Trombe wall
(passive solar system in buildings)

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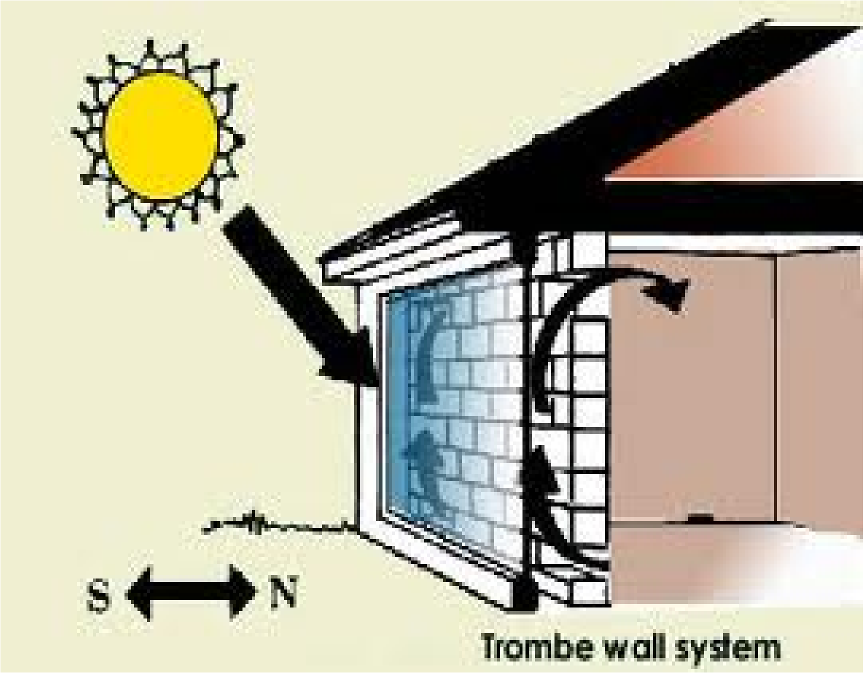
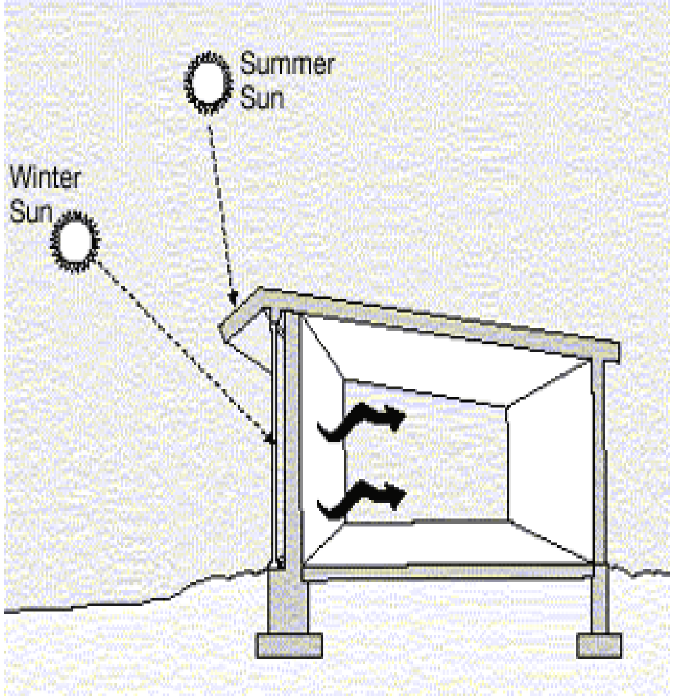
What is a Trombe Wall?

- Examples:



