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Economic evaluation for cooling and ventilation of medicine storage warehouses utilizing wind catchers

Ali Mostafaeipour [a,*], Behnoosh Bardel [a], Kasra Mohammadi [b], Ahmad Sedaghat [c], Yagob Dinpashoh [d]

[a] Industrial Engineering Department, Yazd University, Yazd, Iran
[b] Faculty of Mechanical Engineering, University of Kashan, Kashan, Iran
[c] Mechanical Engineering Department, Isfahan University of Technology, Isfahan, Iran
[d] Faculty of Water Engineering, University of Tabriz, Tabriz, Iran

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ABSTRACT

Renewable energy consumption has become a dominant issue in many countries because of environmental crisis, pollution, climate change and increased costs of non-renewable sources like fossil fuels. Because of global warming and energy prices designers are refocusing on the low carbon credentials of new equivalents. In this context, the main target of the proposed study is to present a new innovative method of cooling the non-refrigerator medicine storage warehouses in order to minimize energy costs and environmental hazards for the city of Yazd in Iran. For this purpose, warehouses with absorption chillers, underground warehouses, and underground warehouses including wind catchers have been analyzed. Then, the equivalent uniform annual cost (EUAC) method was applied for evaluating the costs of the three alternative systems. The results of this study show that the use of wind catcher is far more economical than the absorption chiller cooling system. Moreover, it is concluded that the construction of an underground warehouse with a wind catcher is the most economical option for the storage of medicines than the other warehouses in this case study.

Contents

* Corresponding author. Tel.: +98 913 251 3751.
E-mail address: mostafaei@yazduni.ac.ir (A. Mostafaeipour).

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1. Introduction

Industrial development caused humans to extend their destruction domain in nature. The outcome of this problem is contamination of soil and water and air pollution, which are progressively increasing. So, we are facing two major crises such as environmental and energy issues [1]. A major portion of energy consumption belongs to residential and commercial buildings for cooling and heating purposes. In order to choose the best alternative efficient system for buildings, different renewable sources of energy should be considered. Commercial and residential buildings have a great impact on energy consumption and environmental pollution. Buildings usually consume 35–40% of the primary energy, 30–40% of all raw materials used, 15–20% of all water used, and 10% of land use. Annually, staggering 3 billion tons of raw materials are used for building activities worldwide [2,3]. Buildings pollute the environment especially in big cities in many countries due to almost 35–40% of all greenhouse gas emissions, 30–35% of all solid waste generation, and about 20% of water effluents [2,4]. In Iran, consumption of energy in the building sector for cooling and ventilation is about 40%. There is a big demand to reduce this amount of consumption in order to achieve reduced pollution in the environment [5–7]. Suitable methods to resolve the present issues of the existing buildings are required because it is not possible to move them [2]. In this study, a new innovative method of cooling the non-refrigerator medicine storage warehouses is introduced for the city of Yazd in Iran using wind catchers. To examine the efficiency of the method, warehouses with absorption chillers, underground warehouses, and underground warehouses including wind catchers have been compared.

The main objectives in sustainable building design are to lower the energy consumption and also the life-cycle costs of the building. By lowering of the energy demand, the performance of the buildings would be improved considerably [8]. Creativity in the design of the buildings is a key step in order to achieve sustainable buildings with less consumption of energy. After removing of the subsidies by the government, the cost of fuel consumption to provide the proper temperature for keeping the medicines in a warehouse especially in the summer has increased rapidly due to the high consumption of absorbing chillers. The purpose of this study is to analyze the feasibility for the construction of wind catchers in the underground warehouses. It seems if we could provide the proper temperature for maintaining medicines by using renewable energy sources such as wind and also using thermal variation of the underground warehouse, we can reduce unnecessary costs. Energy consumption has become a dominant issue in many countries because of environmental crisis, pollution, climate change and increased costs of fossil fuels. Moreover, the unit energy prices have risen so it is important to find alternative cheaper and environment-friendly resources of energy with low carbon generation.

Spanaki et al. [9] designed a proper roof pond for passive cooling system, and then introduced the advantages and disadvantages of ponds as well as the design considerations. The conventional and intelligent control systems of the green concept for cooling and ventilation of buildings were discussed in order to provide free energy [10–13]. Saadatian et al. [14] reviewed wind catchers technology in order to provide space cooling and ventilation. A comprehensive list of phase change materials (PCMs) which are being used and can be used for free cooling of buildings was prepared [15,16]. The passive solar technologies for space heating and cooling were discussed and their advantages and limitations were highlighted; also, the relative efficiencies and applications of the various technologies were presented [17,18]. Sadineni et al. [19] discussed passive building energy savings in building envelope components. Pacheo et al. [20] reviewed energy efficiency of buildings, which is useful for residential buildings.

The rest of this paper is structured as follows: Section 2 describes wind catchers thoroughly. Geographical characteristics are discussed in Section 3. In Section 4, methodology is discussed. In Section 5, case study of three different designs is presented. Economic evaluation is discussed is Section 6. Finally, conclusions are drawn in Section 7.

2. Wind catchers

One of the old natural methods of air conditioning for buildings is using a wind catcher, which uses wind energy for the cooling process and makes pleasant air flow in the rooms, the hall and the basement of the buildings as well as warehouses. Wind catchers are tall towers which are built on the roofs of the houses with different forms in the central and the southern cities of Iran. As a matter of fact, using wind catchers has been common in Iran especially in the desert areas for many years. The wind catchers are usually found in different shapes, namely, they are one-sided, two-sided, four-sided and eight-sided. The shapes of the wind catcher have different designs. In Yazd city, located in arid central part of Iran, all the existing wind catchers are tall four-sided or eight-sided chimney shapes. In contrast, in Maybod city which is located near Yazd city at a distance of 50 km, the wind catchers are short and with only one-side chimney shape. People in Maybod had to build the wind catchers in the opposite direction of dust wind and in the direction of favorable wind. Since Yazd city is located between two mountains, desert wind is less strong and the taller wind catchers can be constructed. In general, the one-sided wind catchers are usually short but the four-sided and eight-sided wind catchers are taller. As an illustration, the taller wind catchers are built in eight-sided shape in order to have high stability against wind pressure. Generally, as long as the wind blows, the wind catcher pushes the interior warm air outside the building. Wind catchers are designed according to wind speed and wind direction of a specific region to achieve better performance.

Wind catchers have been used in buildings in most of the Middle Eastern countries for many centuries and they are known as Bawdgir in Iran [21–24]. They were constructed, traditionally, from wood-reinforced masonry with clay and sun-dried clay bricks. The height of the wind catchers are between 2 and 20 m above the building roof. Clearly, taller towers capture winds at higher speeds and less dust [21,24–26]. Fig. 1 shows a typical four-sided wind catcher in a garden (Khan Garden) close to the city of Yazd. Among the country's famous wind towers are Dowlatabad garden wind catcher, the historical Borujerdi house's tower and the Abbasian Badgir in Kashan [27].

Most wind catchers in warm dry regions were used to help balance humidity inside the structure. In many buildings in desert areas, the wind towers were built on top of a lavabo