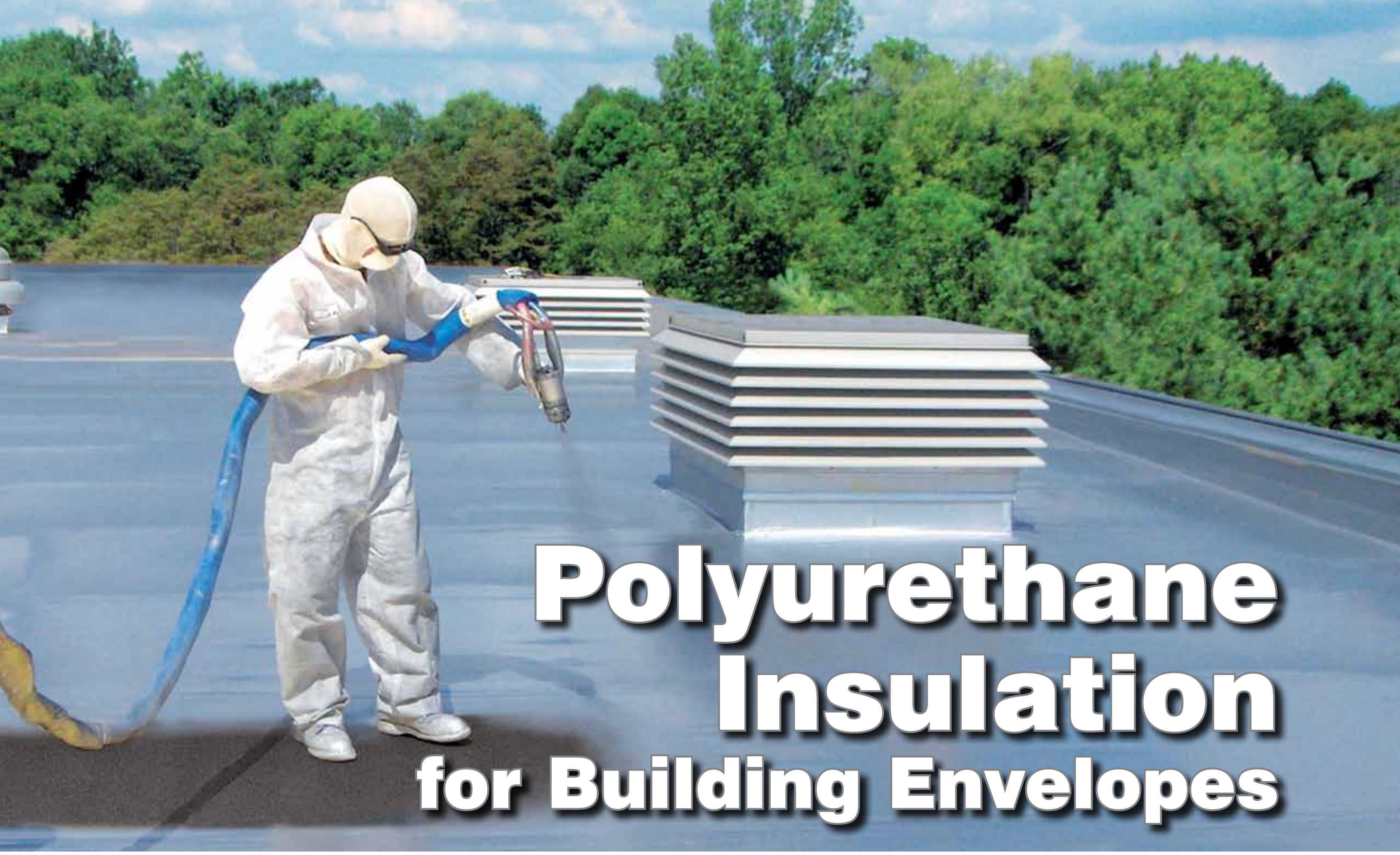

Polyurethane Insulation for Building Envelopes

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Introduction

India is seeing dramatic increases in domestic energy consumption. Ongoing industrialization and continuing development have already caused energy and peak demand shortages at an average of around 8% and 12% respectively, over the last 10 years.

