3.4. What is passive solar cooling system?

Passive cooling achieves high levels of natural convection and heat dissipation by utilizing a heat spreader or a heat sink to maximize the radiation and convection heat transfer modes. In architectural design, natural resources like wind or soil are used as heat sinks to absorb or dissipate heat. This leads to proper cooling of electronic products and thermal comfort in homes or office buildings by keeping them under the maximum allowed operating temperature. A growing trend in this regards can be witnessed in what is commonly known in the industry as passive houses (Zaharia, A., 2021).

Passive solar cooling is a method of reducing the cooling loads in buildings by utilizing natural processes and design strategies to mitigate solar gain and enhance thermal comfort. The approach is based on the principles of passive solar heating, but applied to cooling instead.

Passive solar cooling techniques include:

1. **Natural ventilation:** This can be achieved by designing the building to take advantage of prevailing winds, and by providing operable windows and vents. The goal is to create a flow of air through the building that carries away heat. The building design should include features such as wind towers, courtyards, and skylights to enhance the natural ventilation process.
2. **Thermal mass:** This refers to the use of materials with high heat storage capacity, such as concrete or masonry, to absorb and store heat during the day, and release it at night. These materials can be used in the construction of walls, floors, and ceilings. The thermal mass should be placed in the right location to maximize its performance and it should be insulated to prevent heat loss.
3. **Shading:** This can be achieved by using overhangs, shading devices, or vegetation to reduce the amount of direct solar radiation entering the building. Shading devices such as louvers, screens, and awnings can be used to control solar gain and glare. Green roofs and walls can also be used to reduce heat gain and to improve the building's thermal performance.
4. **Radiant barriers:** These are reflective materials used to reduce the amount of heat absorbed by a building's envelope. Radiant barriers can be installed in the roof or walls to reduce heat gain, and they can be combined with insulation to improve the building's thermal performance.
5. **Night-sky cooling:** This involves using radiative cooling to the night sky as a means of rejecting waste heat from the building envelope. This method can be achieved by using high-emissivity coatings on the roof and walls, and by providing an airspace between the insulation and the roof or walls.
6. **Stack ventilation:** this method is based on the principle of buoyancy-driven ventilation, where warm air is expelled from the building through vents or openings located at the top of the building and the cool air is drawn in through vents or openings located at the bottom of the building. Stack ventilation can be enhanced by using thermal chimneys and ventilated attics.
7. **Cross-Ventilation:** This strategy involves creating an airflow through the building by opening windows or vents on different sides of the building, to create a natural flow of air that carries away heat. This method can be enhanced by using clerestory windows, operable vents in the roof, and by providing thermal chimneys.

All these techniques should be integrated into the building design and should be based on a thorough analysis of the local climate and site conditions, such as solar radiation, temperature, humidity, wind, and precipitation (Fig. 3.4.1). Passive solar cooling can significantly reduce the cooling load of a building, and can lead to significant energy savings, improved thermal comfort, and reduced environmental impact. The design should consider the building's orientation, envelope, and the use of natural light to optimize the passive cooling performance.

Green roofs and walls can help to reduce heat gain by providing shading and insulation, and by evapotranspiration, which is the process of water evaporating from the plants. Green roofs and walls can also improve air quality, reduce stormwater runoff, and enhance the building's aesthetic.

