

THERMAL INSULATION MATERIALS MADE OF RIGID POLYURETHANE FOAM (PUR/PIR)

Polyurethane – Enhancing Everyday Life

Polyurethane is widely used in modern life, including shoe soles, mattresses, steering wheels, and insulation systems. Its properties can be precisely adjusted during manufacturing — rigid, flexible, integral, or compact — allowing cost-effective solutions for nearly every application.

Long-Term Thermal Efficiency

Rigid polyurethane foam (PUR/PIR) includes both polyurethane (PUR) and polyisocyanurate (PIR) insulation materials.

Its excellent thermal performance is achieved through closed-cell foam technology using blowing agents such as pentane or CO₂.

Main Benefits

- Extremely low thermal conductivity
- Durable and dimensionally stable
- Service life exceeding 50 years
- Reduced environmental impact
- Resource and energy conservation

Why PUR/PIR Insulation Is a Smart Investment

Rigid polyurethane foam (PUR/PIR):

- Provides long-lasting thermal insulation with minimal maintenance
- Improves property value and indoor comfort
- Reduces heating costs through major energy savings
- Is cost-effective and simple to install

WHAT IS RIGID POLYURETHANE FOAM (PUR/PIR)

Main Types of PUR/PIR Insulation

Insulation Boards

Rigid polyurethane foam (PUR/PIR) boards offer:

- High mechanical strength
- Good resistance and durability
- Easy installation
- Compatibility with other construction materials

They are widely used for insulating walls, roofs, ceilings, and floors.

Rigid Polyurethane Foam (PUR/PIR) for Insulation

Rigid polyurethane foam (PUR/PIR) is a highly efficient insulation material for both new construction and renovation projects due to its exceptionally low thermal conductivity.

Key advantages include:

- Higher insulation performance with thinner material layers
- Easier installation in limited building cavities
- Significant energy savings, reducing building energy consumption by over 50%
- Strong mechanical properties and excellent adhesion to other materials

Applications include:

- Roof, wall, floor, and ceiling insulation boards
- Window frame insulation
- Foam sealants
- Metal-faced sandwich panels for industrial buildings

Metal-Faced Sandwich Panels

Sandwich panels consist of a rigid PUR/PIR core with metal facings on both sides.

Main applications:

- Roof and wall systems
- Industrial and commercial buildings
- Refrigeration and cold-storage facilities

Key benefits:

- Lightweight construction
 - Fast installation in all weather conditions
 - High prefabrication quality
- Strong structural reliability and safety

Block Foam

PUR/PIR block foam can be cut and shaped for:

- Technical insulation
- Industrial equipment
- Building service installations

In-Situ Foams

In-situ polyurethane foams are produced directly on-site using specialized equipment.

- They are mainly used for:
 - Technical insulation applications
 - Seamless insulation systems
 - Sprayed or mould-filled insulation solutions

The foam is applied directly onto surfaces or poured into moulds, creating a continuous, gap-free insulation layer.

TECHNICAL AND PHYSICAL PROPERTIES OF RIGID POLYURETHANE FOAM (PUR/PIR)

The performance of rigid polyurethane foam (PUR/PIR) depends on its structure, raw materials, and manufacturing process. Key evaluation criteria include:

- Thermal insulation performance
- Mechanical strength
- Moisture resistance
- Fire performance
- Durability and ageing resistance

PUR/PIR insulation materials combine extremely low thermal conductivity with high mechanical strength and long-term durability.

Factors Affecting Thermal Conductivity

Thermal conductivity depends on:

- Cell gas type
- Density
- Temperature
- Moisture exposure
- Ageing over time

Influence of Density

Typical building-grade PUR/PIR density:

- 30–45 kg/m³
- Up to 100 kg/m³ for specialized applications

Thermal conductivity changes only slightly across common density ranges.

Thermal Conductivity

Thermal conductivity (λ) measures heat transfer through a material. Lower thermal conductivity means better insulation performance.

Thermal resistance (R) is calculated as:

$$R = \frac{d}{\lambda}$$

Thermal transmittance (U-value) is:

$$U = \frac{1}{R}$$

PUR/PIR insulation materials are tested according to EN 13165 standards.

