21MEO110T: Energy Systems for Sustainable Buildings

Unit II: Passive solar heating & cooling

(Thermal Insulation & thermal bridge)

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THERMAL INSULATION

Thermal Insulation

- Materials that insulate well do so because they are poor conductors of heat.
- **Thermal insulation** is an important tool to reduce energy consumption in **buildings** by preventing **heat** gain/loss through/from the **building** envelope. **Thermal insulation** is a **construction** material with low **thermal** conductivity, which should be less than 0.1W/mK
- Ideally, all the surfaces between building and the outside should be insulated.
- There are lots of choices for insulation - loose fill *(consists of small particles of fiber, foam or other materials)*, batts or rolls of the pink stuff *(Fiberglass insulation),* rigid boards and foam-in-place *(polyurethane is sprayed into the wall or ceiling cavity)*.

Thermal insulation

Builders, Architects and Service Consultants alike are constantly looking for ways to enhance energy-efficiency in buildings.

Optimum level of building insulation not only helps lower monthly energy bills, but also adds to the overall comfort. Insulation helps maintain comfort temperature by reducing leakages.

With the advent of green technologies and practices, today the potential to save energy by design can be as high as 40-50 %.

Insulation in buildings is assuming tremendous importance and has a potential to reduce energy consumption to an extent of 5-8 %.

Thermal insulations

Why Insulation?

Buildings without insulation and air-tight envelope can result in major energy wastage.

Benefits of Insulation

- 5-8% energy savings with a payback of 1-2 years
- Provides thermal as well as acoustical insulation
- Resistant to moisture
- Resistant to air infiltration

Applications of Insulation materials

- Exterior walls
- Interior walls
- Over the deck (roof)

Properties to be considered in selection of Insulation materials

R-value: Insulation is rated in terms of thermal resistance, called R-value, which indicates the resistance to heat flow. The higher the R-value, the greater the insulating effectiveness. The R-value of thermal insulation depends on the type of material, its thickness and its density.

R-value is the reciprocal of the time rate of heat flow through a unit area induced by a unit temperature difference between two defined surfaces of material or construction under steady-state conditions. R-value is expressed in m^2 K/W.

U-factor (thermal transmittance) is the heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side. U-value is expressed in W/m^2K.

The relationship between U-factor and R-value is not always exactly the inverse and therefore R-value cannot be precisely extrapolated for a material of different thickness. However, assuming an inverse relationship may be adequate.

Types of insulation material

Autoclaved Aerated Concrete Blocks

Autoclaved Aerated Concrete (AAC) blocks are produced using materials including silica sand, lime, cement, gypsum, water, fly-ash and aluminum powder. The special combination of these substances yields a material with excellent construction properties such as thermal insulation, structural strength, density and fire resistance.

ASHRAE* Building Envelope Requirements

Opaque Elements (Insulation)	Non Residential		Residential	
	Assembly Maximum (W/m^2K)	Insulation Minimum R value (m^2K/W)	Assembly Maximum (W/m^2K)	Insulation Minimum R value (m^2K/W)
Roofs, entirely above deck	U-0.360	R-2.6 ci[a]	U-0.360	R-2.6 ci
Roofs, entirely under deck	U-0.720	R-5.2 ci	U-0.720	R-5.2 ci
Walls, above grade	U-3.293	-	U-0.857[a]	R-1.6 ci[a]

*ASHRAE - American Society of Heating, Refrigerating and Air-Conditioing Engineers
[a]ci - continuous insulation

Typical thermal properties of insulation materials:

The typical U values of walls & roof materials are given below:

Material	U-value (W/m^2K)	Thickness (mm)
RCC Walls	1.95	225
AAC Blocks	0.67	230
Concrete Roof	2.5 – 3.0	150

The U-values of common insulation materials are given below:

Material	U-value (W/m^2K)	Thickness (mm)
Extruded Polystyrene (XPS)	0.028	60
Glass Wool stuffing	0.25	150
Expanded Polystyrene (EPS)	0.30	100
Air (Still)	0.20	30

Extruded Polystyrene

Extruded polystyrene (XPS) is a type of insulation material with a high R-value, good moisture resistance, high structural strength and low weight. Extruded polystyrene is used extensively as thermal insulation in industrial, commercial and residential construction. It is commonly used in wall and roof applications.

Expanded polystyrene

Expanded polystyrene (EPS) is a type of insulation that provides thermal and acoustical insulation with characteristics such as low weight, high moisture resistance and high structural strength. Expanded polystyrene can be used to insulate the walls and roofs. Commercially this is often referred to as thermocol.

Glass wool

Glass wool is an insulation material which gives efficient thermal insulation. It is light in weight and provides good acoustic insulation also. It is commonly used for duct and wall thermal insulation.

Insulation applications

Heat balance of a building would reveal that atleast 15 to 20 % of the heat ingress into a building can be through walls and roof. Hence, insulating walls and roof is extremely critical in the energy performance of a building.

