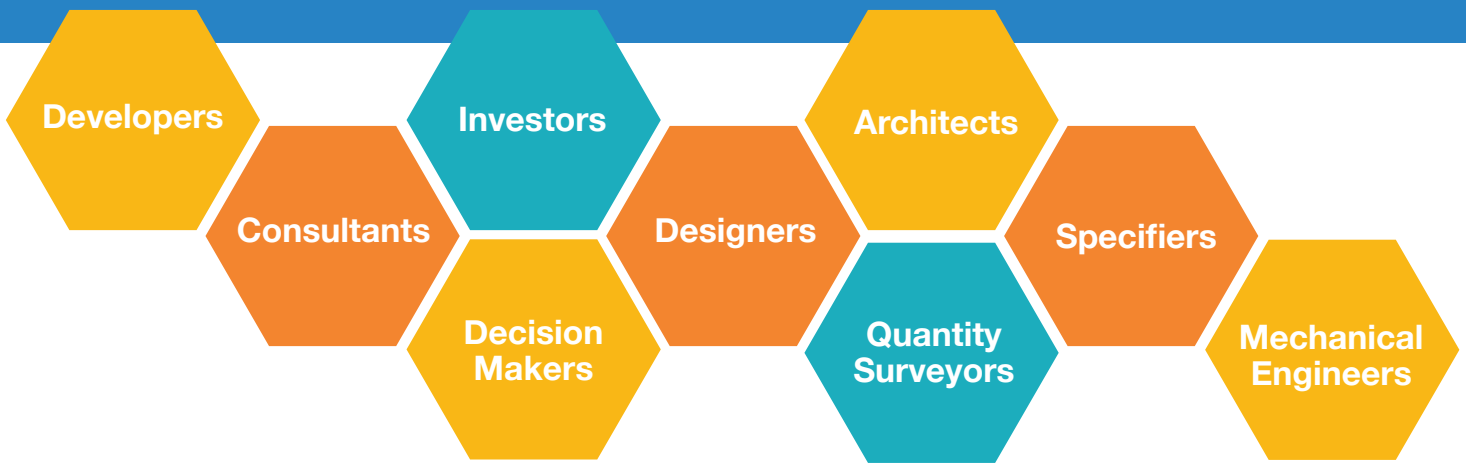
A guide to selecting the appropriate generic type of thermal insulation for long-term energy savings in building construction.



Generally, the selection of thermal insulation material considers properties such as the thermal resistance (R value), obtained by calculation using the laboratory test of the thermal conductivity (k value) of that material:

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

R = Thermal resistance value
d = Thickness of insulation (meters)
k = Thermal conductivity value

The R value is expressed as unit = **W/m²°K** (in the metric system) and equal to: **Ft² f.h/Btu** (in the Imperial system). The thermal conductivity property of a material, its compressive strength and its water absorption is determined through laboratory testing.
Moisture absorption by insulation materials severly affects insulating ability, which must be well understood, and considered when choosing appropriate thermal insulation.

Exhaustive research was conducted for many years at **CRREL** (Cold Regions Research and Engineering Laboratory), part of the United States Army Corps of Engineers, "**Engineering Research and Development Centre**", located in Hanover in Grafton County, New Hampshire – U.S.A. This research facility provides scientific and engineering support to the U.S. government and its military, besides technical support to non-government customers. Over **1000 days (3 years)** of monitoring, testing and in-depth scientific research was conducted by "**CRREL**" into the effects of moisture absorption, with the results approved for public release, as reprinted from proceedings of:

The third International symposium on Roofing Technology, held in **Montreal, Quebec, Canada,** whose research goal was to determine moisture gain and its thermal consequences for insulation, when subject to thermally induced vapor pressure gradients.

The insulation wetting test program was put in place, and common thermal insulation products were studied and evaluated. The test revealed essentially that all insulation types can get wet when subject to thermally induced vapour pressure gradients, even materials that wet very slowly, such as Extruded Polystyrene and Cellular glass.

