in flat roofing sealed with bituminous roof covering. Rigid polyurethane foam (PUR/PIR) is a thermosetting plastic and does not melt under the effects of fire.

Furthermore, a number of special polyurethane products can be installed as insulation under poured-asphalt floor screed and withstand temperatures of +200°C without additional heat protection, or can be used for cold-temperature applications down to –180°C.

## Chemical and Biological Stability

Contact with chemicals can affect the properties of insulation materials. However, insulation boards made of rigid polyurethane foam (PUR/PIR) are for the most part resistant to the common chemical substances used in building. This includes for instance most solvents as used in adhesives, bituminous materials, wood protection products or sealing compounds. In addition, the insulation material is not susceptible to the effects of plasticizers used in sealing films, or to fuels, mineral oils, diluted acids and alkalis, exhaust gases or aggressive industrial atmospheres.

Rigid polyurethane foam (PUR/PIR) does not rot; it resists mould and decay and is odour-neutral.

UV radiation causes discolouring in rigid polyurethane foam (PUR/PIR) insulation boards without facings or at the cut faces, and over time leads to a low-level sanding effect on the surface. However, this is not a technical drawback. The surface sanding can be removed in subsequent work steps.

## Hygiene and Food Preservation

The insulation efficiency of rigid polyurethane foam (PUR/PIR) is a key property for the low temperature preservation of food during processing, storage and distribution to the consumer and can save as much as fifty percent of valuable food that would otherwise rot before it is consumed.

Hygiene is an important consideration where food is processed. Rigid polyurethane foam (PUR/PIR) core sandwich panels constructions eliminate cold bridges which ensure that both surface and interstitial condensation will not occur, as this could lead to the formation of bacteria and mould growth. They are supplied with easy to clean food-safe liners especially designed to comply with the regulations.

In refrigerated transport, the thickness of the insulation is constrained by the maximum width of truck and a minimum internal dimension dictated by the size of standardized pallets. Studies have demonstrated the key role of rigid polyurethane foam (PUR/PIR) core panels on $CO_2$ saving.

Hygiene is equally important for other processes that require a clean environment, such as electronic and pharmaceutical industries. These are no negligible areas of activities when we see the trend to higher technology industries and the increasing life expectancy depending on proper and adapted medication.

## Life Cycle Analysis and Energy Balance

Studies show that, over a useful lifetime of more than 50 years, thermal insulation products made of rigid polyurethane foam (PUR/PIR) save many times the energy that is consumed during their production. The energy inputs for the manufacture of rigid polyurethane foam (PUR/PIR) are recovered as a rule after the first heating period. 100 kW·h of energy is consumed in the manufacture of an 80 mm-thick rigid polyurethane foam (PUR/PIR) board with a surface area of 1 $m^2$ and with aluminium facings. When rigid polyurethane foam (PUR/PIR) insulation boards with a thickness of 80 mm and aluminium facings are used to improve the thermal insulation of an inclined roof in an old building, it is possible to save 160 kW·h of energy per square metre of roof each year, making a total of 8,000 kW·h over the 50 years of the product's useful lifetime.

## CFC Free

Rigid polyurethane foams (PUR/PIR) are CFC free.