3.1. What are the basic elements of passive solar design?

Passive solar design uses the energy from the sun for the heating and cooling of living spaces, without relying on mechanical devices. The system relies on the natural heat transfer processes of conduction, convection and radiation in order to collect, store and redistribute the solar energy (WEB-1: *Architecture design basics. Passive solar design*).

Passive solar design takes into account the buildings site, climate and materials to minimise the use of energy and is centred around the movement of the sun. The passive system is considered to be simple, not requiring any substantial use of mechanical devices such as pumps, fans or electrical controls (WEB-1: *Architecture design basics. Passive solar design*).

A passive solar building is a structure that is designed to make optimal use of the sun's energy for heating and cooling purposes. This type of building must meet three basic requirements to function effectively: building orientation, thermal accumulation, and heat retention.

Building orientation is critical in passive solar design. The building must be positioned in such a way that it can act as a solar collector, allowing the sun's rays to enter the building when heat is needed and keeping them out when it is not. This is typically achieved by orienting the building towards the south in the northern hemisphere and towards the north in the southern hemisphere, where the sun is most intense.

The building must also be a thermal accumulator, retaining heat so that it can be used during cold times when the sun is not shining, as well as keeping the building cool during hot periods. This is typically achieved through the use of solid building materials like stone and concrete, which are highly effective at retaining heat.

Finally, a passive solar building must be a good heat trap, using heat efficiently and losing it slowly. This is accomplished primarily through the effective use of insulation, which reduces heat loss, as well as by reducing air infiltration and optimizing windowing. To achieve this, the thermal insulation in a passive solar building must be extremely effective, and thick walls are often built up using 'super insulation' to achieve high R-values.

There are three basic types of passive solar design: direct gain, indirect gain, and isolated gain, which all aim to provide passive solar space heating. The direct gain system is the simplest, allowing sunlight to enter the building through south-facing windows and strike thermal mass (floor and walls), which absorb and store the solar heat (Fig. 3.1.1).

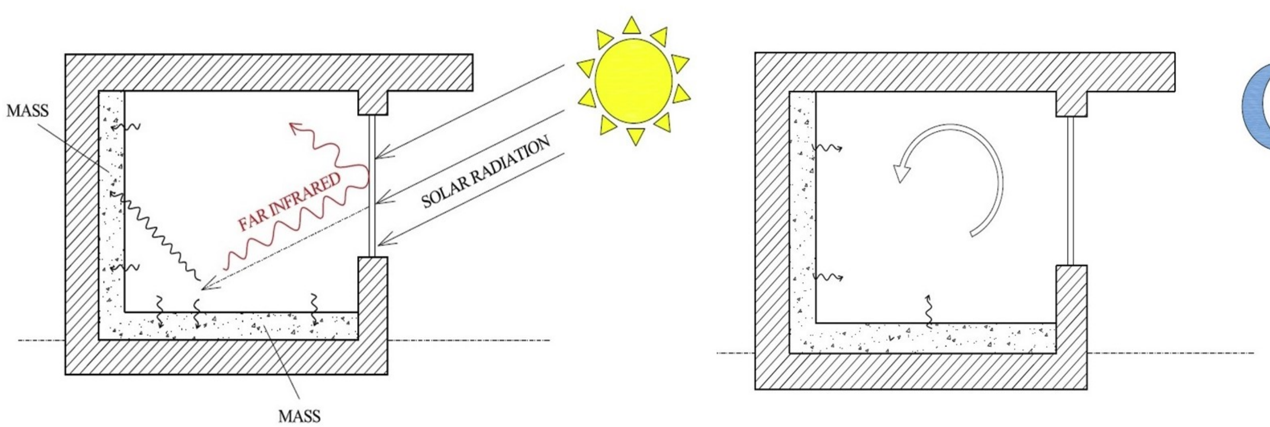

Fig.3.1.1. Direct gain solar heating system. (Source: own elaboration).

The indirect gain system uses a trombe wall, which uses the basic elements of heat collection and storage in combination with convection. The amount of passive solar energy a building can collect depends on factors such as the area of glazing and the amount of thermal mass. It is recommended to have 1m^3 of thermal mass with a high heat-absorbing surface per 1 m^2 of glazing to optimize passive solar heating.

The trombe walls are generally employed for the passive heating purpose and utilized for cold climatic conditions. However, some types of trombe walls are also useful for cooling purpose. Based on the type of application either heating or cooling, trombe walls are classified as heating based trombe wall and cooling based trombe wall (Dnyandip K. Bhamare, Manish K. Rathod, Banerjee, J., 2019).