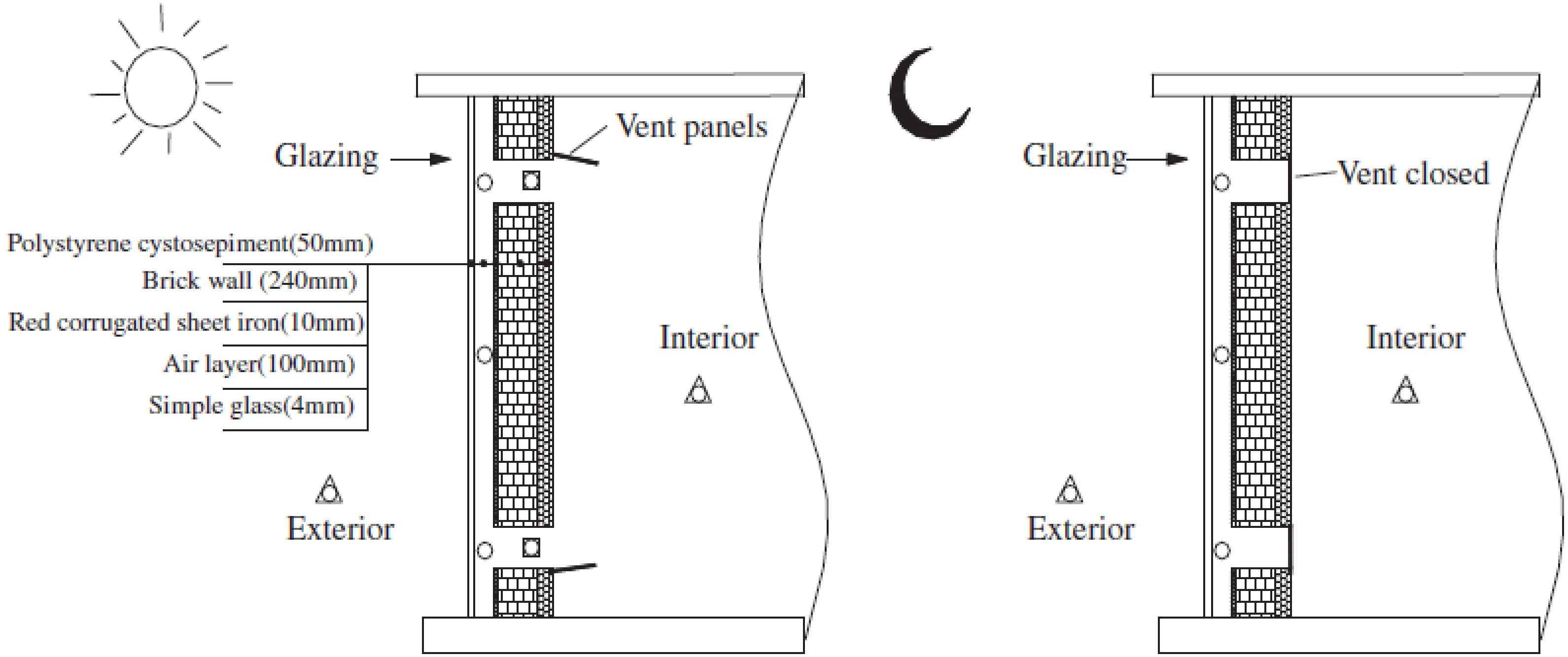


What is a Trombe Wall?

- A passive solar system in buildings
- Adapted to the south-facing walls (in the northen hemisphere)
- The basic system consists of the south wall (masonry wall painted black), a glass cover-plate (on the exterior), and the air channel between them
- The wall incorporates vents at the bottom and at the top for the circulation of air in the air channel.
- Solar energy is collected (the system works as a solar collector) and stored in the wall. This energy is released to the air flow in the channel and directly to the room

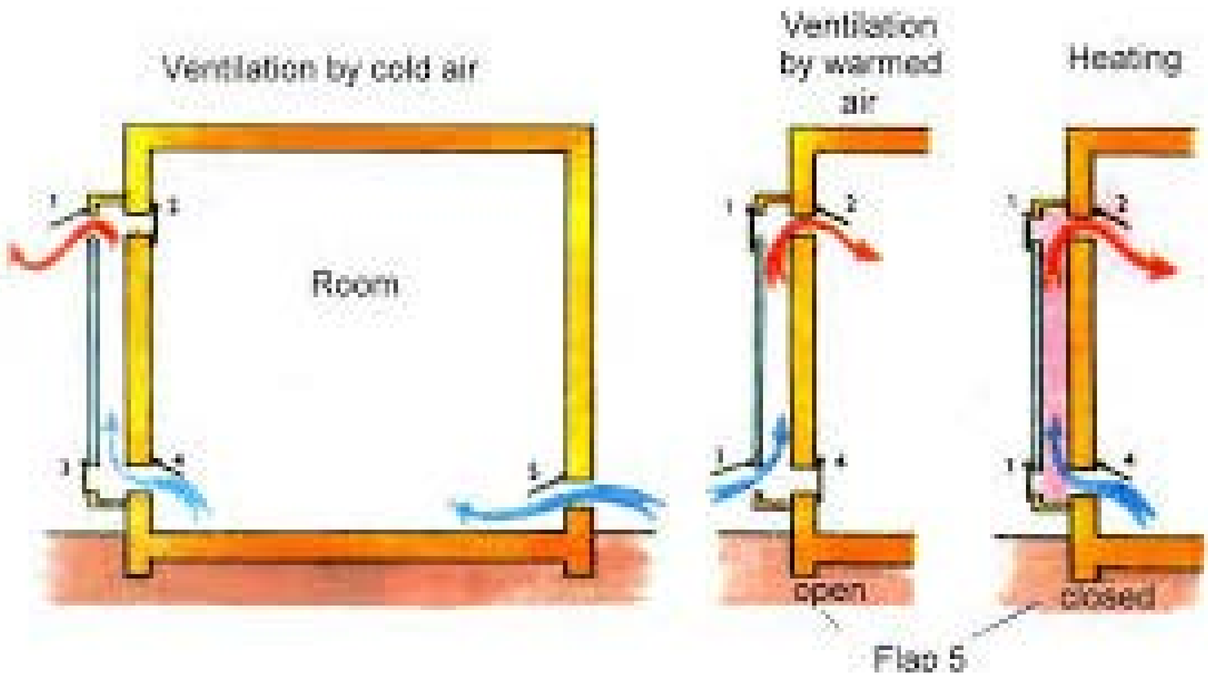
What is a Trombe Wall?