Influence of Cell Gas

PUR/PIR achieves excellent insulation performance through low-conductivity blowing agents such as:

- Pentane
- CO₂
- HFC blowing agents for special applications

The closed-cell structure (>90% closed cells) helps retain insulating gases over long periods.

Long-Term Thermal Performance

PUR/PIR insulation maintains stable thermal performance for decades. After initial gas stabilization, thermal conductivity changes only minimally.

Expected service life:

- More than 60 years in practice

Declared thermal conductivity values already account for ageing effects.

MECHANICAL PROPERTIES

Compressive Strength

Mechanical performance depends primarily on density. Typical compressive strength or compressive stress at 10% deformation:

- Around 100 kPa for standard applications
- Higher values for heavy-load applications such as flat roofs or floors

Testing is conducted according to EN 826

Influence of Cell Gas

PUR/PIR performs reliably under continuous long-term loads (compressive creep).

Long-term deformation remains below:

- 2% over 20–50 years

This makes PUR/PIR suitable for:

- Flooring systems
- Flat roofing
- Industrial applications

Testing follows EN 1606

MOISTURE AND WATER RESISTANCE

Moisture Behaviour

Due to its closed-cell structure, PUR/PIR:

- Does not absorb moisture from air
- Does not transport water by capillary action
- Maintains insulation performance under normal moisture exposure

Water vapour diffusion problems generally occur only when installation defects are present.

Vapour Diffusion Resistance

Water vapour resistance is expressed through the diffusion resistance factor μ and equivalent air layer thickness s_d :

$$S_d = \mu \cdot s$$

PUR/PIR typically provides high vapour resistance depending on facings and density.

THERMAL EXPANSION AND HEAT STORAGE

Thermal Expansion

PUR/PIR expands minimally under temperature changes.

Typical thermal expansion coefficient:

$$3-8 \times 10^{-5} \text{ K}^{-1}$$

Expansion depends on:

- Density
- Facing type
- Installation conditions

Tensile, Shear, and Bending Strength

PUR/PIR insulation systems also provide strong:

- Tensile strength
- Shear strength
- Bending resistance

Typical ranges:

- Tensile strength: 40–900 kPa
- Shear strength: 120–450 kPa
- Bending strength: 250–1300 kPa

These properties make PUR/PIR suitable for:

- ETICS systems
- Industrial panels
- Composite building elements

Water Absorption

Typical water absorption after 28-day immersion:

- Approximately 1.3% by volume

Even after prolonged exposure to water:

- Thermal conductivity increases only minimally

PUR/PIR also performs well under:

- Frost-thaw cycles
- Ground-contact perimeter insulation conditions

Heat Capacity

Specific heat capacity of PUR/PIR:

- Approximately 1400–1500 J/(KG·K)

Although some insulation materials store more heat, simulations show that:

- Solar radiation and window shading have a much greater impact on summer indoor comfort than insulation heat storage capacity.

TEMPERATURE STABILITY

PUR/PIR insulation materials:

- Operate long-term between -30°C and $+90^{\circ}\text{C}$
- Resist short-term temperatures up to $+250^{\circ}\text{C}$
- Do not melt under fire exposure because they are thermosetting plastics

Special formulations can withstand:

- Asphalt temperatures up to $+200^{\circ}\text{C}$
- Cryogenic temperatures down to -180°C

FIRE PERFORMANCE

European Fire Classification

PUR/PIR products are classified under EN 13501-1 using Euroclasses:

- A1 to F

Classification depends on:

- Foam formulation
- Facing type
- Smoke development
- Burning droplets

PUR/PIR is a thermosetting plastic and:

- Does not melt
- Does not produce flaming droplets under fire exposure

SUSTAINABLE DEVELOPMENT WITH RIGID POLYURETHANE FOAM (PUR/PIR)

Sustainability involves balancing:

- Environmental protection
- Economic efficiency
- Social well-being

In construction, sustainability must consider the full life cycle of buildings and materials, including:

- Resource conservation
- Energy efficiency
- CO_2 reduction
- Recycling potential
- Long-term cost savings
- Human comfort and health

CHEMICAL AND BIOLOGICAL RESISTANCE

PUR/PIR is generally resistant to:

- Lime, cement, gypsum
- Bitumen
- Fuels and mineral oils
- Diluted acids and alkalis
- Industrial atmospheres

It also:

- Resists mould and rot
- Is odour-neutral
- Does not decay biologically

UV exposure may cause surface discoloration or slight sanding effects, but without technical damage.

