Review on Solar Chimney in Natural Ventilation

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Abstract: *Because of potential advantages in terms of operating expense, energy demand, and co2 emission, passive ventilators are increasingly being recommended as an alternative to mechanical ventilation systems. Solar chimneys are effective displacement ventilation systems that rely on environmental drivers of change, such as solar irradiance. Since the 1990s, a considerable portion of studies has been focused on solar chimney. This paper presents an overview of solar chimneys, focusing on their architecture or framework, operation, categorization, and applications in different ways*.
Keywords: Solar Energy, Solar Chimney, Natural Ventilation, Passive Cooling

I. Introduction

Natural ventilation is an essential sustainable architecture design method that has been known to humanity for millennia and is gaining popularity due to its possible improvements over mechanical systems in terms of energy efficiency, cost, and ecological benefits. Ventilation systems have negative energy consequences since they use more electricity for lighting. Some cities' air conditioners demands consume nearly all of their electricity grid capability [1]. When climate and operating circumstances are favorable, natural light is predicted to yield cool efficiency improvements of the scale of 10% and system energy reduction of the order of 15% of yearly electricity consumption.

A solar chimney is a sort of passive heating and conditioning device which can be used to both control and ventilate the temperature fluctuations. Solar chimney, like a Trombe wall or a sun wall, are a means of achieving environmentally friendly building architecture. Solar chimneys are basically hollowed canisters that connects and inside a structure around the outside of the structure.

Indoor air ventilation in buildings is influenced by a number of factors. And there is no air penetrating or leaking out, insulation the buildings and properly closing the apertures to reduce thermal loss exacerbates pollutants. As a result, ventilation is unavoidable. The use of an inactivity systems in buildings venting eliminates this challenge and helps to reduce energy carbon emissions and pollution.

Due to the chimneys principle, a solar thermal collector is a container made solar inactive device that enhances indoor environment quality by increasing ventilation in the buildings [2].

The solar thermal collector is essentially a giant NCS with a big solar collectors that absorbs energy from the sun at the bottom. It heats the air in the operation, then raises to generate circulating. The large chimneys contributes to the increased buoyant forces and circulating velocity. A solar chimney can be used for a multitude of purposes, including passive ventilation and lighting of dwellings, energy production dryness, and even establishing a climate conducive to plant culture. Figure 1 (A) shows the schematic diagram of a solar chimney-powered buildings air conditioning system, wherein the solar thermal collector replaces a blower or ventilation system without requiring any energy.. Cooler plate (plates with a hollow chamber filled with water and small perforation to wet the garments covering the plates) can be installed at the air inflow duct to provide some coolness.

Similarly, Fig. 1 depicts the utilization of a solar thermal collector for energy production (B). In Manzanares (south of Madrid, Spain), a demonstrator plant based on the conceptual was owned and designed continuously from 1986 to 1989, with a maximum output of 50 kW. The power plant had a collectors with a circumference of 240 meters and a 195-meter tall chimneys with a diameter of 10 metersFor energy production, a standard turbines technology has been used. The concentrated solar power stations has the potential to contribute to energy production in some parts of the world, including Australia, Asia, and Africa.

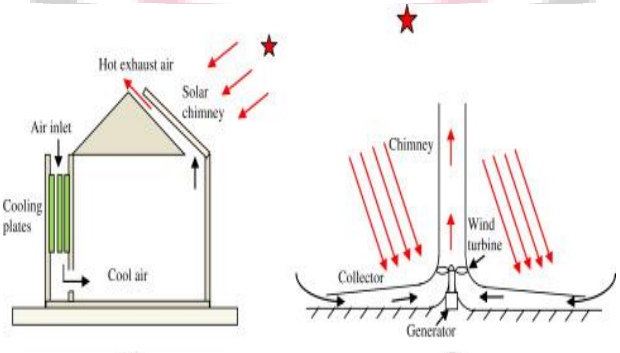

Figure 1 (A) Building Ventilation (B) Power Generation

A solar chimneys is a technique that may be used to improve the venting of a home or business, and it works on the same idea as a fireplace. Heat rises naturally, much like air rising through some kind of chimneys, causing a draft and carrying the smokes with it. Whenever a fire burns in the fireplaces, this suction is the reasons how there is no smoking in the house.

