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Hybrid ground coupled heat exchanger systems for space heating/cooling applications: A review

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ABSTRACT:- Ground coupled heat exchanger (GCHE) systems are used for space heating/cooling across the globe. Hybrid GCHE systems are being preferred over unitary system due to higher efficiency. GCHE system can be classified as earth air heat exchanger (EAHE) and ground source heat pump (GSHP). Fast depleting stocks, recent rise in costs of fossil fuels and its serious impact on climate makes it imperative to adopt renewable and environment friendly sources of energy and energy conservation. The aim of this study is to review the current status of hybrid GCHE systems with passive renewable systems. The paper concisely explains EAHE, GSHP and various passive techniques commonly used for space heating/cooling and review state of the art of hybrid EAHE and GSHP systems. A comparative study of various technologies has been presented and their role in energy conservation highlighted.

Keywords:- GCHE systems, Space heating, Space cooling

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I. INTRODUCTION

Rapid growth in infrastructure sector, industries and buildings has resulted in increased energy demand for space heating/cooling [1–4]. Around 32–33% out of total energy consumption is utilized for space heating/cooling [5,6]. Space heating/cooling and air circulation are complimentary to each other. Efficient air circulation with air-cleaning unit helps to increase efficiency and energy conservation [7,8]. Prevention of air infiltration is equally significant to conserve energy [9,10]. Green building control strategies use various concepts of natural heating, cooling, ventilation and air-conditioning [11,12]. Varying power output limitation of renewable energy technology prevents their use on large scale. Therefore, to promote renewable technology, incremental adoption of combination of various hybrid techniques play important role towards energy conservation and mitigate the impact on environment through emission reduction [13,14]. Hybrid GCHE (i.e. EAHE, GSHP) systems are getting popularity around the world. They are helpful in multiple applications including design strategy of demand side management, alternative to the mechanical vapor compression system, space heating/cooling, etc. Arteconi et al. [15] tested the hybrid GSHP system and concluded that hybrid system could be used for designing the strategy of demand side management. Switching off the GSHP system during peak hours (16:00–19:00 h) could flatten the load curve in addition to providing comfort to the building's occupants through other passive systems. Balbay et al. [16,17] tested the vertical GSHP system and developed computer models to analyze the melting of the snow/ice occurred in bridge and pavement surfaces in winter. The data obtained from experimental and computerized studies were in good agreement. Esen et al. [18–27] tested the heating performance of the horizontal GSHP and found that it was economical than the conventional heating methods (electric resistance, fuel oil, liquid petrol, gas, coal and oil) except natural gas. It was observed that numerical results and experimental results were very close. The performance of GSHP system was better than the air-coupled heat pump system for space cooling. Energetic and exergetic efficiencies of the horizontal GSHP system increased with rising the ground temperature for heating season. Adaptive neuro-fuzzy inference system (ANFIS) could be used to predict the performance of the GSHP system quite perfectly. Further, its performance could be enhanced by using hybridized structures such as fuzzy weighted pre-processing based ANFIS. Performance of an artificial neural network (ANN) could be improved with a statistical weighted pre-processing method with the minimum data set. The computation of support vector machine model was faster than other techniques i.e. ANN and ANFIS. Qi et al. [28] reviewed the progress of GSHP with hybrid energy systems all over the world. They concluded that use of GSHP hybrid systems would be the strategic and essential for the efficient utilization of renewable energy for sustainable development. However, the paper did not include EAHE system. EAHE with solar, energy storage, conventional heating/cooling systems provide significant energy savings. This paper describes the GCHE and passive techniques generally used for space heating/cooling. A review state of the art of hybrid EAHE and GSHP systems with various passive renewable energy systems have been presented.

II. OBJECTIVES

Increased requirement of space heating/cooling has resulted in increased power demand, CO emission and global warming. As per latest IPCC report, CO2 emission must be decreased by 40–70%. By 2050 from 2010 to limit the two degree global temperature increase compared to pre-industrial level [29]. One ton reduction in CO emission is equal to one ton carbon credit earned. It financially works out to be $28.37 per ton [30]. Therefore it plays key role in getting economic viability of hybrid GCHE systems.

Space heating/cooling techniques have multiple primary objectives. These are

- To achieve the lowest possible working cost;
- To operate under environmentally safe condition;
- To install at the lowest possible initial cost;
- To enhance interior comfort level and system durability;
- To establish ease of service and maintenance
- To earn additional revenue under certified emission reduction (CER) scheme.

III. SPACE HEATING AND COOLING SYSTEMS

Systems for space heating/cooling can be classified as passive and active systems.

3.1 Passive System

Passive/renewable/natural systems are based on inexhaustible renewable resources i.e. solar, wind, etc. Renewable energy has many advantages like no harmful release, environmental damage, habitat loss, etc. These are trombe wall/solar wall, solar chimney, wind towers, phase change materials (PCM), ground cooling, evaporative cooling, thermal insulation, etc.