Reducing Energy Consumption and Emissions

Buildings account for more than 40% of total energy consumption in the EU. Improving insulation efficiency is essential for:

- Reducing fossil fuel use
- Lowering greenhouse gas emissions
- Increasing energy efficiency

Rigid polyurethane foam (PUR/PIR) contributes significantly through its:

- Very low thermal conductivity
- Long service life
- High insulation efficiency

Better building insulation helps reduce CO_2 emissions and supports international climate goals such as the Kyoto Protocol targets

Hygiene and Food Preservation

PUR/PIR insulation plays an important role in:

- Food preservation
- Refrigeration systems
- Clean industrial environments

Main Benefits

- Minimizes heat transfer in refrigerated storage and transport
- Reduces food spoilage
- Eliminates cold bridges and condensation
- Helps prevent bacteria and mould growth
- Supports hygienic conditions in food, pharmaceutical, and electronics industries

PUR/PIR sandwich panels are commonly used with easy-to-clean food-safe liners designed to meet hygiene regulations targets

Recycling and Energy Recovery

Rigid polyurethane foam (PUR/PIR) insulation materials are highly durable and can often last for the full service life of a building.

After demolition or dismantling, PUR/PIR materials can be:

- Reused
- Recycled
- Used for energy recovery

Material Recycling Options

Clean PUR/PIR waste can be:

- Reused for attic or floor insulation
- Processed into recycled pressed boards
- Used as oil absorbents
- Mixed with cement for insulating mortar
- Chemically recycled through glycolysis

Energy Recovery

Impure PUR/PIR waste can be:

- Incinerated in waste-to-energy plants
- Converted into usable thermal energy

This reduces the need for additional fossil fuels and lowers environmental impact.

Life-Cycle Analysis and Energy Balance

Environmental assessment of insulation materials must consider:

- Raw materials
- Manufacturing energy
- Emissions and waste
- Product lifespan
- Energy savings during use

PUR/PIR insulation materials provide substantial long-term energy savings.

Energy Performance Example

- Manufacturing 1 m² of 80 mm PUR/PIR insulation board requires approximately 100 kWh of energy
- The same insulation can save about 160 kWh per year in roof applications
- Over 50 years, total savings can reach approximately 8,000 kWh

In most cases, the production energy is recovered during the first heating season.

Environmental Advantages of PUR/PIR

Rigid polyurethane foam (PUR/PIR):

- Reduces long-term heating and cooling energy demand
- Helps lower greenhouse gas emissions
- Supports sustainable construction practices
- Offers long service life with minimal maintenance
- Provides recycling and energy recovery opportunities after use

PUR/PIR insulation can reduce heating costs by up to 30% over a service life exceeding 50 years.

MANUFACTURE OF RIGID POLYURETHANE FOAM (PUR/PIR) INSULATION MATERIALS

Rigid polyurethane foam (PUR/PIR) is produced through a chemical reaction between two liquid base components and a blowing agent such as pentane or CO₂.

During mixing:

- A polyurethane polymer matrix is formed
- Heat generated by the reaction causes the blowing agent to expand
- The foam structure develops closed cells with insulating properties

Foam density and performance characteristics are controlled through:

- Blowing agent quantity
- Additives and catalysts
- Manufacturing conditions

MANUFACTURE OF PUR/PIR INSULATION BOARDS

Continuous Laminator Process

Flexible-faced PUR/PIR insulation boards are manufactured continuously using laminators.

Process Overview

- The reaction mixture is poured onto a lower flexible facing
- The foam expands inside the laminator
- An upper facing is added during expansion
- The laminate hardens and is cut to size

Typical board thickness:

- Up to 200 mm

Common Facing Materials

- Mineral fleece
- Glass fleece
- Aluminium foil
- Composite films
- Functions of Facings

Facings may provide:

- Vapour barriers
- Moisture protection
- Mechanical protection
- Decorative surfaces

Boards can also include:

- Tongue-and-groove edges
- Stepped profiles
- Flat edges

Composite insulation panels may additionally include:

- Chipboard
- Plasterboard
- Mineral-based rigid layers

MAIN PUR/PIR PRODUCT TYPES

Factory-made PUR/PIR products include:

- Insulation boards with flexible facings
- Block foam
- Sandwich panels with rigid facings

In-situ PUR/PIR foam is produced directly on construction sites.

