Passive Ventilation and Solar Chimney: A Review

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Abstract

The vigorous growth of global economy expanded by 3.7% in 2018 and increasing demand of heating and cooling in buildings has increased the energy consumption throughout the world. Worldwide energy consumption rate has grown to about twice the rate of growth since 2010 to 2.3% in 2018. The share of energy use in buildings is increasing due to increasing needs of HVAC. In India, 32% of the total electricity consumption is in residential and commercial spaces which are rapidly increasing with urbanization.The conventional practices being followed have an option of having efficient alternative of passive means of heating and cooling of the buildings. Use of solar chimney involves the solar energy utilization in the air velocity. Literature has been examined on the passive ventilation technologies and presented in this study. Several studies have been performed on the design parameters and the thermal performance of the solar chimney globally. Experimental evaluation and numerical simulations on application of solar chimney in ventilation show the effectiveness of the passive ventilation. Some studies show the effect of design parameters on the air flow rate.Apart from the mathematical and experimental studies, Computational Fluid Dynamics (CFD) studies were also performed by several researchers for the analysis of solar chimney performance. Literature shows that the CFD analysis has been performed to validate the experimental and mathematical results. The review concludes that there is a great scope of full scale experimental analysis of the solar chimney system for the effective ventilation and studies for the Indian context will contribute in the efficient ventilation system design.

Keywords: Natural ventilation, Earth air heat exchanger, thermal environment, numerical analysis.

1. Introduction

The vigorous growth of global economy expanded by 3.7% in 2018 and increasing demand of Heating and cooling in buildings has increased the energy consumption throughout the world. Worldwide energy consumption rate has grown to about twice the rate of growth since 2010 to 2.3% in 2018 (IEA,Global Energy & CO2 Status Report 2019) [1]. Demand for the fuels has risen and renewable energy utilization has also grown, but they are still not able to fulfill the increased demand for electricity. The large energy consumption has increased the global energy-related CO_2 emissions to 33.1%. India together with the China and United States has accounted for about 70% of the total rise in energy demand (IEA, 2019) [1].

The share of energy use in buildings is increasing due to increasing needs of HVAC. In India, 32% of the total electricity consumption is in residential and commercial spaces which are rapidly increasing with urbanization. It is estimated that this electricity consumption in buildings will rise by 860% by 2047 including residential and commercial heating, cooling and lighting applications. The overall energy use in India is 37% of the annual primary energy consumption as per the India Energy Security Scenarios [2].

2. Building Energy Use

The core function of the building energy use is to provide comfortable and healthy indoor environment. The conventional practices being followed have an option of having efficient alternative of passive means of heating and cooling of the buildings. This passive means includes the usage of heating or cooling of air through the earth at certain depth where the temperatures are nearly constant.

2.1 Building energy efficiency

For ensuring the high quality of life, building energy use is needed to be managed. The building energy efficiency is also important in mitigating the climate change. This makes it important to reduce the energy consumption in building and reduce the environmental challenges. It is important to reduce this energy consumption for the sustainable society and reduced usage of non-renewable resources (Perez-Lombard, Ortiz) [3],(Yu et al. 2010) [4]. There is an opportunity in construction of new buildings to provide energy efficient design and limit the use of conventional practices.Application of green technologies and passive features in building designs can reduce the conventional air conditioning requirements in buildings (Santamouris et al., 1995) [5]. Both the energy consumption and emissions of CO_2 can be reduced by improving the energy efficiency of the buildings (Zhang et al. 2013).

Building energy efficiency parameters such as the building orientation, construction materials to be used, solar day light parameters and building design etc. are needed to be carefully considered at the initial design stage. The later modifications in building are not only costlier but limit the efficiency improvement. Modern tools and softwares such as Energy-Plus is available to simulate the energy consumption in buildings. Several optimization techniques such asGenetic Algorithms are being used for the optimal design of energy efficient (Magnier and Haghighat, 2010, Lin and Gerber 2014) [6],[7].

3. Passive Ventilation

Ventilation is very much essential in residential buildings during all the seasons. It is primarily done to exchange the indoor air with the outdoor air to reduce the concentration of the containments in the indoor air [8]. Buildings are being ventilated by the passive and active methods. Those methods used in buildings which are not involving energy use or using minimum energy for their application are the passive methods [9]. They use the energy effectively as compared to the active ventilation methods. Mechanical ventilation needs external energy for the flow of the air while natural ventilation is caused by the driving force of buoyancy (Wang et al., 2014) [10].

There are several passive methods of heating and cooling of buildings in which solar energy is used. To control the indoor humidity and temperature for providing human comfort, passive air conditioning of buildings is an important alternative in HVAC [11]. Passive ventilation techniques are not new and being used since centuries ago [12],[13]. Natural ventilation is found in Zisa, Palermo, Italy which was used as the summer residence of the king. The castle is an excellent example of bioclimatic architecture [14] as shown in figure 1.

Figure 1: Application of natural ventilation

3.1.Solar Chimney

Solar chimney is an effective means of providing natural ventilation. This passive ventilation technique involves the principle of natural convection. The solar chimney as shown in figure 2 has a solar energy collector. The solar energy collector absorbs the solar radiations falling on it. The heating of air creates the natural ventilation in the space through which the solar chimney is connected by means of pipe or some other passage. Flow of air is created through the internal spaces of the building which leaves at the top [15]. Several studies have been performed on the design parameters and the thermal performance of the solar chimney globally. Experimental evaluation and numerical simulations on application of solar chimney in ventilation show the effectiveness of the passive ventilation. Some studies show the effect of design parameters on the air flow rate.

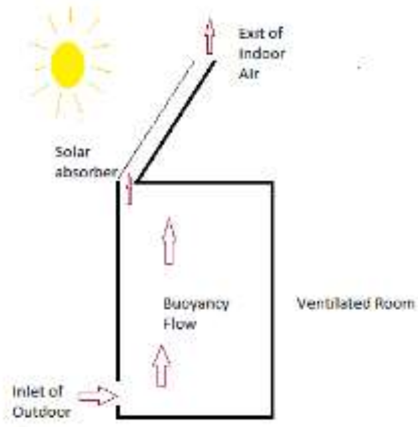

Figure 2: Solar chimney operation

Experimental evaluations of performance of solar chimney on a tilted chimney were performed by Saifi et al. in 2012 [16].Bansal et al., 1993 have conducted some study on the performance of solar chimney and developed a steady state mathematical model [17]. Bassiouny and Koura, 2008 performed numerical and analytical investigations on width of vertical chimney on space ventilation. Apart from the mathematical and experimental studies, Computational Fluid Dynamics (CFD) studies were also performed by several researchers for the analysis of solar chimney performance. Literature shows that the CFD analysis has been performed to validate the experimental and mathematical results. Chung et al. performed the CFD analysis to on solar chimney performance for the determination of its optimum parameters [18].

4. Conclusion

The conventional practices being followed have an option of having efficient alternative of passive means of heating and cooling of the buildings. Use of solar chimney involves the solar energy utilization in the air velocity. Literature has been examined on the passive ventilation technologies and presented in this study. Experimental evaluation and numerical simulations on application of solar chimney in ventilation show the effectiveness of the passive ventilation. Some studies show the effect of design parameters on the air flow rate.Apart from the mathematical and experimental studies, Computational Fluid Dynamics (CFD) studies were also performed by several researchers for the analysis of solar chimney performance. Literature shows that the CFD analysis has been performed to validate the experimental and mathematical results. The review concludes that there is a great scope of full scale experimental analysis of the solar chimney system for the effective ventilation and studies for the Indian context will contribute in the efficient ventilation system design.

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