The trombe wall is an important component of the indirect gain passive solar design system. It is a massive stone structure that is installed on the south-facing side of the building and is positioned behind a facade glass fence. The purpose of the trombe wall is to collect and store the sun's heat energy, which is then gradually transferred into the building's interior space through convection. The wall can be covered with selective absorption foil or painted black to enhance its ability to absorb and retain heat.

The thickness of the trombe wall directly affects the delay time in heat transfer to the interior space. A wall thickness of 20 cm provides a delay time of approximately 5 hours, while a wall thickness of 40 cm provides a delay time of around 10-12 hours. This delay time allows the building to continue to receive heat long after the sun has set, providing a steady source of warmth even when the outside temperature has dropped. The trombe wall is an effective and efficient way to harness the sun's energy for heating purposes and is a key component of a passive solar building design.

The optimal thickness of the trombe wall is 30 cm (WEB-2: *Trombe Wall*).

The trombe wall can be not only concrete but also stone or brick. To improve the heat transfer of the wall, special holes are created at the bottom and top of the wall to ensure natural air convection, and for more efficient heat transfer, fans are installed for forced circulation. The sunlight passes through the glazed window and hit the concrete wall, which is installed at a distance of 100 mm from the glazed window. Ultraviolet rays from the sun hitting the surface of the wall heat it and part of the rays are reflected from the wall in the form of infrared radiation, which does not pass through the glass, thus heating the air as well (WEB-2: *Trombe Wall*).

The trombe wall is a passive solar heating system that can be incorporated into the design of two-story buildings. However, the distribution of heat energy must be considered in the planning process, with living rooms typically located on the warmer second floor. To maximize the efficiency of the trombe wall, a selective coating can be applied instead of dark paint, which has a 90% efficiency compared to 60% (Fig. 3.1.2).

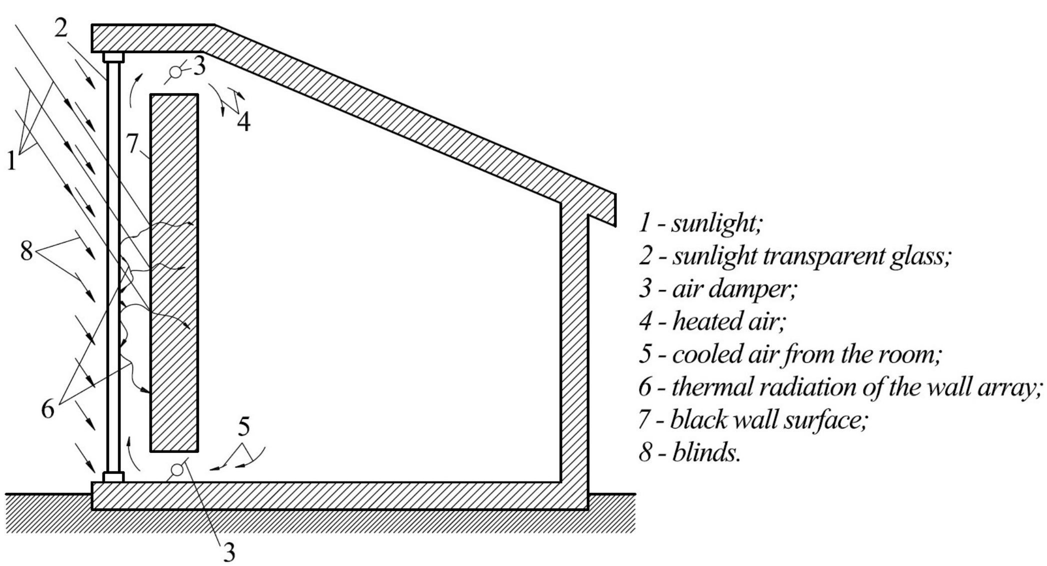

Fig.3.1.2. Trombe wall scheme. (Source: own elaboration baced on Брызгалин, В.В., Соловьев, А.К., 2018).

The isolated gain system also utilizes convection to heat living spaces, but through the use of a sunspace, or solar room, located on the south side of the house. This room has a large glass area and thermal storage mass, and the air heated in the sunspace can be circulated throughout the rest of the home through natural or mechanical means. Sunspaces are often used in residential building renovations and can serve as the primary heating system if thermally isolated from the living area (Fig. 3.1.3).

