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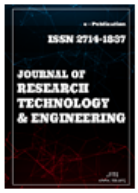

Natural Passive systems to enhance the comfort of buildings

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Abstract: Mainly this research paper investigates passive systems used for buildings. Heating, ventilation, and air conditioning were the major energy consumers in the building industry globally. Due to its proximity to the equator, Sri Lanka has high average temperatures. Therefore, suitable ventilation and daylighting systems must be considered while designing a building or any other type of structure. Natural ventilation and passive cooling have received attention due to the growing contribution of ventilation and air conditioning to the overall energy consumption of buildings. Courtyard passive system used for proper ventilation in old houses as well as modern building designs. In addition, Passive stack ventilation is a widely popular natural ventilation method in residential structures. This method for various applications in buildings is environmentally sustainable. The stack effect caused by the temperature difference between the air inside and outside a building drives passive stack ventilation. A solar chimney & courtyard are some ways to enhance passive ventilation on hot, sunny days when there is a slight temperature differential between the internal and external air. Also, to get good passive lightning from sun. Therefore, this report discusses different types of passive systems and the application of solar chimneys to passive cooling & courtyard systems inside buildings.

Index Terms: solar chimney, ventilation, passive cooling, and passive stack, courtyard system

1 INTRODUCTION

A passive system is a building design strategy that seeks to optimize the use of natural resources such as sunlight, wind, and temperature differences to provide heating, cooling, and lighting for a building. These systems do not require the use of mechanical or electrical devices and instead rely on the natural properties of the building's materials and the surrounding environment to provide comfortable indoor conditions.

Passive systems can be an effective way to increase the energy efficiency of a building, as they can help to reduce the energy required to maintain comfortable indoor temperatures and lighting levels. They can also help to reduce greenhouse gas emissions, as they rely on renewable energy sources rather than fossil fuels. There are many different types of passive systems that can be used in a building, including insulation, solar water heaters, and natural ventilation. By carefully designing and integrating these systems into building, it is possible to create a comfortable and energy-efficient space with minimal reliance on mechanical systems [1]. Utilizing design decisions to maximize heat escape while decreasing heat gain is known as passive cooling. It may greatly improve comfort while lowering energy costs. The major ways to improve heat loss are to add ceiling fans or whole-house fans locate and design apertures to enable optimum ventilation, and make sure any air conditioning complements the building design and insulation. Thermal mass may also be utilized to cool a residence in locations where there is a 6°C or more temperature difference between day and night [2].

2 DIFFERENT TYPES OF PASSIVE SYSTEMS

Several passive systems can be used in building design to improve energy efficiency and comfort. Some standard passive systems include.

- **Passive solar design**

This involves the use of south-facing windows and thermal mass to capture and store solar energy, which can be used to heat a building. Passive solar design is a building design approach that utilizes the sun's energy to provide heating, lighting, and ventilation. The passive solar design does not require mechanical or electrical systems, making it an energy-efficient and cost-effective solution for building design. The passive solar design relies on the physical properties of a building and its surrounding environment to provide a comfortable indoor climate. To improve the benefits of passive solar design, a building should be oriented to take advantage of the sun's path across the sky. This typically involves placing windows and other solar collectors on the south-facing side of the building, where they will receive most of the direct sunlight during the day.

In addition to windows, passive solar design may include using thermal mass, such as concrete or masonry, to absorb and store solar energy [3]. This stored energy can be released gradually to help heat the building at night or on cloudy days. Passive solar design can be an effective way to reduce a building's energy consumption and as well, as improve indoor air quality and comfort [4]. It is particularly well suited for use in climates with a moderate temperature range and can effectively reduce a building's carbon footprint.

- **Natural ventilation**

This utilizes the wind and the stack effect to provide fresh air to a building and remove stale air. Natural ventilation is a passive system that uses the wind and the stack effect to provide fresh air to a building and remove thick air. The stack effect occurs when hot air inside a building rises and is replaced by cooler air from outside. This process can be enhanced by using chimneys or other openings, allowing airflow through the building. To utilize natural ventilation in a building, designers may incorporate various design elements, such as windows, doors, and vents, to allow air to flow freely. These openings should be positioned to take advantage of prevailing winds and temperature differences. In addition, natural ventilation can be combined with other passive systems, such as insulation and thermal mass, to improve the energy efficiency of the building further [5].