Buildings are responsible for around 30% of global energy use and greenhouse gas emissions, according to the Sustainable Buildings and Climate Initiative of the United Nations Environment Program (UNEP SBCI). The challenges with respect to climate-friendly design are expected to grow in the future. For example, rising temperatures increase the demand for energy-intensive air conditioning systems. Therefore, energy saving buildings of the future can make an even bigger contribution to climate protection than today.

The building sector today, already offers a sufficient number of market-ready solutions to support a green building. These solutions can reduce the primary energy requirement by up to 90% compared with conventional buildings. Standard solutions of the one-size-fits-all variety are inadequate for achieving savings of this size, because in order to build environment friendly buildings, it is critical to incorporate local climate conditions into the design from the outset. Retrofitted climate control systems would only drive up costs unnecessarily. To minimize the energy requirements of a building, its shape and envelope must be optimized, daylight exploited to the fullest and the building systems designed for maximum efficiency. The right insulation material plays an important role in achieving energy efficiency; much could be achieved if thermal insulation in general were given sufficient consideration from the start, in the planning phase of a building. Studies show that buildings insulated with sprayed polyurethane foam typically use 30% less energy for heating and cooling compared to buildings insulated with traditional fibrous insulation material.[1]

Architecture and Energy Savings

The building envelope is our "third

[1] *DOE Airsealing*

About the Author

Isaac Emmanuel is a post graduate in polymer chemistry from Chennai University and has spent the past two decades in the field of engineering polymers industry in India. Having worked closely with the automotive, sports, industrial, mechanical and railway segments in developing applications with Bayer range of polymers, he has now shifted to developing ideas in the construction and Cold Chain segments, besides solar, wind and wood binder markets. He is a member of the Sustainability Council of Bayer in India and works closely with industry bodies for the cause of sustainability.

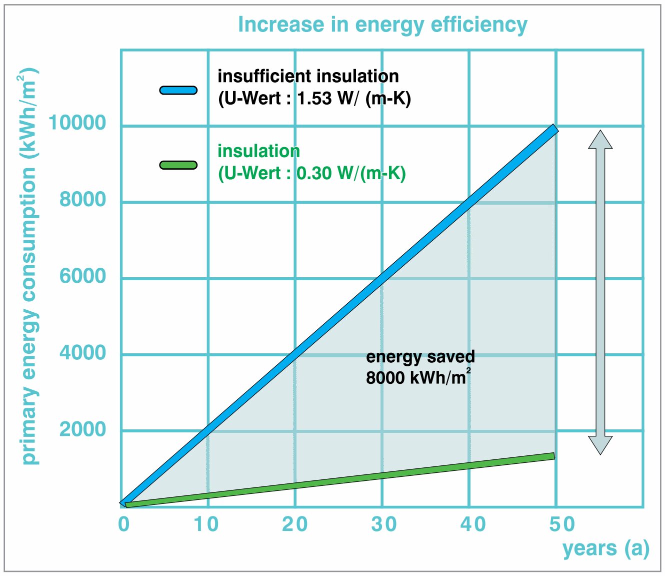


Figure 1: Effect of insulation on energy consumption

skin" (after skin and clothing) where we spend 90% of our daily time. The design and material used in buildings have a direct effect on healthy living. Poor ventilation and high heat transfer coefficient of building materials can lead to condensation and structural damage.

Sustainable construction as an all-in solution is a novel idea in the construction industry. Architects and designers usually face technical challenges in the following areas:

- Compact design: surface area to volume ratio.
- Energy-efficient construction: minimising the U-values, avoiding thermal bridges.
- Excellent thermal insulation in the external components: high insulating efficiency per unit area.
- Wind-tight and air-tight building shell.
- Mechanical ventilation (heat recovery in some cases): limiting the relative humidity.
- Rapidly controllable heat/ cold distribution: adaptability.