The insulation applications are given below:

1.Wall insulation

Walls can be insulated on exterior or interior depending on the architectural aesthetics required. Typical way of insulating an exterior wall is shown in figure 1.

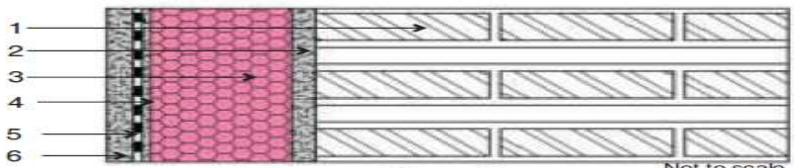


Figure 1
Exterior wall Insulation

Insulation on the exterior

1. Brick work
2. Plaster
3. Insulation
4. Polymerised mortar, 2 coats
5. Reinforced fibre
6. Elastomeric coat

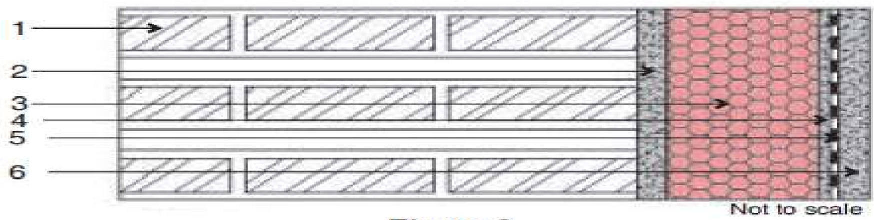


Figure 2
Interior wall Insulation

Insulation on the interior

1. Brick work
2. Plaster
3. Insulation
4. Polymerised mortar, 2 coats
5. Reinforced fibre
6. Elastomeric coat

2. Air cavity walls

Air can also be an excellent insulator. Many of the buildings have been constructed with the masonry brick walls with an air gap of 20 to 30 mm, which provides good insulation.

3.Roof insulation

Roof can be insulated either over the deck or under the deck. Generally, over deck insulation is preferred, so as to avoid the absorption and retention of heat by the concrete surface.

Under deck insulation can also be considered but the thickness of insulation should be higher. Typical way of insulating the roof over the deck is shown in figure 3.

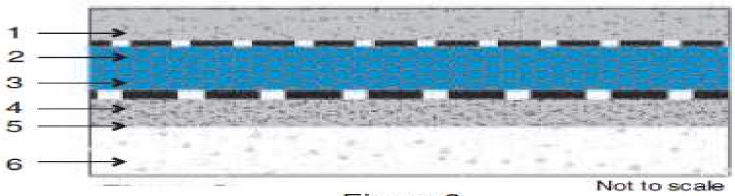


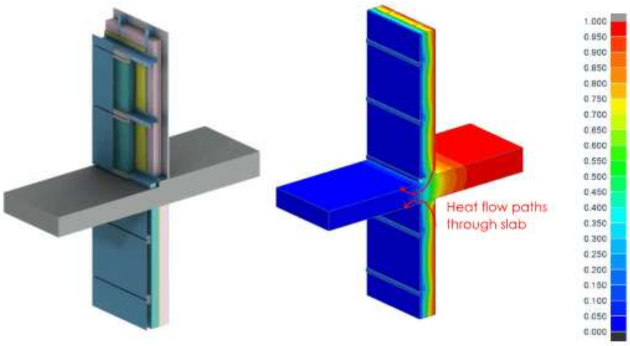
Figure 3
Over-deck Insulation

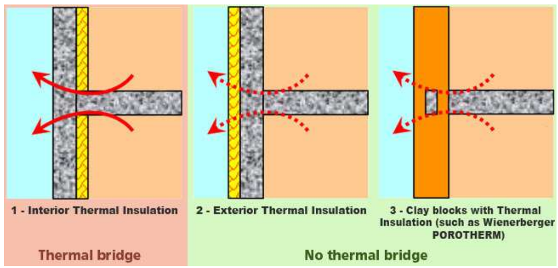
Over-deck Insulation

1. Final screed
2. Separation layer
3. Insulation
4. Water proof membrane
5. Base screed
6. Concrete roof deck

Thermal bridges

- A thermal bridge describes a situation in a building where there is a direct connection between the inside and outside through one or more elements that are more thermally conductive than the rest of the building envelope.
- As a result, there will be wasteful heat transfer across this element, its internal surface temperature will be different from other, better insulated internal surfaces and there may be condensation where warm, moist internal air comes into contact with the, potentially cold, surface. This condensation can result in mould growth.





thermal bridges

Thermal Bridge

Definition:

A thermal bridge is an area or component of a building that has a **significantly higher heat transfer rate than the surrounding materials**. This is often due to the presence of structural elements, such as steel beams or concrete slabs, that conduct heat more efficiently than insulation materials.

Causes:

- Use of conductive materials (e.g., metal frames, concrete).
- Poorly insulated areas around windows, doors, and junctions.
- Structural elements penetrating the insulation layer.