The referred to research test evaluation, was conducted for a period exceeding **1000 days (3 years)** under strict monitoring, applying the same conditions for several types of thermal insulation such as:

Cellular glass, Expanded Polystyrene, Extruded Polystyrene, Fibrous glass, Cork, Fibreboard, Polyurethane Rigid Foam, Polyisocyanurate Rigid Foam "modified Polyurethane", Phenolic, Urethane Foamed-in-place "Spray Polyurethane Foam", Perlite, Light weight concrete, Gypsum .... etc.

Findings

Moisture reduces the insulating ability of insulation. The rate of wetting varies greatly among insulation types, and performance curves were developed. The reduced thermal value is termed as thermal resistance ratio (**TRR**).

TRR – This is the ratio between a material's wet thermal resistivity to its dry thermal resistivity, expressed as a percentage. A dry specimen has a **TRR** of **100%**. As moisture accumulates within Insulation, its TRR decreases.

The attached performance curve shows the **TRR** of extruded polystyrene with a density of **32kg/m³** stays above **80%**, even after **1000 days (3 years)** of continuous testing and evaluation.

By comparison, the **TRR** of expanded molded polystyrene for example with a density of **48kg/m³** drops to **42%**, and the **TRR** of expanded molded polystyrene with a density of **32kg/m³** drops to **20%**, when subjected to the same test conditions, and test period.

Conclusion

TRR decays with moisture absorption over time. Only extruded polystyrene and cellular glass could survive for years without gaining excessive moisture, and qualify to be used. It is imperative to note the Cellular glass can be destroyed by freeze-thaw action when moisture is present.

TRR remained an acceptable criterion for selection of thermal insulation material.

PASS-FAIL Criteria due to Moisture Content Dry insulation has a TRR of 100%. As moisture accumulates within an insulation, its TRR decreases.

The research study recommended the use of a **TRR** of **80%** as the lowest acceptance value for any insulation. Insulation with a **TRR** below **80%** is considered "wet" and unacceptable due to its loss of insulating ability.

What purpose does effective Thermal Insulation in buildings fulfill?

Insulation serves to restrict heat flow into and out of buildings. In meeting the building design objectives, HVAC systems can be right sized for optimum operation, thermal comfort, and energy efficiency. Thermal comfort delivers productivity and health benefits, just as control of heat flow protects temperature sensitive products, and production yields, for the agricultural market.

Good thermal insulation, properly specified and installed, provides energy efficiency benefits for the life of the building, positively contributing to national, organisational, and personal carbon emission objectives.

Key performance properties to evaluate different thermal insulation choices.

- Thermal Conductivity
- Water Absorption
- Density
- Water Vapour Permeability
- Dimensional Stability
- Thickness
- Flexural Strength
- Fire Characteristics
- Compressive Strength

= Consider all major properties in combination to determine the appropriate thermal insulation type. The product selected should comply with local and international specifications and standards, supported by proven research and 3rd party evaluations, and should meet the long term thermal performance objectives.

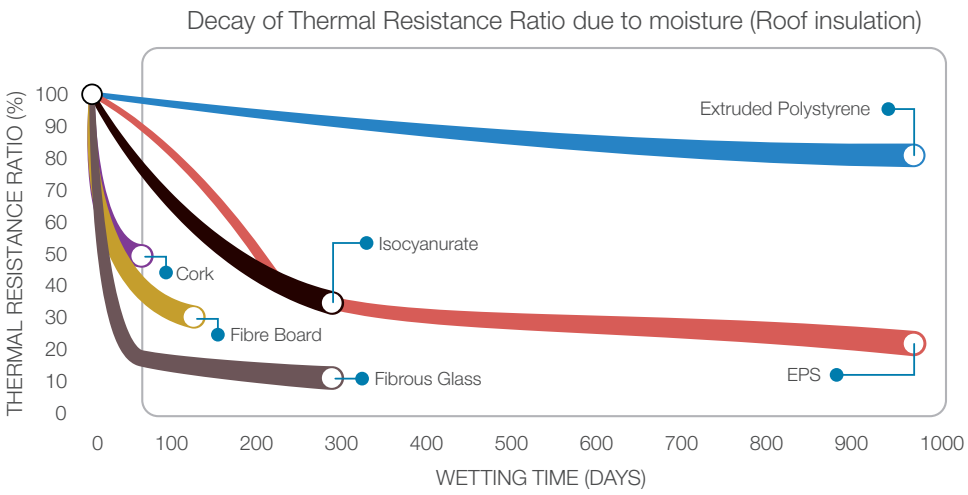
The benefit of good thermal insulation choices and risks of bad choices?