Natural ventilation can be an effective way to reduce the energy required for cooling and heating a building [6]. It can also improve indoor air quality by providing constant fresh air. However, natural ventilation is unsuitable for all facilities and climates, as it requires a certain wind speed and temperature difference to work effectively.

- **Thermal chimneys**

These use convective air currents to ventilate and cool a building. A thermal chimney is a passive system that uses convective air currents to ventilate and cool a building. A thermal chimney consists of a vertical shaft that extends from the roof of a building to the ground level. The post is lined with a material that absorbs heat, such as masonry or concrete. As hot air rises inside the chimney, it warms the walls of the chimney and creates a convective air current. These current draws cooler air from outside the building into the lower levels while simultaneously expelling hot air from the top of the chimney.

Thermal chimneys can effectively ventilate and cool a building, particularly in hot, dry climates. They can also be used in combination with other passive systems, such as natural insulation and ventilation, to improve the energy efficiency of the building further [7]. However, thermal chimneys are unsuitable for all buildings and climates, as they rely on convective air currents to function effectively.

- **Insulation**

This slows the transfer of heat from one area to another, helping to reduce heat loss in winter and heat gain in the summer. Insulation is a material used to slow heat transfer from one place to another. In the context of a building, insulation is typically used to reduce heat loss in the winter and heat gain in the summer. This can reduce the energy required to maintain a comfortable indoor temperature, lowering energy bills and reducing the building's overall energy consumption. Several types of insulation can be used in construction, including fiberglass, cellulose, and spray foam. The type of insulation most suitable for a particular building will depend on various factors, including the climate, the type of construction, and the location of the insulation within the building. In addition to reducing energy consumption, insulation can also help to improve indoor air quality by reducing drafts and helping to maintain a consistent indoor temperature. It can also help reduce noise transmission between different building areas. Insulation is a passive system that does not require mechanical or electrical systems.

- **Green roofs**

These use plants and soil to insulate a building and absorb rainwater, reducing the amount of storm water runoff and mitigating the urban heat island effect. A green roof is a passive system that uses plants and soil to insulate a building and absorb rainwater. Green roofs can be either intensive or extensive, depending on the depth of the earth and the types of plants used. Intensive green roofs are typically deeper and can support a wider variety of plants, including shrubs and trees. These green roofs require more maintenance and may require irrigation, but they can provide a wide range of benefits, including insulation, storm water management, and recreation space.

Extensive green roofs are shallower and typically use low-maintenance plants like grasses and sedums. These types of green roofs require minimal maintenance and can be an effective method to reduce the amount of storm water runoff from a building, as well as mitigate the urban heat island effect. Green roofs can reduce a building's energy consumption and operating costs and improve indoor air quality and comfort. They may significantly lower a building's carbon footprint and are especially well suited for usage in cities.

- **Earth sheltering**

This involves using the earth as a thermal mass to help regulate the temperature inside a building. Earth sheltering is a passive system that uses the earth as a thermal mass to help control the temperature inside a building. Earth sheltering involves building a structure wholly or partially underground, using the earth as insulation to help maintain a consistent indoor temperature. Earth sheltering has several benefits, including energy efficiency and improved indoor air quality. The earth surrounding earth-sheltered building acts as a thermal mass, absorbing and storing heat during the day and releasing it at night. This can reduce the energy required for heating and cooling the building. In addition, earth sheltering can help to improve indoor air quality by reducing drafts and maintaining a consistent indoor temperature.

Earth sheltering is particularly well suited for use in climates with a moderate temperature range and can effectively reduce a building's carbon footprint. However, it is essential to carefully design and construct an earth-sheltered building to ensure it is safe and structurally sound.

- **Daylighting**

This involves using windows and skylights to provide natural light inside a building, reducing the need for artificial lighting. Daylighting is a passive system that uses windows and skylights to provide natural light inside a building, reducing the need for artificial lighting. Daylighting can be an effective way to reduce a building's energy consumption and operating costs, as well as improve indoor air quality and comfort.

To maximize the benefits of daylighting, a building must be designed to take advantage of the sun's path across the sky [8]. This typically involves placing windows and skylights on the south-facing side of the building, where they will receive the most direct sunlight during the day. In addition, using reflective surfaces, such as white paint or mirrors, can help to reflect sunlight more profoundly into a building. Daylighting can be combined with other passive systems, such as insulation and thermal mass, to improve the energy efficiency of a building further. However, it is essential to carefully design and position windows and skylights to avoid overheating or glare, which can be uncomfortable or harmful to occupants.

