The role of the building's envelope in the conception of sustainable architecture

Building envelope design, energy efficiency and renewable energies

Paul Klee
credit to "Mark Harden"
Overview

Building envelope

• quick flashback: to introduce the current situation
• envelope design: curbing energy consumption
• envelope: optimizing the use of alternative energies
• advice to make optimum use of renewable resources
Current situation

The low cost of fossil fuels

- has allowed for the quick development of technical equipment
- has led builders to neglect the thermal aspect of the envelope
Current situation

Today poorly insulated, the envelope fails to maintain temperature inside.
The cost of this economic model

The intensive consumption of hydrocarbons has 3 heavy consequences

- a high environmental cost
  - FF combustion emits greenhouse gases
  - FF are non-renewable resources
  - the search for new FF deposits extends the deterioration of our environment
- a high social cost
  - FF prices have soared
- a high human cost
  - FF combustion emits carbonic gas

This model is no longer viable.
Buildings are big energy consumers

Source: INSEE
How can the design of the building’s envelope alone contribute?

- to curb the energy demands required to power a building,
The building’s envelope must be designed

I. to be energy efficient

• to avoid unnecessary energy consumption
• to curb the consumption of all types of energies

II. to optimize the use of alternative energies

• based on local renewable resources
• to avoid using fossil fuels
I. The building’s envelope must be designed for **energy efficiency**

5 conditions to design an energy-efficient envelope in the aim of reducing energy consumption for

- Heating / cooling
I. The building’s envelope must be designed for **energy efficiency**

- by enhancing insulation on opaque walls
1. The building’s envelope must be designed for energy efficiency

→ enhancing insulation on opaque walls

The function of insulation:
• to reduce thermal exchanges between interior and exterior

The best insulation:
• air trapped in air bubbles

Elements to be insulated:
• facades
• roofs
• grounds
• soffits
I. The building’s envelope must be designed for energy efficiency

- by enhancing the insulation on opaque walls
- by choosing thermally efficient glass walls
Thermal performance of glass walls depends on:

- the nature of the opening and the frame
- the nature of the glazing
- the external protection

I. The building’s envelope must be designed for energy efficiency

→ choosing thermal-efficient glass walls
1. The building’s envelope must be designed for **energy efficiency**

- by enhancing the insulation on opaque walls
- by choosing proper glass walls
- by treating thermal bridges

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I. The building’s envelope must be designed for **energy efficiency**

→ treating thermal bridges

Thermal bridges are points or linear areas of construction where the insulating barrier is broken.

They lie in the connections between:

- facades and floors
- roofs and walls
- wherever the insulation is broken
I. The building’s envelope must be designed for energy efficiency

- by enhancing the insulation on opaque walls
- by choosing proper glass walls
- by avoiding thermal bridges
- by achieving airtightness
I. The building’s envelope must be designed for **energy efficiency**

→ achieving airtightness

An airtight envelope is obtained by proper implementation of its different materials.
I. The building’s envelope must be designed for **energy efficiency**

- by enhancing the insulation on opaque walls
- by choosing proper glass walls
- by avoiding thermal bridges
- by achieving airtightness
- by implementing devices to reduce thermal exchanges
I. The building’s envelope must be designed for **energy efficiency**

→ implementing systems to reduce thermal exchanges

There are some devices conceived to avoid thermal exchanges. The best known is the air lock
I. The building’s envelope must be designed for energy efficiency

Compliance with these 5 conditions helps to limit thermal exchanges, thereby reducing the heating and cooling consumption of buildings:

- by enhancing the insulation on opaque walls
- by choosing proper glass walls
- by avoiding thermal bridges
- by achieving airtightness
- by implementing devices to reduce thermal exchanges
I. The building’s envelope must be designed for energy efficiency

The shape of the building will also play an important role in its energy efficiency

Each designer must find the best solution to solve the equation between thermal performance, energy efficiency and the building’s needs.
The building’s envelope must be designed to optimize renewable resources.

The envelope, can, by its form and design,

- optimize the natural renewable resources
- offered by its surroundings
- for the energy needs of buildings

- Heating / cooling
- Lighting
- Domestic hot water production
- Electricity production
- Ventilation
11. The building’s envelope can be designed to collect renewable resources offered by the 4 natural elements

- The sun, for its heat inputs and light
- Air, for its motion force
- Water, for its cooling characteristics
- Earth, for its thermal properties
II. The building’s envelope must be designed to optimize thermal properties of earth

In the surface layers, earth is heated by the sun

As of a depth of 2 m: the soil temperature becomes constant:
6° C – 10° C (winter – summer)

Soil property can be optimized

→ directly, to preheat or cool air

→ by “geothermal heat pump systems” for heating, cooling and producing domestic hot water
II. The building’s envelope must be designed to optimize thermal properties of earth

Winter: soil temperature is higher than the exterior temperature

Canadian well. Used during the winter to preheat air

Winter: soil temperature is higher than the exterior temperature

-10°C fresh air

The air introduced into the duct will be heated
II. The building’s envelope must be designed to optimize thermal properties of earth

Provencal well. Used in summer to cool air

Summer: soil temperature is lower than the exterior temperature

The air introduced into the duct will be become cooler
The building’s envelope must be designed to optimize thermal properties of earth.