- Daytime vs. night time



What is a Trombe Wall?

- For building ventilation, the glass can also incorporate vents (the systems acts as a solar chimney).



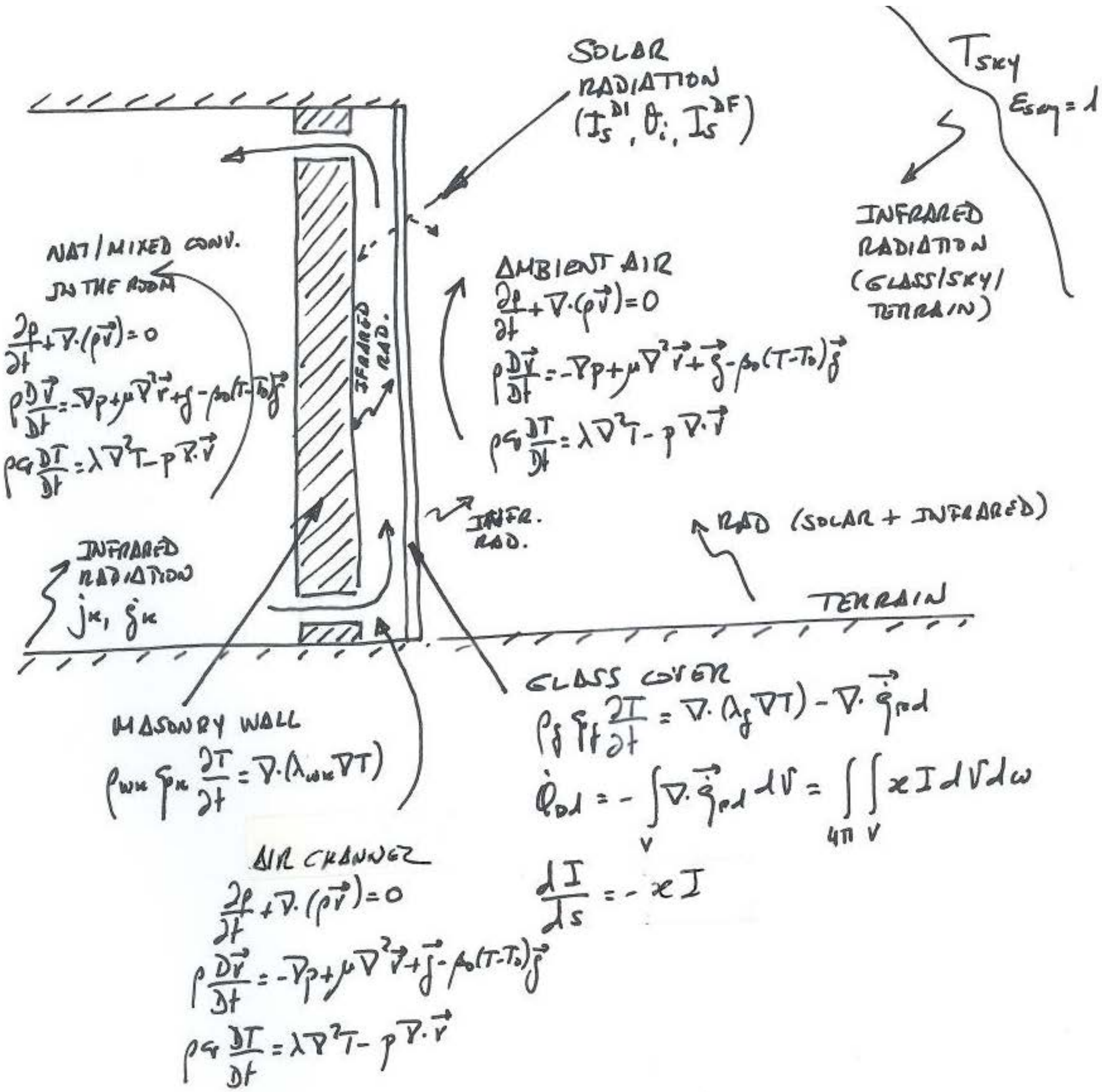
Improvements to the basic Trombe wall design