The architectural challenge comprises of synthesis of technically perfect construction, correct use of materials, sensible utilization and efficient project planning. Effectively, it boils down to giving the design processes a specific direction governed by external factors like conservation of resources, climate protection, energy efficiency and developing a new aesthetic.

With the new role play of architects as stylists and engineers, their responsibilities widen to

- Create appropriate architectural designs from it, not simply "form follows U-value".
- Author new developments, e.g. in the styling of façades of large, complex buildings.
- Design an energy system, a power station, a living system that can respond to changes in the environment.
- Turn the technical requirement to a style challenge.

Energy efficiency in architecture would be inconceivable without the use of insulating materials. Optimum energy efficiency can be achieved with high-performance insulating materials such as polyurethane rigid foam. Life Cycle Assessments (LCA) performed on insulation products have demonstrated that energy savings during the use phase far outweigh energy associated with manufacturing the raw material, formulating components, transporting, installing and managing at end-of-life. LCA for some individual chemical product applications, including insulation, were calculated in the ICCA[2] report. The life cycle assessment is a recognized multi-step, well-structured methodology that performs environmental impact analysis (based on *ISO 14044:2006*). LCA assess energy and environmental impacts of a material in a specified application from cradle to end-of-life.

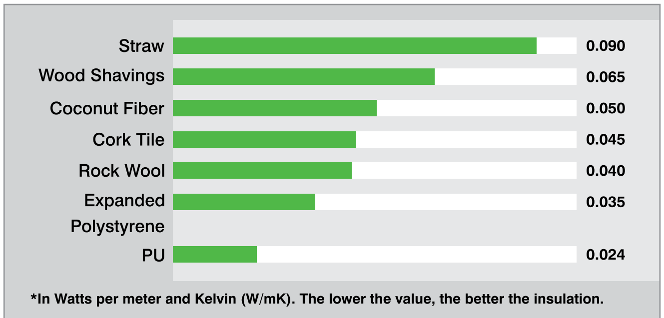
LCA results support decision-making on new projects and compare the energy and environmental impact of different products with quantitative data factoring in all the life cycle phases[3]. LCA calculations show that the highest values obtained with an increase of insulation can contribute substantially to energy efficiency improvement. It contributes to fossil fuel conservation and greenhouse gas reduction. A building and its shell constitute a system with a long life and a correspondingly long-term energy-saving effect.

Less is More

Insulation takes space. How much depends on the insulating performance of the material used. Rigid foams made of polyurethane insulate better than any other commercially available insulating material. This saves space, provides for thin solutions and even allows for more living space.

Insulation effectiveness is a function of the type and thickness of the material used to make it. In this context, the lower the thermal conductivity (λ) of the material, the better its insulating performance.

Against this backdrop, rigid polyurethane foam possesses a unique advantage. Of all the commercially available insulating



Better than rock wool and better than expanded polystyrene: PU is the best commercially available insulating material.

Figure 2: Comparison of thermal conductivity of common insulation materials

[2] *International Council of Chemical Associations, Innovations for Greenhouse Gas Reductions, July 2009*

[3] *See Energy and Environmental Benefits of Insulating Commercial Buildings with Polyiso at www.bayermaterialsciencenafta.com for an example of an LCA.*

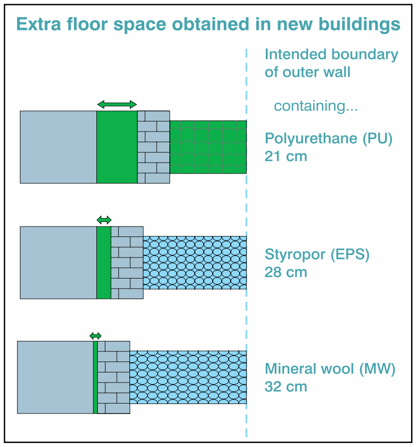


Figure 3: Space saving with different insulation materials

materials, it exhibits the lowest value at 0.024 watt per meter per degree Kelvin[4]. Other insulating materials, such as polystyrene, rock wool, glass wool or hemp fibers, display significantly higher thermal conductivity values.