MANUFACTURE OF PUR/PIR BLOCK FOAM

PUR/PIR block foam can be produced using:

- Continuous processes
- Discontinuous processes

Continuous Block Foam Production

- The reaction mixture is poured into a moving U-shaped paper channel
- Foam expands during conveyor transport
- Finished blocks are cut to length

Discontinuous Block Foam Production

- Components are mixed in an agitator
- The mixture is poured into mould boxes
- Foam expands and hardens into rigid blocks

After curing, blocks are cut into:

- Insulation boards
- Pipe insulation
- Roof wedges
- Custom moulded sections

Additional facings can be bonded afterward for specialized applications.

MANUFACTURE OF PUR/PIR SANDWICH PANELS

PUR/PIR sandwich panels may be produced using:

- Continuous laminator systems
- Discontinuous mould systems

Continuous Metal-Faced Sandwich Panels

Manufacturing Process

- Foam is applied onto a metal facing
- Metal sheets are usually pre-profiled for rigidity
- Foam expands and bonds to upper and lower facings
- Finished panels are cut to required length

Main Features

- Tongue-and-groove edges
- Factory-installed seals
- Air-tight construction
- High strength with low weight

Typical Dimensions

- Width: 800–1250 mm
- Length: up to 24 m

Applications include:

- Industrial buildings
- Roofing systems
- Wall cladding
- Cold storage facilities

Discontinuous Sandwich Panel Production

- Facings are fixed inside moulds
- Foam mixture fills the cavity
- Multiple panels may be produced simultaneously

IN-SITU DISPENSED PUR/PIR FOAM

Dispensed foam is used to fill enclosed cavities between surfaces.

Typical applications:

- Pipe insulation
- Cavity filling
- Technical insulation systems

EUROPEAN HARMONISATION AND CE MARKING OF RIGID POLYURETHANE Foam (PUR/PIR) Insulation Products

The European construction sector aims to create a unified market by:

- Harmonising technical standards
- Removing trade barriers
- Supporting free movement of construction products within Europe

These regulations help improve the competitiveness of the European building industry.

MANUFACTURE OF IN-SITU PUR/PIR FOAM

In-situ PUR/PIR foam is produced directly on-site using spray equipment.

Process

- Components are heated and pressurized
- Materials travel through heated hoses
- Components mix inside the spray gun
- Foam is sprayed or dispensed onto the substrate

Two application methods are used:

- Spraying
- Dispensing

SUMMARY OF PUR/PIR MANUFACTURING METHODS

PUR/PIR insulation materials are manufactured for:

- Building envelopes
- Roofing systems
- Wall systems
- Building services insulation
- Industrial and refrigeration applications

Production methods include:

- Factory-made insulation boards
- Block foam cutting
- Sandwich panel laminating
- On-site sprayed or dispensed foam systems

IN-SITU SPRAYED PUR/PIR FOAM

Characteristics

- Applied directly onto dry, clean surfaces
- Installed in multiple passes
- Creates seamless insulation
- Fully adheres to the substrate

Main advantages:

- No joints
- Continuous insulation layer
- Strong adhesion

EUROPEAN CONSTRUCTION PRODUCTS REGULATIONS

The European Construction Products Directive (CPD) establishes the legal framework for placing construction products on the market.

Building products must demonstrate compliance with essential requirements to ensure safe and reliable construction when properly designed and installed.

CE MARKING

CE marking confirms that a product complies with European regulations and harmonised standards.

It serves as a technical passport allowing insulation products to be traded throughout the European common market.

CE MARKING INCLUDES

- The CE symbol
 - Manufacturer identification and address
 - Year of manufacture
 - Coded technical product information
 - Manufacturer's declaration of conformity
- The manufacturer is responsible for affixing the CE marking and ensuring product compliance.*

Essential Requirements

Construction products must support:

- Mechanical resistance and structural stability
- Fire safety
- Hygiene, health, and environmental protection
- Safe use
- Noise protection
- Energy efficiency and thermal insulation

Product requirements are defined through:

- Harmonised European Standards (hEN)
- European Technical Approvals (ETA)

These standards are developed by the European Committee for Standardization (CEN) on behalf of the European Commission.

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