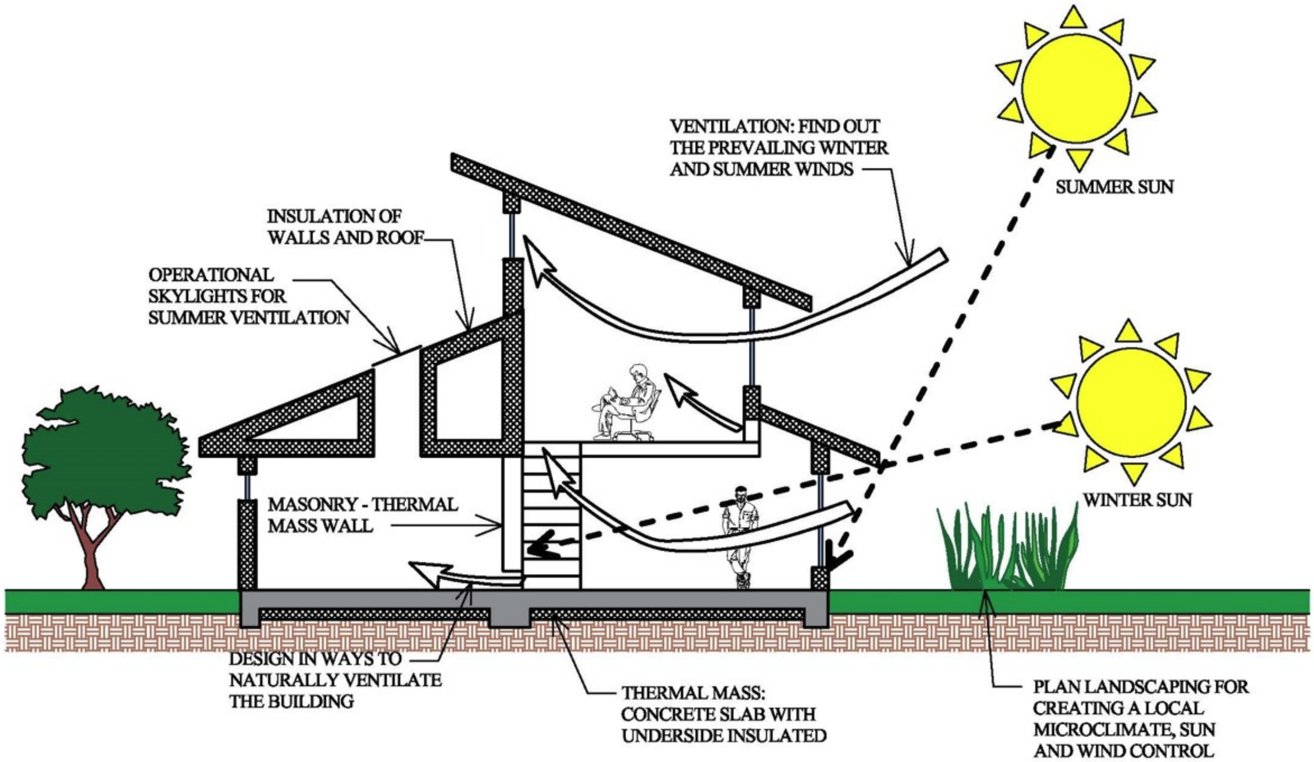

Fig.3.4.1. Natural ventilation of a passive house. (Source: own elaboration).

Important aspect is the use of earth-air heat exchangers (EAHEs). EAHEs are underground ducts that can be used to ventilate a building with cool air during the summer. The cool air is obtained from the earth, which has a relatively constant temperature throughout the year. EAHEs can be used in combination with other passive cooling techniques, such as natural ventilation and thermal mass, to enhance the building's thermal performance.

The conceptual structure of the EAHE-assisted building ventilation system is illustrated in Fig.3.4.2. The underground buried pipe is the core component of the EAHE system. The ambient air is pumped into the pipe and exchanges heat with the adjacent underground soil therein, and eventually is supplied into indoor space for building ventilation. At a certain depth, the temperature of underground soil is approximately constant throughout the whole year. In summer, the hot ventilation air releases heat to the surrounding soil and is precooled before entering the indoor space. In winter, the cold ventilation air can absorb heat from the surrounding soil and be preheated. As a result, the energy demand for cooling and heating ventilation air can be significantly reduced by utilizing low-grade natural energy sources. Perhaps the EAHE system may be treated as a seasonal thermal energy storage system for the hot-summer and cold-winter climate (Zhang, Ch., Wang, J., Li, L., Wang, F., Gang, W., 2020).

At an underground depth of 5 m, the temperature of underground soil is approximately constant throughout the whole year with an amplitude of less than 0.6 °C. A longer pipe length can achieve a larger temperature difference between the outlet air of the EAHE system and ambient air. For the pipe length longer than 80 m, the outlet air temperature of the EAHE system keeps approximately constant throughout the whole year despite the strong fluctuation of the ambient air temperature. Moreover, the internal diameter of the buried pipe shows a limited impact on the thermal performance of the EAHE system. Therefore, a depth of 5 m and a length of 80 m are recommended considering the compromise between thermal performance and construction costs of the EAHE system (Zhang, Ch., Wang, J., Li, L., Wang, F., Gang, W., 2020).