Insulating materials are important in the first place, because standard building materials, such as concrete, brick and wood, conduct heat relatively well. By comparison, the thermal conductivity of concrete (λ=2.1) is nearly 90 times higher than that of polyurethane. As a result, even a relatively thin layer of polyurethane one centimeter thick insulates just as well as a concrete wall 90 centimeters thick.

For example, 21 centimeters of polyurethane insulates just as effectively as 28 centimeters of expanded polystyrene or 32 centimeters of mineral wool.

This difference can be of great significance to developers or building owners. In the case of new buildings, for instance, walls can be of a thinner design overall when using polyurethane. This ultimately means increased interior space, i.e. more living space. In the same example, the gain with polyurethane for every exterior wall requiring insulation is equivalent to 7 centimeters compared with polystyrene and as much as 11 centimeters compared with mineral wool. The same applies for floor, ceiling and roof insulation. In these areas, the use of polyurethane enables the best-possible ceiling height for a given level of insulating performance. Similar advantages exist when subsequently insulating an existing building.

It is often impossible to install layers of insulation on the exterior, either for reasons of space or because it is a landmark building. Interior insulation, on the other hand, inevitably means a loss of living space. As described above, this loss can be minimized by using polyurethane. Even if it is possible to install exterior insulation, the thinner solution with polyurethane still offers the most advantages. The thicker the façade insulation, the farther back the windows recede into the façade. This is an aesthetic disadvantage and limits the view from the window.

The PUF Advantage

Rigid polyurethane foam is suitable for extended use at temperatures of -30 to +90°C. Even contact with the chemical substances typically found in construction, such as adhesives,

PU and PIR comply with the fire standards

wood preservatives or bitumen, does not affect polyurethane. The material does not rot, resists mold and is odor-neutral.

Because rigid polyurethane foam has a closed-cell structure, it does not absorb moisture from the air or exhibit capillary activity. This means the usual building dampness does not penetrate the material if installed properly – an important aspect, because otherwise the insulating properties would deteriorate.

The closed-cell structure also ensures that the gas contained in the pores cannot escape. Special facings on rigid PU foams further prevent air from penetrating the material. Both aspects are decisive for maintaining good insulating properties over an extended period of time.

As an organic material, polyurethane is flammable. However, flammability in itself is not the problem. After all, other building materials, such as wood, also burn. What is important is that by adding flame retardants, rigid polyurethane foams can be produced that are classed as having low to normal flammability. They can be used as thermal insulation in virtually every application in the building industry. Classifications of this kind are based on standardized tests.

So, an eventual fire cannot spread undetected through an insulation layer. Similarly, the reigniting of a previously extinguished fire is observed just as rarely. Another important aspect in practice is that rigid PU foam does not melt or form flaming droplets in a fire. This distinguishes PU from polystyrene, which softens even at comparatively low temperatures, melts and the flaming droplets can even spread a fire.

A lot of progress has been made in recent years in the field of flame protection for rigid PU foams. For example, new PU formulations with an excess of isocyanate have been developed, known as polyisocyanurate (PIR). The resulting foams are inherently more resistant to heat. They require only one-third the amount of flame retardant contained in older rigid foams.

Conclusion

Over the years, polyurethane foam has emerged as the insulation of choice for building envelopes due to its low conductivity, good gas and vapour barrier properties, low flammability, self adhesion, chemical stability, construction efficiency and ease of application compared to other insulation materials.

[4] *Thermal conductivity describes the heat flow (in watts (W)) through a layer of material one square meter in size and one meter (m) thick, when the temperature difference between the two sides is one Kelvin (K) (equivalent to one degree Celsius).*