- **Heat recovery ventilation**

This captures heat from exhaust air and preheats incoming fresh air, reducing the energy required for heating. Heat recovery ventilation (HRV) is a passive system that captures heat from exhaust air and uses it to preheat incoming fresh air, reducing the energy required for heating. HRV systems typically consist of a network of ducts and a heat exchanger, which transfers heat from the exhaust air to the incoming fresh air. HRV systems can be an effective way to improve the energy efficiency of a building, particularly in climates with cold winters. By capturing and reusing heat that would otherwise be lost, HRV systems can help to reduce a building's energy consumption and operating costs. In addition, HRV systems can help by providing a constant supply of fresh air to improve indoor air quality and remove stale air [6]. HRV systems can be combined with other passive systems, such as insulation and thermal mass, to improve the energy efficiency of a building further. However, it is essential to carefully design and install an HRV system to ensure it functions effectively and efficiently.

By combining multiple passive systems, designers can create highly energy-efficient buildings with minimal mechanical and electrical systems.

3 COURTYARD PASSIVE SYSTEM

A courtyard passive system is a design approach that leverages the use of an open central area within a building. It creates a more comfortable and sustainable living environment [9]. The courtyard serves as a natural ventilation and lighting system, providing fresh air and natural light to the surrounding spaces [10]. By using the courtyard as a focal point, architects and designers can create a more sustainable and energy-efficient building by reducing the reliance on mechanical systems like air conditioning and lighting [11]. This approach is particularly effective in warm climates where overheating and lack of natural light can make buildings uncomfortable [12]. Overall, the courtyard passive system is an innovative way to blend modern design with traditional building practices to create a more comfortable, sustainable, and livable space.

A courtyard is an open space within a building or group of buildings surrounded by walls or buildings. Courtyards can be an effective passive system for improving the comfort and energy efficiency of a building [13]. One-way courtyards can function as a passive system by providing natural ventilation. By placing windows and doors on the courtyard side of a building, it is possible to create a stack effect that draws fresh air into the building and removes stale air. The courtyard can also serve as a thermal sink, absorbing and dissipating heat during the day and releasing it at night.

In addition to ventilation, courtyards can provide natural light and improve indoor air quality. By allowing sunlight to enter the building through windows and skylights, it is possible to save energy by reducing artificial lighting and improving indoor air quality [14]. Courtyards can also serve as a gathering place and provide a sense of community within a building. However, it is essential to carefully design a courtyard to ensure that it functions effectively as a passive system and does not create unwanted glare or overheating.

Below (Fig. 1. & Fig. 2.) Shows some old house designs, which is, used courtyard passive system for proper ventilation and lighting.

Fig. 1. Courtyard cooling design with pond [15].

Fig. 2. Richmond Castle - Kalutara-Sri-Lanka [16].

Below (Fig. 3.) shows the working mechanism of Courtyard passive system in day and nighttime. Also (Fig. 4.) Shows deep courtyard working mechanism in a house.

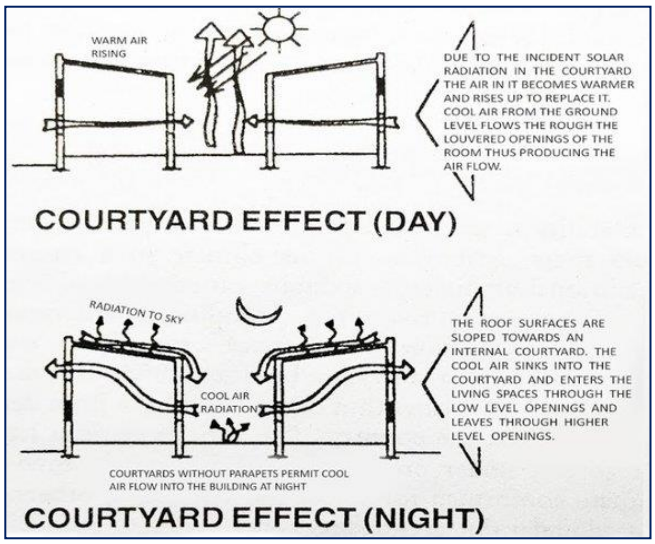

Fig. 3. Courtyard Effect at day nighttime [17].