Appropriate design, and selection of the correct type of thermal insulation correctly installed provides long term energy-efficiency, with reported energy cost savings of as much as 40% in climate extremes. Good thermal insulation will last for the anticipated life of the building, with minimal deterioration in thermal performance, and thereafter be re-purposed, re-used or re-cycled. Good thermal design allows the mass of the insulated building to contribute to stabilising internal temperatures, adding to overall temperature moderation.

Environmental factors like ultra-violet light and weathering may have a negative effect on insulation thermal performance, as will incorrect application and installation. Insulation should not compromise building integrity, nor increase health and safety risks to occupants, through flame spread, toxicity, sick-building syndrome, or allergies. Dust accumulation can affect fibrous thermal insulators, displacing air, compressing the products and increasing thermal conductivity.

How does moisture affect thermal insulation?

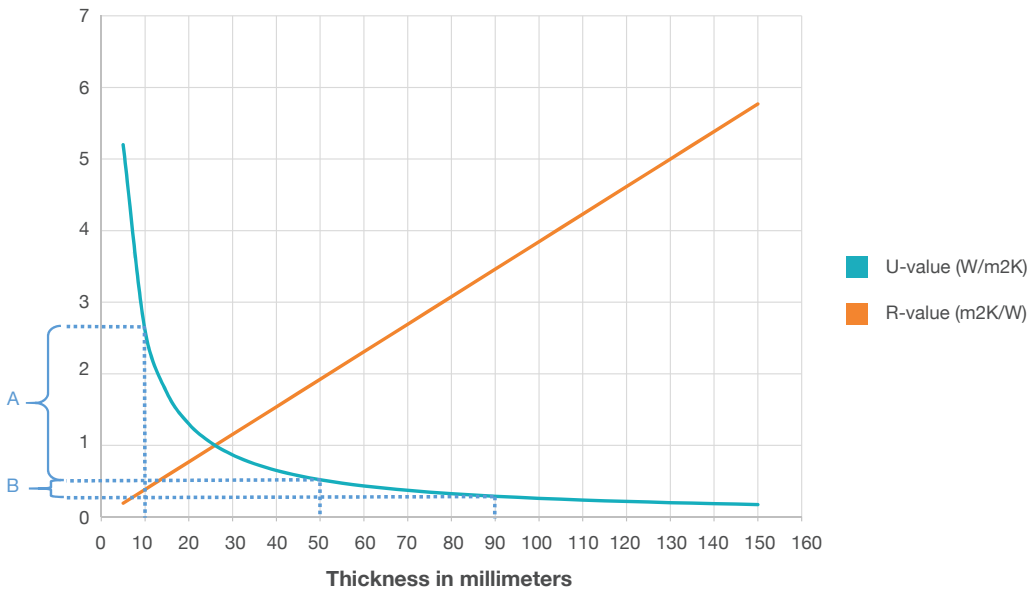
The biggest factor leading to the reduction of insulation thermal performance is moisture penetrating the insulation, which has a dramatically negative effect on thermal performance.



Performance Curve

The TRR is the thermal resistance ratio, the comparison between the thermal resistance of the generic type of thermal insulation when dry, as compared to thermal resistance when exposed to moisture over time.

Insulation with good moisture resistance can be used effectively in challenging applications, such as high humidity environments, bathrooms and kitchens, indoor pools, roof gardens, façades, inverted roofs, cavity wall and foundation perimeter applications.