The natural heat from the sun raises the temperature in a solar air heater, causing it to expand and creating a draught that propels the heated air out of the building. Cooling air from underneath is drawn into the chimneys for heat, whereas heater is expelled from the top. The act of drawing in cooler air causes air circulation, which allows the building to breathe.

The location of a solar air heater is among the most critical factors to be considered. The solar chimneys must be installed on top of a building in an area where the sun's energies are naturally reflected. The optimum situation is to situate the chimneys where the sun shines the brightest in the afternoon. It's also crucial to think about the sun chimney's thermophysical behavior and construct it using substances that absorb one of most energy. A black framing, tinted glass, and insulating glazed are common features. Also keep in mind that now the production of solar chimneys is important—the larger the chimneys, more the efficient this will be.

II. Architecture of Solar Chimney

Solar chimneys are typically tall, wide constructions that face the sun and have a dark-colored, matte surface that absorb solar irradiance. The air on the inside of the chimney is heated when the staircase heats up. The hot air rises up into the attic and escapes through the top. In a procedure termed as convection, as this warmer air rises, it draws additional air in there at the bottom of the chimneys. This can be utilized to drive passively ventilated in structures wherein crossing or added the following isn't enough and developers don't want to use energy-intensive mechanical ventilation.

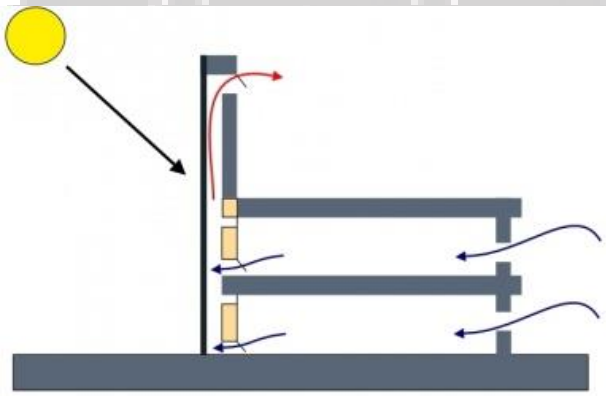

Figure 2 Solar Chimney

Solar chimneys are very useful in hot and humid tropical settings. They are most effective when they become tall and wider but not too deep, because this proportions maximizes both the volume of water that really can collect energy from the sun and the surface energy in touch with the airflow on the inside of the chimneys.

Multiple chambers can be used to enhance contact area, and minerals with strong thermal conduction qualities, such as metal, can be used to maximize the temperatures achieved only within chimneys. Low emissivity coatings and glass, similarly to the designs of trombe sidewalls, can also be employed to limit thermal losses from the outside.

The chimney must be insulating first from building for heat gains to not be transmitted into controlled territories. In colder weather, the chimneys can be closed at the top to direct accumulated heat into the structure.

A solar thermal collector is a sort of passive solar heating and cooling device that can be used to both regulate and ventilate the temperature of the room. Sun columns, like a Trombe wall or a solar wall, are a means to achieve environmentally friendly building architecture. Solar chimney are basically hollowed canisters that connect from inside a structure around the outside of the buildings.

In the winter, house window, walls, and flooring can be constructed to collect, preserve, and transmit energy from the sun of heat, while in the summer, they can be engineered to refuse sun's radiation. This is known as climatological design or installing solar panels. One of the most efficient solutions for home heating is solar thermal technology. It can significantly improve a structure's fuel efficiency and, in some situations, provide 100 percent of a home's heating. Housing that are heated nearly exclusively by the sunlight to someone with south-facing windows that offer only a percentage of the heat exchanger are all examples of indirect energy homes [3].

Sun chimneys (SC) are an effective way to incorporate ventilation system in building that have access to solar energy. It is most commonly used in moderate climates and settings where a small amount of indoor fluctuation is acceptable. This technology does not require a large wall and, because it uses adequate ventilation for heaters, could provide better air quality than a non - load bearing wall. A number of academics have investigated solar chimneys for a variety of purposes, include natural convection of building, electricity production, and so on.

III. Literature Review

(Zhang, Tao, et al., 2021) [4] seeks to investigate the airflow characteristics from the inside of a wall solar chimney and the connected ventilation complex and multifactorial, as well as the efficiency of solar chimneys, in a variety of configurations (i.e., chimney cavity and room) and environmental forces (i.e., solar radiation intensity). The trade-offs among buoyancy channel flow and flow velocity are then used to identify crucial geometric characteristics of solar chimneys and buildings designs. An increase in chimneys heights and inlet locations (until the midway height of the wall) resulted in an efficiently convert in circulation rate, much like in single stack application.