An example of air intake ducts of a Canadian / Provencal well in Freiburg (Germany).
II. The building’s envelope must be designed to optimize thermal properties of earth

An example of ducts emerging inside the building
Secondary School, Klaus, Vorarlberg (Austria), Dietrich and Untertrifaller arch
Geothermal heat pump systems

- Singular points
  - vector of transmission: water
  - heat pump, device which increases temperature

- Use:
  - for heating, for cooling
  - for domestic hot water production

- 2 systems of geothermal heat pumps:
  - “closed loop system” works with heat transfer fluid

II. The building’s envelope must be designed to optimize thermal properties of earth
II. The building’s envelope must be designed to optimize thermal properties of earth

“Geothermal heat pump systems”

- “open loop system” works with ground-water
II. The building’s envelope can be designed to optimize sun resources

- Optimizing the sun’s heat: for heating and domestic hot water production
- Optimizing the sun’s light: for lighting and electricity production

2 systems to optimize solar gains
- “Passive solar energy”
- “Active solar technology”
In the passive solar energy system, the envelope must be designed to:

- collect
- store
- distribute the sun’s heat

without the aid of technical equipment for this conversion.

**Use**: to preheat air

**Operating principle**

- envelope receives the sun’s heat,
- heat is stored in the structure,
- heat is released into the room.

Very important points:
- the glass wall must face south, (northern hemisphere)
- solar masks must be avoided.
Operating principle: - double skin façade -

Day: the sun heats the air trapped in the air space.

2 things occur:
- solar heat
  - triggers a convection phenomenon
  - is stored in the thick wall

Passive solar energy
Solar heat recovery system (hybrid system)

Envelope design: more sophisticated

South-facing envelope is composed of:
- a thick wall of dark colour
- a glazing wall
- devices allowing air to circulate
- a night protection

II. The building’s envelope must be designed to optimize solar heat

Envelope design: more sophisticated
11. The building’s envelope must be designed

Passive solar energy
Envelope design - double skin -

Operating principle
At night, heat will also be released

It will then be necessary:
• to close the night curtain
• to close the slots

The thick wall will continue to diffuse the heat stored during the day

© Anna Wagner
Thermal panels: active solar technology

Important points:
- Thermal panels: face south
- Inclination must be between 30° and 45°
  - Collect heat from the sun
  - Warm the heat transfer liquid
  - For domestic hot water production

The building’s envelope must be designed to optimize solar heat by “active solar technology.”

“Active solar technology” uses technical processes to convert solar energy.
The light penetration into the room depends on:
- the orientation
- the location
- the size
  of the window in the facade

Performance
South-facing lateral windows

Use: for lighting

Generally, the projection of daylight penetrating through an opening equals approximately one and a half times the height of the window measured from lintel to ground

II. The building's envelope must be designed to optimize sunlight
II. The building’s envelope must be designed to optimize sunlight.
The openings are composed of:
- large main lateral windows
- glazed panels allowing light to penetrate

The building’s envelope must be designed to optimize sunlight.
II. The building’s envelope must be designed to optimize sunlight to avoid heat inputs.

- Light emitted by the sun carries heat inputs.
- In summer, south and west-facing windows require external protection to stop solar heat.

School in Vorarlberg (Austria), Dietrich and Untertrifaller arch.
II. The building’s envelope must be designed to optimize sunlight.
II. The building’s envelope must be designed to amplify sunlight

Building’s envelope devices to amplify daylight in interior spaces

The main ones are:

- lightshelves
- skylights
- light or solar tubes
II. The building’s envelope must be designed to amplify sunlight. Light shelves, white or reflective devices placed outside the windows, can increase light by 50% compared to non-equipped windows. Portcullis House, London (UK) Hopkins arch.

South-facing windows fitted with lightshelves let in 50% more light than non-equipped windows.
11. The building’s envelope must be designed to diffuse sunlight

- skylights
  - windows located on roofs

**Advantage:**
- skylights provide very uniform light performance is better on cloudy days

**Disadvantage:**
- skylights offer poor thermal efficiency

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II. The building’s envelope must be designed

→ skylights


to diffuse sunlight

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II. The building’s envelope must be designed to amplify sunlight using solar tubes, which are pipes lined with highly reflective material that lead the light rays through a building.

Advantage: given their small surface area they don’t allow as much heat transfer as skylights do.

3 elements:
- an external collector
- a pipe light system
- a light diffuser
II. The building’s envelope can be designed

- to optimize sunlight by “active solar technology”

Solar panels:
- active solar technology system
- convert light into electricity

They must be installed:
- on the roof facing south
- at an inclination of 30° and 35°
- without being masked

Municipal building in Vorarlberg (Austria)
H. Kaufmann, arch.
II. The building’s envelope must be designed

Example of the use of solar panels
- they produce electricity
- they provide shade
- they allow light to enter.