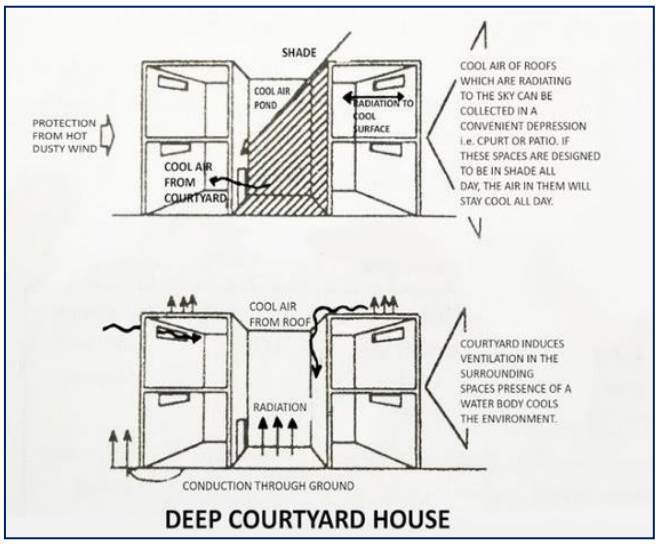

Fig. 4. Deep Courtyard house ventilation [18].

TECHNICAL ASPECTS OF COURTYARD PASSIVE SYSTEM

There are several ways to design a courtyard to maximize its effectiveness as a passive system.

- **Orientation** - To take advantage of natural ventilation and daylighting, the courtyard should be oriented to maximize the exposure of south-facing windows and minimize the exposure of north-facing windows.

- **Window placement** - To allow for cross-ventilation and the entry of direct sunlight, windows should be placed on the courtyard side of the building.

- **Thermal mass -** To help regulate the temperature inside the building, it is essential to incorporate thermal mass, such as concrete or masonry, into the courtyard design. This mass will absorb and store heat during the day and release it at night, helping to maintain a comfortable indoor temperature.

- **Insulation -** To reduce heat loss and gain, it is essential to insulate the building properly. It can be achieved using fibreglass, cellulose, or spray foam [19].

- **Shading -** To protect against overheating and glare, it is essential to incorporate shading devices, such as overhangs or shading screens, into the courtyard's design.

Several additional design considerations exist when designing a courtyard as a passive system.

- **Landscaping:** The landscaping of a courtyard can significantly affect its effectiveness as a passive system. Planting trees and other vegetation can provide shading, absorb heat, and improve indoor air quality.
- **Water features:** Incorporating a water feature, such as a fountain or pond, into a courtyard can help to dissipate heat and create a more pleasant microclimate.

- **Materials:** The materials used for constructing a courtyard can affect its thermal properties. For example, using materials with high thermal mass, such as concrete or masonry, can help to regulate the temperature inside the building.

- **Size:** The size of a courtyard can also affect its effectiveness as a passive system. An enormous courtyard may be more effective at dissipating heat and providing natural ventilation but may require more maintenance.

By carefully considering these design elements, it is possible to create a courtyard that effectively functions as a passive system, improving the energy efficiency and comfort of the building.

PROS & CONS IN COURTYARD PASSIVE SYSTEMS

There are many several pros and cons to consider when we use a courtyard as a passive system, as follows [20].

Pros –

- **Energy efficiency -** A courtyard can help reduce a building's energy consumption by providing natural ventilation and daylighting, reducing the need for mechanical heating, cooling, and lighting systems.

- **Improved indoor air quality -** A courtyard can provide a constant supply of fresh air and remove stale air, improving indoor air quality.
- **Reduced operating costs -** By reducing energy consumption, a courtyard can help to lower a building's operating costs.
- **Outdoor space -** A courtyard can provide a pleasant space for occupants to gather and relax.

Cons –

- **Initial cost -** The courtyard construction has a higher upfront cost than other passive systems [21].
- **Limited effectiveness in certain climates -** A courtyard may not be effective in all climates, depending on factors such as humidity, wind speed and temperature [22].
- **Maintenance requirements -** A courtyard may require regular maintenance to keep it clean and in good condition.
- **Privacy -** A courtyard may not provide the same level of privacy as an enclosed outdoor space.

Incorporating a courtyard into the design of a building can be an effective way to improve the energy efficiency and comfort of the building. A well-designed courtyard provides natural ventilation, daylighting, and thermal mass, reducing the energy required for heating, cooling, and lighting. A courtyard can also improve indoor air quality and provide a pleasant outdoor space for occupants.