(Maerefat & Haghighi, 2010)[5] The utilization of a network comprising of a Solar Chimney (SC) and an Equipped with two Cooling Cavity (ECC) to increase passive cooling and ventilation systems in a sun household has already been proposed in this research. The program's capacity to meet individualized temperature requirements, as well as the implications of key structural parameters on system stability, have been investigated. The relationship between application performance and outdoor ambient temperature has been investigated in order to find the optimal operating settings for thermal environment.

(Yong et al., 2014) [6] A solar chimney is a hybrid of an energy from the sun stacks and steam air conditioning system in which air inside the solar air heater expands due to solar radiation heat and raises out of the chimneys outputs, bringing cooler air through a building through to the open windows. The pull effect is further enhanced by the pushing impact of the external ambient wind. The goal of this research into the effects of air temperature frequency and internal heat capacity on the temperature and humidity of the solar chimney duct system and teacher's classroom decoration in tropical Singapore is to determine the impact of ambient temperature speed and institutional latent heat upon that temperature and humidity of the thermal performance duct system and teacher's classroom interior.

(Daghistani, 2021) [7] Increased air pollution in the physical environment poses a severe health risk, especially for commuters. In municipal contexts, this study introduces a prepared and characterized of a solar chimney street-lighting pole (SCSLP) that moves dirty air away from either the relatively close region to an upper space. Through into the circulation of air heat by passively solar energy obtained from the SCSLP's wall and solar collectors, the proposed system provides an inclined plane air circulation. The present investigation used ANSYS CFX simulation (SIM) capability to evaluate the performances of the proposed technology.

(Nakielska & Pawłowski, 2017) [8] At a time whenever energy conservation is receiving an amount of publicity, the industry, amongst many others, is seeking innovative technological solutions. The hunt for novel solutions is currently a global trend in the construction industry. These technologies allow for the pleasant usage of building structures while also ensuring that electricity demand is reduced. Solar chimneys, which use solar energy to enhance gravity circulation, could be a solution to the issue. Solar chimneys have been used in the passive cooling of buildings in hot areas. Cold is utilized to promote ventilation system in temperate climates. In Poland, the issue of the heat exchanger is not well-known. The construction of two main research locations in Bydgoszcz enabled the study of the effect of solar chimneys on room thermal environment.

(Solgi et al., 2018) [9] Many research have been conducted to model and evaluate the performance of NV in a variety of environmental conditions and type of construction. This study summarizes the most groundbreaking research on nighttime ventilating techniques and outlines the main topics and prospects in current research. It also divides NV performances into three categories: climate, construction, and technical characteristics. The paper demonstrated that nighttime circulation solutions are efficient in most climates, however optimization is necessary, like with most passive cooling techniques.

(Lal, 2013) [10] With the constantly increasing population, the requirement for design and construction is increasing. It causes structures to grow vertically and necessitates adequate ventilation and natural lighting. Because the natural air circulation system does not function well in traditional structures, fans and air conditioning units are required to provide enough ventilated and space heating. The building sector utilized the most electricity generally, with heating, ventilation, and conditioning systems accounting for the majority of it. The use of solar chimneys and coordinated techniques in building for heaters, ventilating, and ventilation systems can help to lessen this burden. It is a long-term solution for certain construction applications. The concept, various methods of evaluation, modelling and performances of hybrid renewable energy characteristics, application, and integrative techniques were all evaluated by the authors.

(Zhang, Yang, et al., 2021) [11] A new trend in space air conditioning systems in building is combining naturally ventilated technologies. The merged technologies were then subjected to a critical assessment in order to provide an understanding of innovative ideas and prospective attempts. The benefits of integrated natural ventilation systems can indeed be summed up across several fundamentals, which would include outperforming single appearance, maintaining internal temperature security, suddenly realising frictional heating rehabilitation, having overcome solitary inadequacy, and that provide a more complete and accurate and useful power system. Due to the intricacy, the majority of extant

studies on strong second are focused on thermally buoyant, with only a limited number dealing with the conjunction of steam and gravitational acceleration structures.