Municipal building in Vorarlberg (Austria)
H. Kaufmann, arch.
II. The building’s envelope must be designed to optimize air resources

Air properties are used to ventilate naturally to cool in summer to produce electricity

Main characteristics:
- its acceleration (Venturi effect)
- its natural convection (temperature difference)
To optimize air resources for natural ventilation, a facade must be exposed to prevailing winds. The building’s envelope must be designed for natural ventilation.

- Air enters through openings.
- Sweeps through the interior.
- Is sucked out by the opposite facade.
To improve the draw implementation of a thermal or solar chimney

A pipe exposed to the sun’s heat by heating the air inside the pipe

Heat triggers a convection process “a chimney effect”

II. The building’s envelope must be designed for natural ventilation

System used:
- to extract stale air,
- to cool volumes where heat has accumulated
II. The building’s envelope must be designed for natural ventilation.

- 3 devices to naturally ventilate:
  - a Canadian / Provencal well
  - a ventilation shaft
  - towers, solar chimneys
11. **The building’s envelope must be designed for natural ventilation**

- the bottom of the ventilation shaft
  - located at the ground level
  - allows the arrival of fresh air

- Upper part: glass roof
  - heated by the sun
  - warms the air of the shaft
  - generates a convection process

The temperature difference causes:
- the air diffused can rise naturally
- central body of the ventilation shaft
II. The building’s envelope must be designed for natural ventilation.

The grids through which fresh air delivered by the ventilation shaft is introduced into the reading rooms.
II. The building’s envelope must be designed for natural ventilation

After sweeping through the reading rooms, stale air is removed by solar chimneys.
II. The building’s envelope must be designed for natural ventilation.

Solar chimneys: metal scales on top, heated by the sun, increase the draw to extract stale air and heat.
11. The building’s envelope can be designed to produce electricity.

Two towers shaped like wings facilitate the acceleration of wind.

Shape: increases the efficiency of wind turbines: benefit from the Venturi effect, to produce electricity.

Other property of Ventury effect: as air is accelerated it is also cooled.
II. The building’s envelope must be designed to optimize water resources

Water is valued:
- for its driving force
- for its capacity
- to evaporate on contact with heat

Evaporation: temperature decreases

This characteristic can be optimized to cool interior spaces.

It becomes an increasingly expensive resource; rain water must be collected for multiple purposes.
II. The building’s envelope must be designed for cooling.

The pool contributes to cool the lobby space. As it evaporates water vapour:
• lowers the temperature
• cools air

Solar Fabrik, Freiburg (Germany)
F. Rolf, M. Hotz / R. Amann

© Anna Wagner
II. The building’s envelope must be designed

Rainwater collected at the top is used to
• water the garden
• fill the pool

Vegetation like water:
• to cool air in summer
• to maintain a constant hygrometry level during all seasons.
11. The building’s envelope must be designed to regulate hygrometry.

A variant for cooling and regulation of hygrometry: by green roofs.

Plants store moisture from rain and release it gradually.
11. The building’s envelope must be designed to regulate hygrometry for cooling.

Green walls: very similar role to that of green roofs.

Green wall: cools the public square outside the entrance of the building.

aixa Forum, Madrid (Spain)
erzog, P. de Meuron arch.

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To make optimum use of natural resources

1. **analyse the site’s potential** (select the most efficient resources)
   
   An environmental study of the site should be conducted, including:
   
   - a soil survey (conductivity and the hydrology system)
   - a study of solar exposure (the best orientation)
   - a wind study, the “wind rose” (detect the prevailing winds)
   - a rain study (estimate the amount of retrievable water)

2. If possible, **consider several systems to optimize renewable resources** in relation to the building’s needs

3. **Avoid implementing expensive devices if benefits is not conclusive**

4. **Collect also information** about the context (urban, legislative etc)
   
   - in case of natural ventilation: check that air intakes are properly placed
   - in case of rainwater retrieving: check that this is compatible with national legislation.

5. **Ask for specific studies**, such as the heliodon, (detect solar masks)
Example of heliodon
calculated on the 21st of June (summer solstice), in Paris from sunrise to sunset
To conclude

- The building’s envelope: in relation with the local climate.
- Role of climate today: a major player as it provides alternative energies.
- Retrieval of this energy remains more expensive.
- The building’s envelope must be energy-efficient in order to avoid
  - burning fossil fuels
  - wasting this costly energy.
- Actions are of limited use: if we fail to consider the logical design of envelope.
- This conception demands strict rules of use: not to upset the efficient natural mechanism
- Similarly, the maintenance of these buildings: an understanding of the relation between the building’s envelope and climate,
- so as not to counteract the building’s logic and therefore its energy performance.
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