Therefore, it is essential to carefully consider the design and orientation of a courtyard to ensure that it functions effectively as a passive system. This may involve using windows, doors, and shading devices, as well as incorporating thermal mass and insulation. By carefully considering these design elements, it is possible to create a courtyard that effectively functions as a passive system, improving the energy efficiency and comfort of the building.

4 SOLAR CHIMNEY HYBRID VENTILATION SYSTEM

A solar chimney employs a natural draft to transport air upward by turning solar energy (heat) into kinetic energy (air motion). As temperature rises at constant pressure, air density falls. In other words, the buoyancy force causes warmer air than the surrounding air to rise. A solar chimney uses this natural occurrence and warms the air using solar energy. Air cannot be heated by solar radiation directly since it is a transparent fluid that transmits radiation. To allow solar heat to be transported to the atmosphere through convection, a solar chimney must have a solar absorber, or a surface formed of a material that absorbs solar energy. The "greenhouse" effect is used most frequently in solar chimney designs, which feature air chambers with a transparent material (glass) on one side and a solar absorber on the other [23]. These solar chimneys resemble solar air collectors in many ways. Solar vents can be used for various purposes, including ventilation, power production, and food drying. (Fig. 5.) Illustrates the solar chimney ventilation principle. Solar chimney ventilation is a type of stack ventilation by heating exhaust air in a solar chimney with solar radiation; the driving force in this situation, buoyancy force, increases [23].

Solar chimney ventilation operates even when the external temperature is equal or higher than the internal air temperature, in contrast to passive stack ventilation, which depends on the difference in indoor and outdoor temperatures. A solar chimney could take on a variety of shapes. A solar chimney may be built as a standalone structure or a ventilation system component [24]. Solar chimneys can also be used for Cooling

or ventilation at night, although they must have a heat storage mass. By using this technique, the purpose of the solar Chimney can be changed as follows [23],

- Solar Chimney for ventilation of buildings
- Solar Chimney for space heating and ventilation
- Solar Chimney for space cooling and thermal comfort principle of solar Chimney

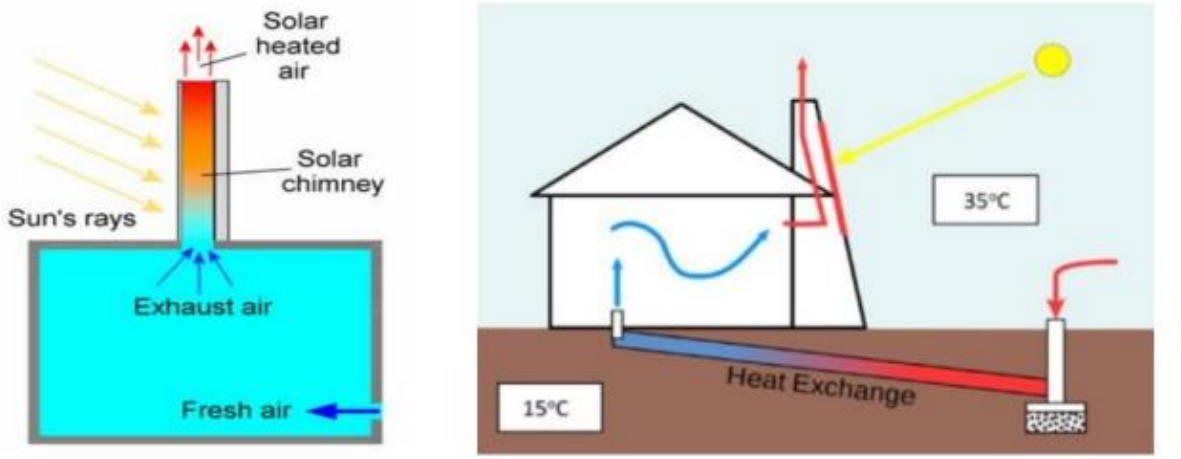

Fig. 5. Principle of solar Chimney

TECHNICAL ASPECTS OF THE SYSTEM

This system operates as a hybrid system to provide passive building cooling. Because it uses a pipeline system to intake fresh and cool air when the heated air was passing to outside through the Chimney, this pipeline comes from underground to the natural Cooling of outside air. Therefore, this system is consisting of two parts. The solar chimney functions as a thermal engine by turning thermal energy into the kinetic energy of moving air. The solar Chimney creates airflow through a structure, and the air density difference at the Chimney's entrance and output during ventilation can offer Cooling or heating [25]. Solar chimneys are a type of solar power plant that enhances natural ventilation in buildings by harnessing the convection of air heated by passive solar energy. A solar chimney comprises a solar glass collector that uses solar energy during the day to raise hot air produced in the collection and a vertical shaft that serves as a chimney to improve building cooling and ventilation. Three crucial components of the solar Chimney's basic design are as follows [25]:

The solar collector - Both direct and the collector uses diffuse solar rays. This may be found on the Chimney's top section or may cover the entire shaft. This element's orientation, glass type, insulation, and thermal characteristics are essential for capturing, retaining, and making use of solar gains.