(Jafari & Poshtiri, 2017) [12] This research suggests a novel solar system and build passive heatsinks. A solar-powered adsorbent cooler, a solar chimneys, and a conditioning channel make up the system. The system is hypothetically modelled, with temperature difference, humidity levels, and air change per hour (ACH) being measured. Furthermore, the effects of various parameters such as ambient circumstances, room cooling requirement, solar chimney diameters, and conditioning channel measurements on room temperature and ACH are investigated.

IV. Combined Solar Chimney

Solar energy is currently one of the most widely used renewable energy sources. A solar thermal collector [13] is a cost-effective technique that combines chimneys technique with concentrated solar utilisation technologies to boost a building's ventilation system. A glass, an outlet temperature, and a storing wall make up the basic construction of something like the solar thermal collector. An inclined-roof solar thermal collector, a vertical sun chimneys, and a Trombe wall solar chimney are the three primary architectural types model is a combination of a solar thermal collector and a buildings. In the summer, a vertical solar thermal collector or one with an angled roof provides better circulation, but they have been not suited for winter heating. Summer circulation and electric baseboard heaters are both possible with a Trombe wall. When employed in the summertime, nevertheless, the ventilated flow velocity is frequently reduced, resulting in overheating [13].

Figure 3 shows the schematic representation of the combined solar chimney (CSC). A Trombe wall and also a predisposed solar chimneys were used to construct the construction, which included an exterior glass cover and an internal memory wall within both unreinforced and reinforced parts. Here between exterior absorber surface and the inside storage wall, an air passage was created. The combination solar chimney had four different modes of operation: spontaneous circulation in the summertime, generally pro in the springtime, heating systems in the wintertime, and pre - heating in the cold season. The shifting of the ventilation system could be used to change the operational parameters. In the summer (S1), the naturally ventilated method was to open the indoor environment outflow, the rooftop air news source, and the northern air intake while closing all other valves, as indicated in Figure 3.

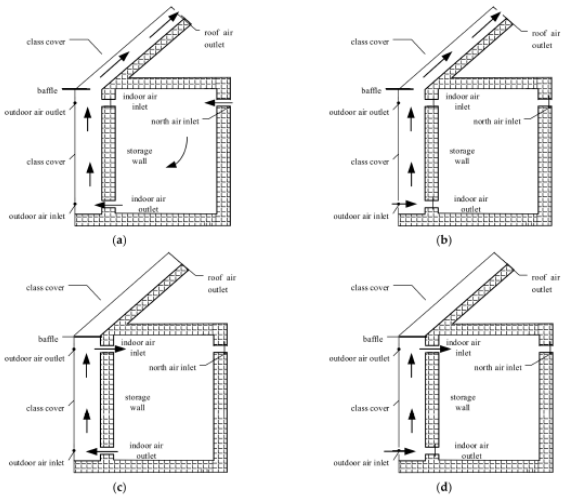

Figure 3 Schematic diagram of a combined solar chimney: (a) summer natural ventilation mode [13]

In the summer (S2), the anti-overheating option would have been to open the exterior air input and the rooftop air exit while closing all those other valves. The barrier in both settings above would be open. In the winter (W1), the heating energy method would have been to open the interior air input and outflow while closing all those other vents. In the winter (W2), the microwave heating method would have been to open the exterior and indoor air inlets while closing all the other outlets. The barrier in both settings above would be closed.

V. Working of Solar Chimney

Solar chimneys can be found all over the world, however their structure and material differ. Climate, cardinal point orientation, and insolation are the most significant external factors in determining chimneys architecture. Regardless of their differences, numerous investigators are testing chimneys which have the same components: air input and output, glazed, and thermal capacity.

Figure 4 illustrates the component of a solar thermal collector. The sun heats up the testing stands through to the glass throughout the day. The additional heat flux delivered to the air being vented from the room produces a warming of the planet in the ducts, forcing warm air to move upwards through the exit at the same time. The "chimney effect" is

enhanced as the differential in barometric pressure in between intake and output increases. Furthermore, the energy accumulated in the walls throughout the day is released at night. The collection of energy is increased when thermal storage is black.. The energy generated during the night allows for greater air flow velocity in the ducts of a solar chimney. It also generates an increase in cross ventilation in the rooms in which the solar thermal collector has been one of the ventilated system's components.