It should be noted that the application of the EAHE-assisted building ventilation system in the heating season performs much better than that in the cooling season. It mainly results from the fact that the EAHE system only helps to reduce the sensible cooling and heating loads of building ventilation. This means that dry climates may be very suitable for the EAHE-assisted building ventilation system, and the energy-saving potential of this system may be limited for the humid climates (Zhang, Ch., Wang, J., Li, L., Wang, F., Gang, W., 2020).

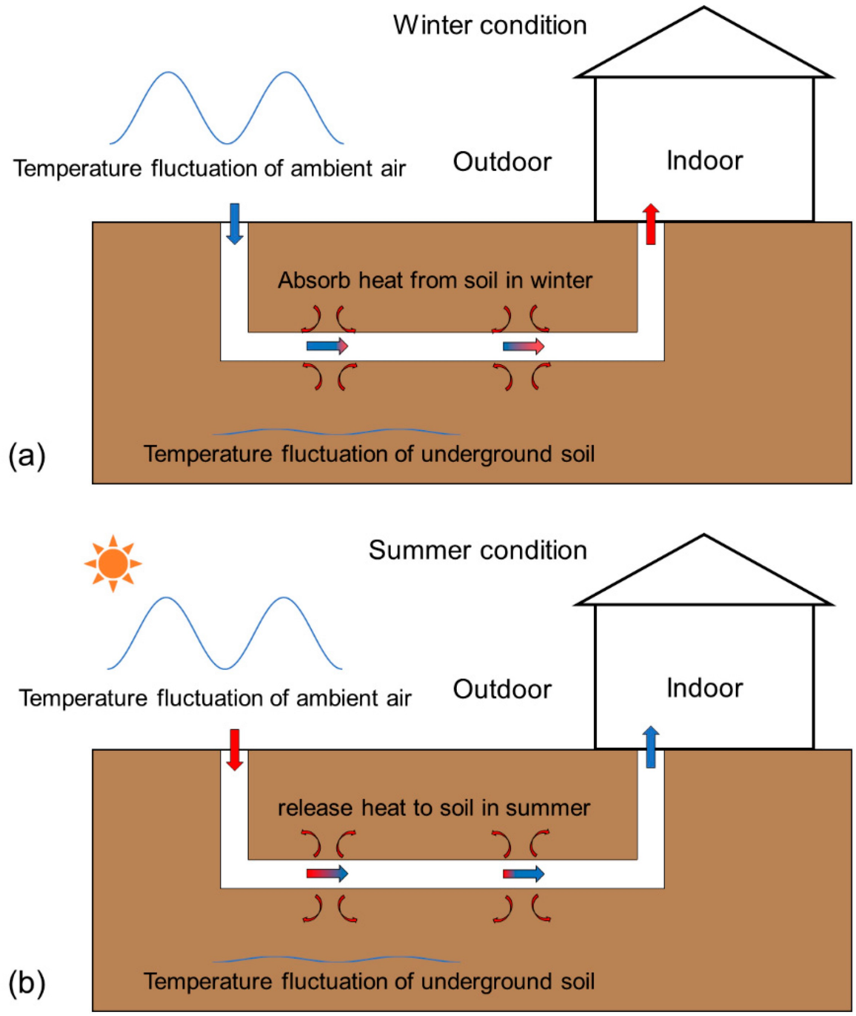

Fig.3.4.2. Schematic and principle of the earth-to-air heat exchanger (EAHE)-assisted building ventilation system: (**a**) winter condition; (**b**) summer condition. (Source: Zhang, Ch., Wang, J., Li, L., Wang, F., Gang, W., 2020).

Using passive cooling strategies in combination with active cooling systems can be very effective. For example, a building can be designed to take advantage of natural ventilation and thermal mass during the day, and then use an active cooling system such as an air-conditioning unit at night, to maintain comfortable temperatures.

References

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