The main ventilation shaft (Chimney) - Since the Chimney is the actual thermal engine of the plant, its position, height, cross-section, and thermal characteristics are all crucial factors. There are numerous well-known methods for constructing chimneys, and they have all been applied to cooling towers without the need for any unique development.

Inlet and outlet air apertures: Since hot air is lighter than cold air, it rises in the Chimney. More hot air is subsequently drawn in from the collector by the Chimney's suction, which also makes room for the entry of cold air. As a result, these pieces' aerodynamic properties, sizes, and placement are crucial to the design.
A separate earth pipeline, as shown in (Fig. 6.) does this air intake in this cooling system. The Earth Pipe Cooling system uses a long, underground pipe with cooled air supplied at one end and ambient air intake at the other. The line is buried underground at the deepest possible level to achieve the best results, but the two pipe ends are exposed. This method channels ambient air via an underground pipe in warm climates, removing excess heat from the earth for Cooling. To produce cool air at the other pipe end for the comfort of the occupants, there should be enough airflow into the buried pipe intake. If insufficient, a fan blower is required at the buried pipe air intake to increase airflow. Passive Cooling Using an Earth-to-Air Heat Exchanger and a Solar Chimney the following four primary parameters affect the performance of earth pipe cooling,

- Pipe length
- Pipe radius or diameter
- Depth of the pipe inserted into the ground
- Airflow rate inside the pipe

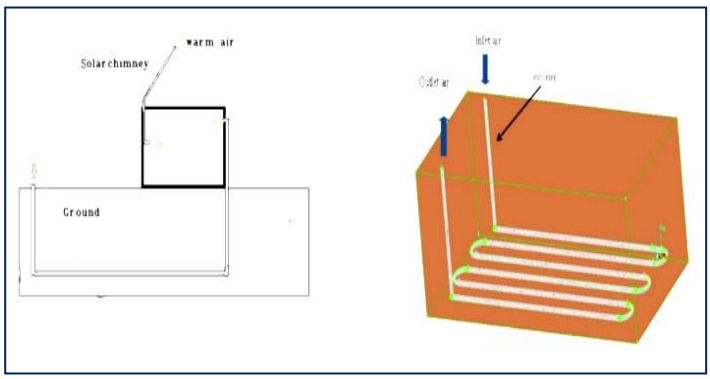

Fig. 6. Earth Air cooling pipeline system

In conclusion, solar chimney is a passive system that uses the sun's energy to create a natural flow of air within a building. It works by utilizing the principles of convection, where warm air rises & cool air sinks. The solar chimney consists of a tall, vertical shaft that is made of a dark material to absorb as much sunlight as possible. At the base of the chimney, cool air is drawn in, and as the sun heats it, it rises up through the chimney and out of the top. This creates a vacuum that pulls cool air into the building, providing a constant flow of fresh, cool air. The solar chimney is a sustainable and energy-efficient way to ventilate buildings, reducing the need for artificial cooling systems and their associated energy costs.

5 CONCLUSION

This report mainly discussed passive systems for proper ventilation and lighting in buildings. And there are many advantages like running continuously and offering improved ventilation rates, needing little maintenance, depending less on natural forces (such as wind and fans) to ventilate, having more options for air intake, better air quality, lower noise levels, and enhanced passive cooling during the summer are some of them.

Many researchers have been motivated by the concept of energy-efficient structures to work on reducing the cooling load on buildings by utilizing passive cooling techniques. Traditional air conditioning systems can be entirely replaced by implementing these integrated solutions for building space conditioning. This

lowers the building's energy burden and improves sustainability. Solar chimneys are slightly raising the cost of traditional buildings, but they will be profitable in the long run. Using this system, you can quickly reduce the energy usage for AC machines and fans in warm seasons. The constant usage of artificial ventilation is reduced with natural ventilation. If properly implemented, these passive design techniques can significantly increase energy efficiency in residential buildings and lower energy usage. Therefore, it is cost-effective for all.

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