3.2 Trombe wall

It is an example of indirect solar gain. It is south facing thin, glazed wall. Glass interface is placed say 100 mm to outer wall. This technique absorbs solar energy and ventilates the air. It is able to work in day and night during all weather i.e. winter heating and summer cooling. There are two vents, one is at the top and other at lower of the thermal storage mass glazed wall. During day hours both vents are opened and in the night hours both vents are closed to keep warm the space, as shown in Fig. 1.

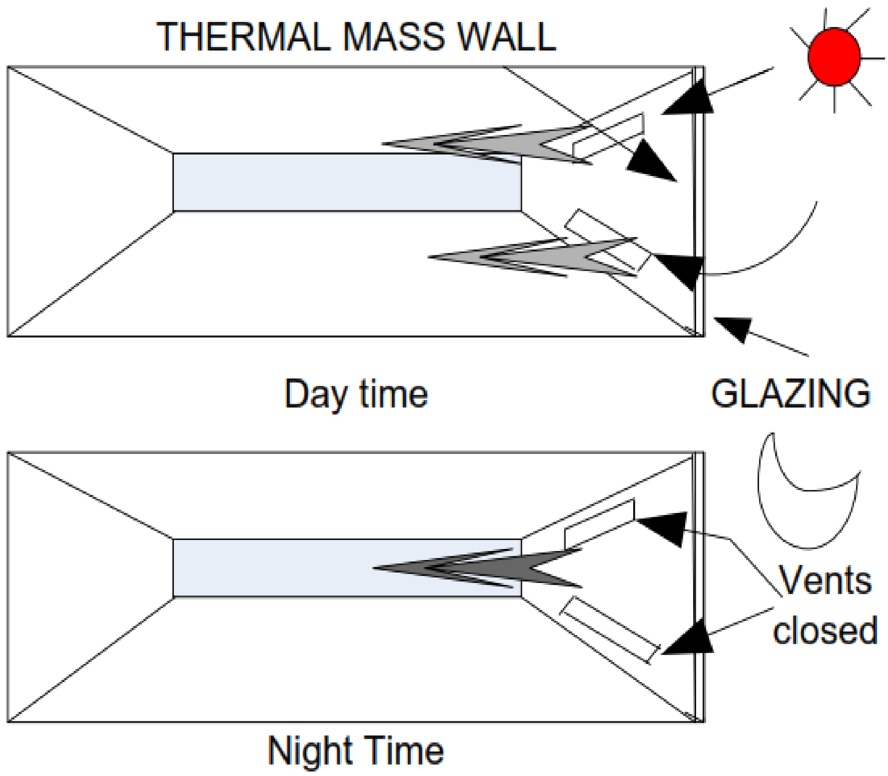

Fig. 1: Day and night operation of trombe wall.

3.2 Solar chimney (SC)

It is an example of direct solar gain, follows the stack effect (temperature difference) principle, shown in Fig. 2. Various factors determine the ventilation rate like efficiency of solar absorbing plate, inclination angle and gap, cross sectional area of inlet and out let vent. This is able to work in both day and night with heat storage mass. Its performance mainly depends on solar radiation, air flow rates, etc. SC can be engaged in various applications i.e. ventilation, power generation, space heating/cooling, food drying, etc.

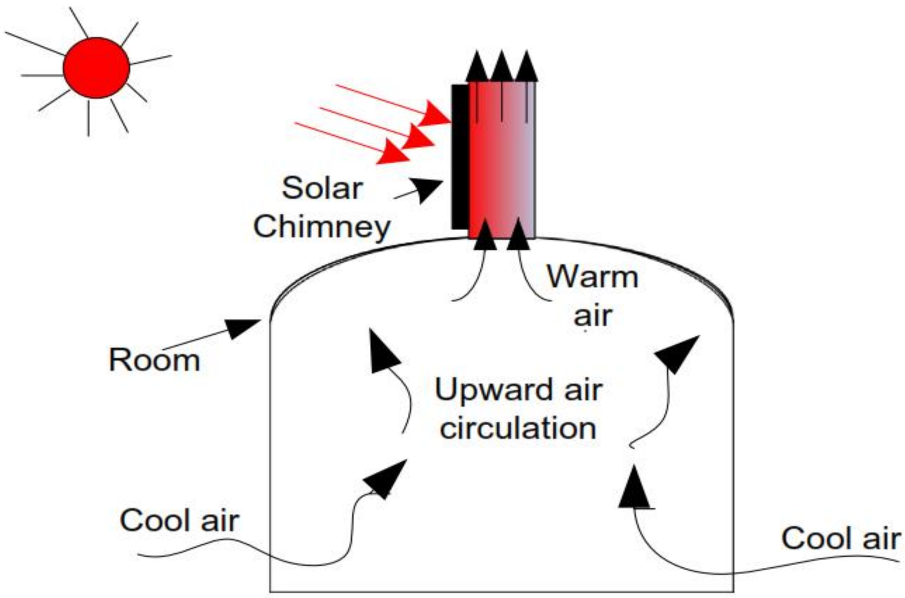

Fig. 2: Solar chimney

3.3 Wind tower

It is also known as wind catcher, preferred in dry climates for cooling purposes, shown in Fig 3. It is fixed at height or top of the building with the one or more openings to catch the wind more from various directions. Advantages of wind tower are easy installation, low maintenance cost, no requirement of electrical energy, ability to turn around to capture the maximum wind speed, reduce green house gases (GHGs) and air pollution, combine with other technologies i.e. air heater, SC,etc.