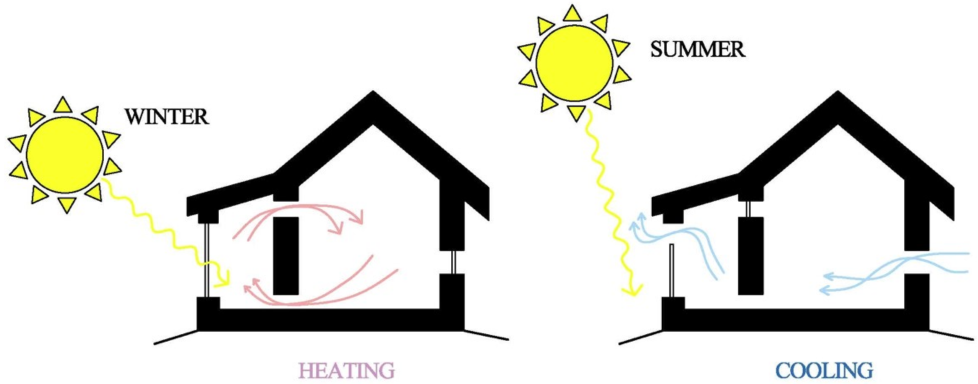

Fig.3.1.3. Sunspace. (Source: own elaboration).

3.1.1. Thermal mass

Thermal mass can be used to store high thermal loads by absorbing heat introduced by external conditions, such as solar radiation, or by internal sources such as appliances and lighting, to be released when conditions are cooler. This can be beneficial both during the summer and the winter (WEB-3: *Thermal mass in buildings,* 2022).

Historically, it has been considered that buildings with more thermal mass are suited to regular occupation, where internal conditions are stabilised by the thermal mass, and moderated by low-level building services inputs. Lighter-weight, more highly-insulated buildings might be better suited to occasional use, where occupants return after some absence and at the flick of a switch, can activate building services systems that will quickly create comfortable conditions (WEB-3: *Thermal mass in buildings,* 2022).

Night-time cooling, however, may require that buildings are unoccupied during the night, and so may be more suitable for an office building than for a hospital, and as the building regulations become more strict, so the performance differences between lightweight and heavyweight buildings are becoming more blurred (WEB-3: *Thermal mass in buildings,* 2022). (Fig. 3.1.4).

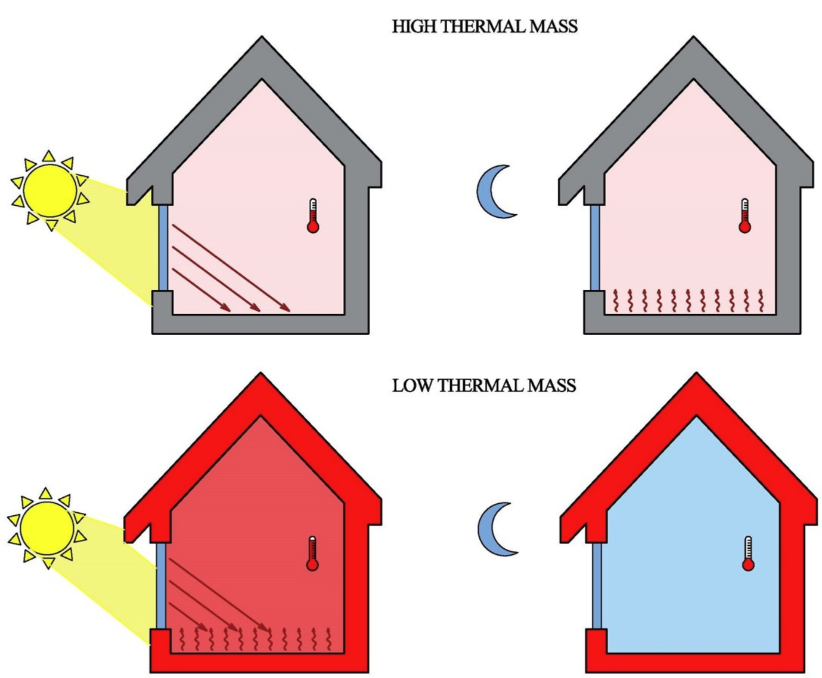

Fig.3.1.4. Hight and Low thermal mass. (Source: own elaboration).

To be effective as a heat storage component in a passive solar building, the material must have adequate heat capacity in order to store enough heat, and it must release the heat at an optimal rate in order to moderate indoor temperature flux. Many metals have high heat capacity, but they are ineffective as passive solar thermal mass because of their high rate of conductance – heat is absorbed and released too fast. On the other hand, wood also has decent heat capacity, but its rate of conductance is too low. By far, the most common form of thermal mass is concrete, masonry, and stone (Russell, J., 2018).

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