- Radiant properties of the masonry wall can be improved if a selective surface is used (e.g. a metal foil glued to the outside surface of the wall)
- Air and heat flow can be enhanced if electric fans controlled by thermostats are installed
- Two layers of glazing material to reduce heat losses to the ambient
- Etc.

Identification of physical phenomena and mathematical formulation

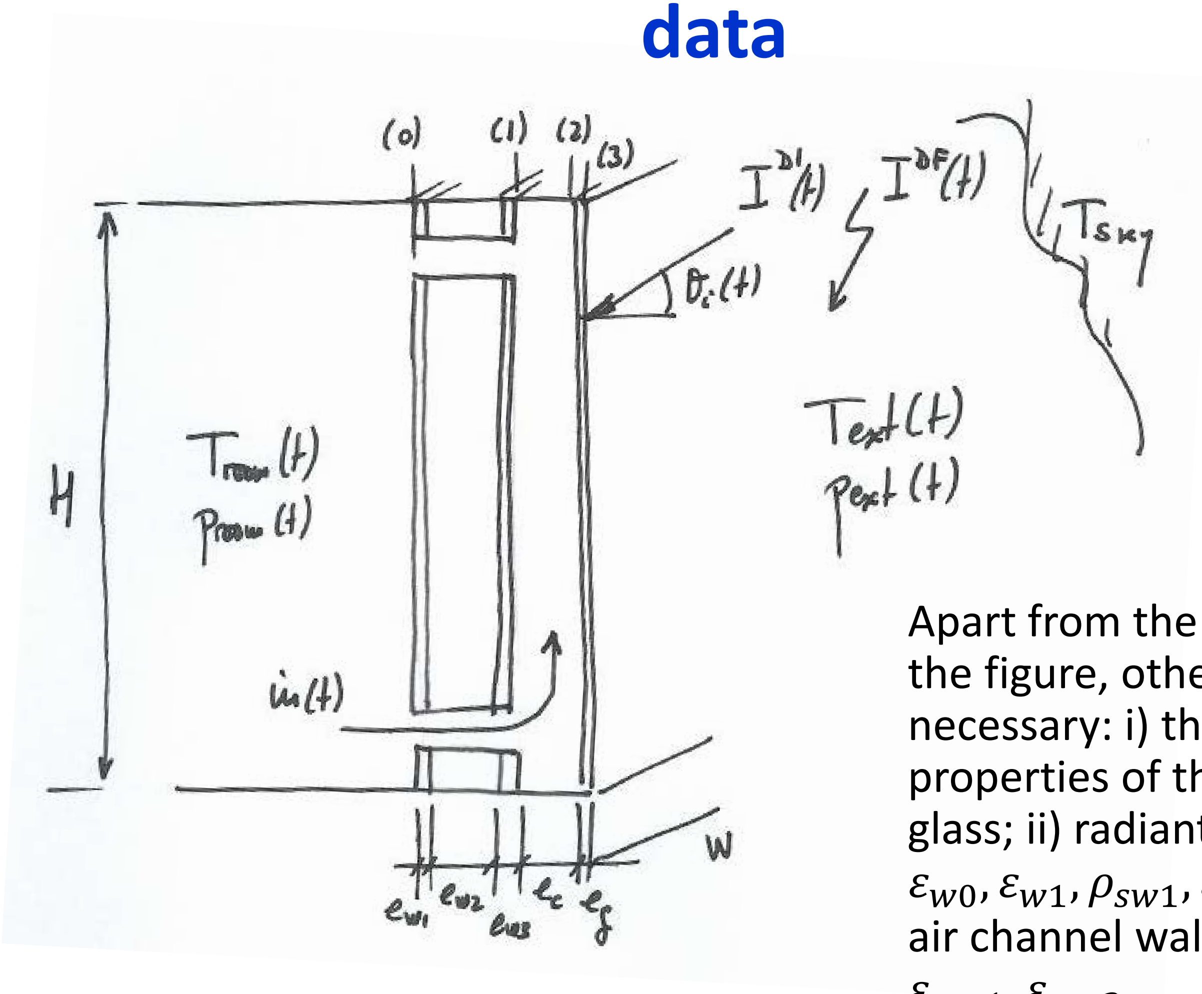
- 3D and unsteady behaviour
- Direct and diffuse solar radiation in the glass cover and the air channel wall
- Infrared radiation between the room walls, in the air channel (wall – glass), and between the glass and the sky
- Conduction heat transfer in the wall (composed wall) and
- Conduction and radiation heat transfer (semi-transparent media) in the glass cover
- Natural/forced convection in the air channel, inside the room, and outside the Trombe wall (ambient conditions)