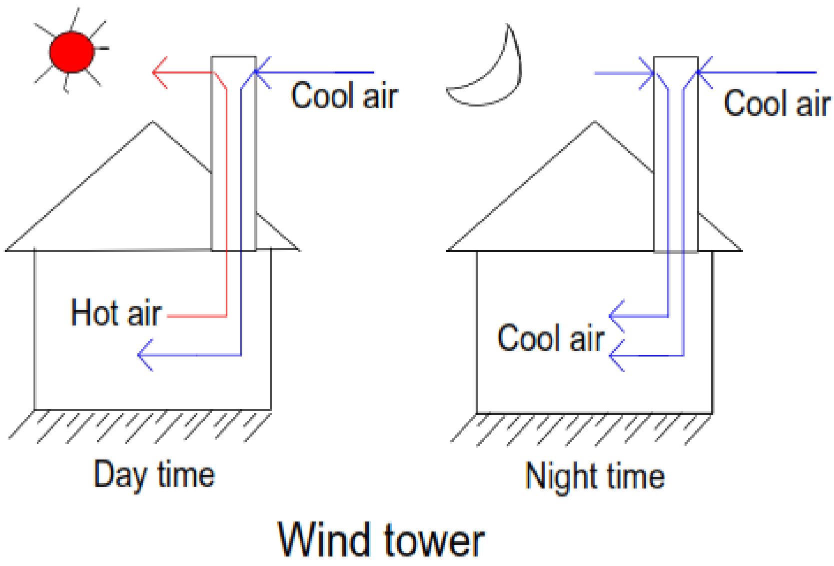

Fig. 3: Wind Tower schematic diagram (day and night time)

3.4 PCMs

PCM is an effective technology to store thermal energy. It has advantages of isothermal nature and high energy storage density. As the name reflects, PCMs may change their phase with a change in temperature. Very common example of PCM is water, but it has limitation that it cannot sustain for long. Duration of storing heat basically depends on latent heat of the materials. PCM can be broadly classified as organic, inorganic as shown in Fig. 4.

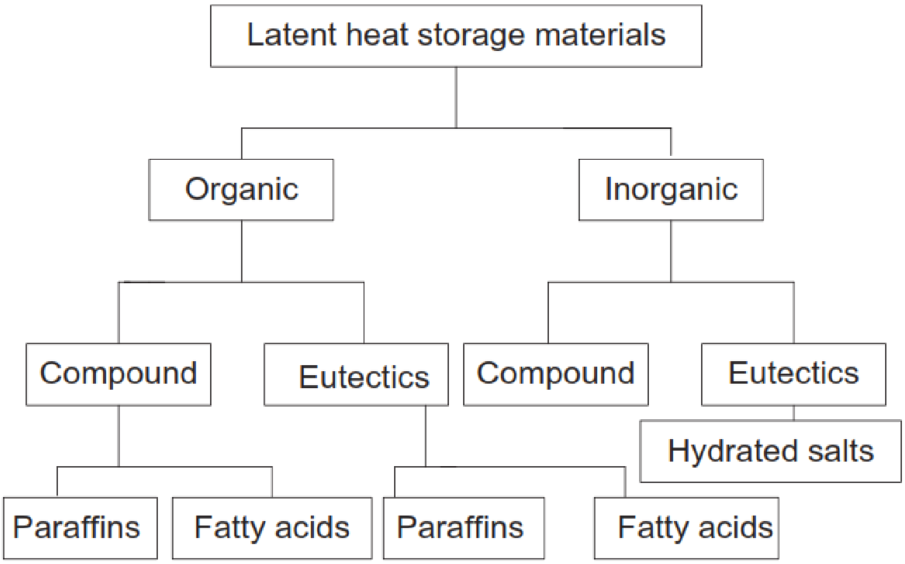

Fig. 4: Classifications of phase change materials

IV. CONCLUSIONS

GCHE systems are recognized to be outstanding in space heating/cooling and have been widely used for years. From the literature review, it is observed that neither GCHE nor passive technologies alone are satisfactory in majority of the cases. The desired solution appears to be emerging in the combination of GCHE and passive systems. Review of hybrid GCHE systems concluded that hybrid of EAHE with evaporative cooler could increase cooling effect by 69% and reduce length of buried pipe up to 93.5%. EAHE with PCM enhanced the cooling effect up to 47% as compared to conventional air conditioning system. In addition GSHP with evaporative cooling system approximately doubled the COP. Therefore, to mitigate CO emission and reduce energy consumption, environmentally clean and energy efficient hybrid GCHE systems could Demands of high efficiency and reduction of CO released into the atmosphere.

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