Impacts:

- **Increased Heat Loss/Gain:** Thermal bridges can lead to higher energy consumption for heating and cooling.
- **Condensation Issues:** Cold surfaces created by thermal bridging can promote moisture condensation, leading to mold growth and structural damage.
- **Comfort Issues:** They can create cold spots in a building, affecting occupant comfort.

Mitigation Strategies:

1. **Insulation Continuity:** Ensure continuous insulation around structural components.
2. **Thermal Breaks:** Use materials with lower thermal conductivity (like foam insulation) to separate conductive materials.
3. **Design Considerations:** Optimize building design to minimize the occurrence of thermal bridges (e.g., avoid metal studs in exterior walls).
4. **Thermal Modeling:** Use software to analyze heat flow and identify potential thermal bridges during the design phase.

Thermal Barrier

Definition:

A thermal barrier is a material or assembly designed to reduce heat transfer between two environments (e.g., indoors to outdoors). It acts as insulation, providing resistance to heat flow.

Types of Thermal Barriers:

1. **Insulation Materials:** Commonly used materials like fiberglass, foam boards, or cellulose that provide resistance to heat flow.
2. **Reflective Barriers:** Materials that reflect radiant heat away, often used in attics to reduce heat gain.
3. **Air Barriers:** These prevent air leakage, which can enhance the effectiveness of insulation against heat loss.

Importance:

- **Energy Efficiency:** Enhanced thermal barriers reduce the amount of energy required for heating and cooling, leading to cost savings and environmental benefits.
- **Building Comfort:** Help maintain consistent indoor temperatures, improving occupant comfort.
- **Moisture Control:** Proper installation can also aid in managing moisture within walls, decreasing the risk of mold growth.

Installation Considerations:

- Proper placement of thermal barriers is critical, typically in areas where heat flow is most significant (e.g., attics, exterior walls).
- Ensure that barriers are installed continuously without gaps, as any discontinuity can reduce their effectiveness.

Air Infiltration in Large Buildings

Definition:

Air infiltration refers to the unintended flow of air into a building through cracks, gaps, and openings in the building envelope. This can significantly impact energy efficiency, indoor air quality, and overall comfort.

Importance:

- **Energy Efficiency:** Air infiltration can lead to increased energy consumption for heating and cooling, as conditioned air escapes and unconditioned air enters.
- **Indoor Air Quality (IAQ):** Infiltration can bring in pollutants, allergens, and moisture, affecting IAQ.
- **Comfort:** Drafts and uneven temperatures can result from uncontrolled air movement.

Strategies to Manage Infiltration:

- **Building Envelope Design:** Use air barriers, proper sealing, and materials designed to reduce infiltration.
- **Regular Maintenance:** Inspect and maintain windows, doors, and other potential leakage points.
- **Blower Door Testing:** Assess and quantify air infiltration rates utilizing specialized equipment.

Sources of Odors:

Odors in large buildings can arise from several sources, including:

- HVAC systems
- Restrooms
- Kitchens and dining areas
- Mold or moisture issues

Odor Control Techniques:

- **Ventilation:** Increase fresh air intake to dilute indoor odors.
- **Air Purification Systems:** Utilize activated carbon filters, ozone generators, or UV light systems to neutralize odors.
- **Regular Cleaning:** Maintain cleanliness in kitchens, restrooms, and areas prone to odors.
- **Biological Treatments:** Use environmentally friendly bio-enzymatic cleaners that break down organic materials causing odors.

Heat Recovery in Large Buildings

Definition:
Heat recovery involves capturing and reusing waste heat from various processes, significantly improving energy efficiency in large buildings.

Importance:

- **Energy Conservation:** Reduces the need for additional heating/cooling energy by reutilizing existing heat.
- **Cost Efficiency:** Lowers energy bills, leading to long-term savings.
- **Environmental Impact:** Reduces greenhouse gas emissions by lowering overall energy consumption.

Common Heat Recovery Methods:

- **Heat Recovery Ventilators (HRVs):** Recover heat from exhaust air to preheat incoming fresh air.
- **Energy Recovery Ventilators (ERVs):** Similar to HRVs but also transfer moisture, which is beneficial in humidity control.
- **Chilled Beams:** Utilize waste heat to improve efficiency in cooling systems.
- **Waste Heat Recovery from Industrial Processes:** Capture heat from machinery and equipment for use in heating water or spaces.

Integrating These Systems

- By integrating **air infiltration management, odor removal, and heat recovery systems**, large buildings can achieve a more sustainable and comfortable indoor environment. Key integration strategies include:
- **Optimal HVAC Design:** Combine ventilation, heating, and odor control in a cohesive system to ensure maximum efficiency.
- **Monitoring Systems:** Utilize sensors to detect air quality and temperature, allowing dynamic adjustments to HVAC operations.
- **Regular Audits:** Conduct energy and air quality audits to identify areas for improvement and assess system performance.

Thank you