Identification of physical phenomena and mathematical formulation



Constant air thermal conductivity and viscosity. No emission/scattering effects in the glass. Semi-grey radiation.

Basic model: schematic representation and input data



Apart from the data indicated in the figure, other input data are necessary: i) thermophysical properties of the wall layers and glass; ii) radiant properties: $\varepsilon_{w0}, \varepsilon_{w1}, \rho_{sw1}, \varepsilon_{w2}, \kappa_g, n_g, \varepsilon_{w3}$; iii) air channel walls roughness: $\varepsilon_{r,w1}, \varepsilon_{r,w2}$.

Basic model: basic integral equations

$$\frac{\partial}{\partial t}\int_{V_a}\rho dV+\int_{S_a}\rho\vec{v}\cdot\vec{n}dS=0$$

$$\frac{\partial}{\partial t}\int_{V_a}\vec{v}\rho dV+\int_{S_a}\vec{v}\rho\vec{v}\cdot\vec{n}dS=\int_{S_a}\vec{f}_{(\vec{n})}dS+\int_{V_a}\vec{g}\rho dV$$

$$\frac{\partial}{\partial t}\int_{V_a}\left(h-\frac{p}{\rho}+e_c+e_p\right)\rho dV+\int_{S_a}(h+e_c+e_p)\rho\vec{v}\cdot\vec{n}dS$$

$$=-\int_{S_a}\vec{\dot{q}}\cdot\vec{n}dS+\int_{S_a}\vec{v}\cdot\vec{f}^{\tau}_{(\vec{n})}dS$$

Basic model. Main hypothesis

- Unsteady simulation
- Conduction heat transfer at the wall (composed of arbitrary number of layers of different materials). Two levels of analysis: $T_{w,k}(t,x), T_{w,k}(t,x,y)$
- Conduction heat transfer and radiation in the glass cover. Two levels of analysis: $T_g(t,x), T_g(t,x,y)$
- 1D air flow in the channel: $\bar{\phi}\ (t,y),\ \bar{\phi} = v, p, T$. Two levels of modelling: step-by-step method; semi-implicit method for pressure linked equations
- Unpolarized sun rays onto the glass cover (negligible polarization of the reflected and refracted components).
- Grey and diffuse infrared radiation

Basic model: main resolution steps

- General algorithm
- Resolution of the masonry wall
- Resolution of the glass cover
- Resolution of the air flow in the channel (forced convection; $\dot{m}(t)$ is known or depends on the pressure difference)
- Infrared radiation in the air channel and in the external part of the glass cover
- Direct and diffuse solar radiation in the glass cover and channel wall. Evaluation of the global radiant properties ($T^{DI}, R^{DI}, A^{DI}, T^{DF}, R^{DF}, A^{DF}$)

More advanced analysis

- Multidimensional analysis of the masonry wall: $T_{wk}(t, x, y, z)$
- Multidimensional analysis of the glass cover (participating media): $T_g(t, x, y, z)$
- Radiation effects between the glass cover and the external ambient (terrain, adjacent buildings, etc.)
- Multidimensional natural/mixed/forced convection in the channel ($\dot{m}$ prescribed or unknown). Two approaches: i) semi-implicit method for pressure linked equations (SIMPLER) using RANS modelling (e.g. k-e, k-w models); ii) explicit fractional-step method using LES models.