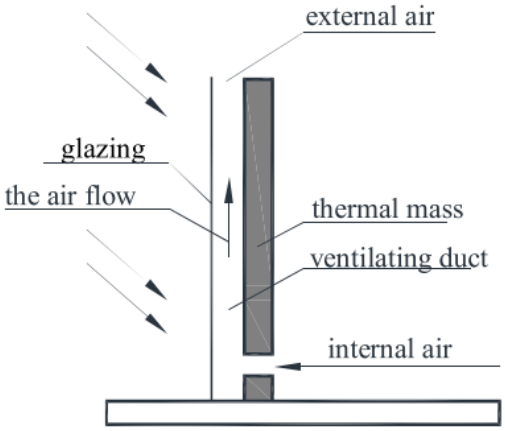

Figure 4 Solar Chimney Schematic Diagram

The solar chimneys has long been recognized as one of the components of an air conditioning system. Together with the advancement of technology, many people have desired to understand the events that occur during chimney operation.
The solar thermal collector has been one of the techniques that uses the buoyant concept to heat air using the greenhouse gasses produced by the solar energy (heat energy) at a minimal cost.The solar thermal collector is a non-mechanical solar thermal air conditioning system that can be mounted on roofs or in walls. The heat is transported via the convection conditioning method, which works by displace internal (warm) air with external (cool) air throughout the day. Solar chimneys are primarily formed of a black, hollowed thermal inertia with a top aperture for hot air egress. The top of something like the chimneys is where the air in the chamber leaves. For room heaters, the technique can also be inverted.

VI. Classification of Solar Chimney

A solar chimneys can be characterized as (i) a vertically solar air heater or (ii) an inclination sun chimneys depending on its placement.. Solar chimneys for buildings ventilated [3] are classed as (i) wall solar chimneys, or Trombe walls; (ii) roof solar chimneys; and (iii) combined wall and roof solar chimneys, depending on their location.The efficiency of solar chimneys is determined by the glazing [8], which can be single, doubled, or tripled glazed. Because the ventilation rate is mostly determined by the height of the solar air heater, it is one of the criteria used to classify it as (i) small, (ii) middle, or (iv) large. Building ventilation (circulation), buildings heater (dwelling), air dryer (crop dryer), and electricity production are all uses for the solar chimney. The classification of a solar thermal collector is also linked to building space heating [13]. It implies that sun chimneys can be classed as (i) integrated with evaporation and condensation, (ii) interwoven with earth-air-tunnel exchanger, and (iii) interwoven with absorbing and adsorbed cooling depending on varied combinations.

A glass cover conceals the solar-radiation-receiving region; small radioisotopes entering the economy thru the transparent cover, as well as large wavelength radioactivity departing the transparent cover, should be kept under control to maximize the green house gases. Solar energy and the amount of windows are linked to the greenhouse effect. The solar chimneys is divided into two types based on the number of windows [3]: (i) single glazing and (ii) multi-glazing.

VII. Buoyancy in solar chimney

Free convection heat transfer first from collectible solar heater towards the surrounding atmosphere causes buoyancy forces. Because of the increase in barometric pressure caused by the process, the fluid (air) moves upwards while gravitation. Reducing the heat loses and faster heat transfer rates will enhance performance since air buoyant is related to temperature variation. Because the volume of air exit the column should always be smaller than the air temperature densities, the high of the tower is limited by this effect [18].There will be stalling in the circulation if the density value first from chimneys is equivalent to the ambient temperature volume, and if the chimneys air concentration is reduced further, air backflow against it ambience will occur, culminating in local waste heat and possibly stalling gravitational acceleration forces. Some type of solar irradiance at the top of the building is required to mitigate this effects.
The working mechanisms of passive heating and ventilation systems are comparable. The buoyant impact, wherein circulation is caused by a change in air temperature and pressure at the input and output, is the driving force that

determines the flow velocity. Typically, façade are built to perform a variety of functions, such as trapping or storing heat, or creating air circulation that provides venting and hence coolness.

VIII. Conclusion

Because of the need to cut down on the amount of electrical power used to cool buildings, there is an increasing demand for different alternatives in this area. Solar chimney are becoming increasingly popular in the construction industry. They make use of low-cost renewable radiation to enhance the environment indoors. A complete analysis of the subject has been offered in order to expose the condition in the application of solar chimneys. Solar thermal collector is a good displacement ventilation solution for enhancing air circulation and providing comfort conditions, as evidenced by the review.

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