Diminishing return on insulation – 10 to 50mm (40mm) = A (U-value improvement), an additional 40mm = B

Discussion of results in relation to building energy transmittance and regulations

In analysing the data supporting the graph above it is apparent that of a 150mm thickness of extruded polystyrene, the first 50mm added performs 93% of the task and the remaining 100mm only 3% of the task.

In achieving the SANS 10400 XA requirement for roofing R-value of 3.7 m2K/W for various climatic zones with 100mm of extruded polystyrene, the first 50mm of XPS insulation does the bulk of the heat transfer limitation task required.

Conclusion

Building Designers may do well to look closely at the prescriptive requirements of the SANS10400XA for roof insulation, and by process of Rational Design assess whether the thickness of insulation is warranted, against the economic contribution of other energy efficiency measures, such as perhaps additional thermal insulation applied in the walls or floors of buildings.

IsoBoard Extruded Polystyrene (XPS)

XPS is characterized by the its homogeneity and 100% closed cell structure. This provides the advantage of sustainable physical and chemical properties over time, including dimensional stability, and extremely low values for water absorption and water vapour permeability. This reflects positively on the long-term Thermal resistance, and building energy conservation goals, as proved by several international scientific research centre reports.

Isofoam SA have produced our product **IsoBoard in South Africa since 1995**, a rigid closed cell extruded **Polystyrene Thermal Insulation board**, manufactured utilizing continuous fully automated extrusion process, in accordance with all local and international relevant standards. Our parent company in the state of **Kuwait** has been manufacturing the same product with the same technology **since 1981**.

IsoBoard is available in board width 600mm, thicknesses between 30 and 80mm, and lengths up to 8000mm. Boards usually have tongue and groove edge profiles, to facilitate adjacent boards interlocking, though may be square edged or ship lapped on request.

IsoBoard has five SA Board of Agre'ment certificates, which address all our popular thermal insulation applications for the building envelope. With 27 years extensive exposure in the sub-Saharan market, we have proven thermal insulation solutions for most building requirements, including industrial,commercial, agricultural, and residential applications.

IsoBoard is as equally suitable and effective as a retro-fit solution, as it has proven to be in new constructions.

Thermal Conductivity tested to SANS 8301	
IsoBoard thermal conductivity k value	0.02624 W/m.K - Test result available

	R-Value	U-Value
Thickness (mm)	Thermal Resistance (m.°K/W)	Thermal Transmittance (W/m2°K)
30	1,143	0,875
40	1,524	0,656
50	1,905	0,525
60	2,287	0,437
70	2,668	0,375
80	3,049	0,328
90	3,429	0,292
100	3,811	0,262

Pricipal Applications	Agrement Certificate
Nail-up Ceiling	2006/323
Over Purlin	2001/287
Over Rafter/Truss	2010/382
Inverted Roof	2000/277
Cavity Wall	2000/276
Under Floor Slab	
Under Soffit	
Retro fit solutions	
Cornice profiles	

Fire Classification: 10400 Part T and SANS 428	
IsoBoard B/B1/2 horizontal and vertical / with or without Sprinklers	
Fire tested insulation combinations:	50mm Isoboard & 135mm Knauf Bulk Insulation FTC 18/256 2018 B/B1/2/H only (USP)
	40mm IsoBoard & 50mm Isotherm B polyester blanket FTC 18/027 B/B1 Residential
	40mm IsoBoard & 70mm Starlite A blanket FTC 16/177 B/B1 Residential

Class B insulation suitable for following occupancies					
A2	Theatrical and indoor sport	A3	Places of instruction	A4	Worship
C1	Exhibition hall	C2	Museum	E4	Health care
F1	Large shop	F2	Small shop	F3	Wholesalers store
G1	Offices				
H3	Domestic residence	H4	Dwelling house	H5	Hospitality

NB: Occupancies excluded from SANS 10400-XA: factories, warehouses, storage and garages.

Scanning QR Code:

1. TRR Assessment Report
2. Prequalification Submission
3. Thermal Conductivity Test

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