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Reduction of energy consumption using passive architecture in hot and humid climates

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ABSTRACT

Energy shortages, pollution, global warming, and the impacts of urban heat islands are among the pressing issues in this century all over the world. Historically, local architecture was based on people's experience and knowledge. It was sympathetic to the climate and environment. After a period of building design that ignored the local climate, more passive buildings, low energy buildings, and zero buildings have come into focus because of the environmental pollution caused by an excessive use of fossil fuels. The historic architectural style in Dezful includes underground shelters, 5–12 m deep, to improve the indoor climate conditions in this hot and semi humid city. This type of underground shelter, known as a Shavadoon, is regarded as one of the passive energy strategies to seek temperature comfort using the earth annual temperature stability and natural ventilation. The present study was conducted in a house owned by Mohammad Reza Ghamsari. The house was used to test the accuracy of numerical simulation of the temperature and air flow within the Shavadoon spaces. Temperature contours, streamlines, and other related findings are reported. The results show that space conditioning costs could be cut and adequate comfort could be derived using such passive heating and cooling systems.

1. Introduction

The harsh ecological conditions in some parts of Iran have made past architects emphasize the harmony between the buildings and nature and design the buildings based on ecological foundations.

The architects in Dezful and Shooshtar, two cities located in hot and semi humid regions, need to combat the common summer conditions of fifty degree temperature and fifty percent relative humidity to reach thermal comfort, So digging rooms as deep as 5–12 meters that one can accesses through many stairs was a suitable option for settlements and was in harmony with the ecology of the region. These rooms, termed Shavadoons, provide desirable conditions using the earth heat balance. In all seasons they work as natural air conditioners besides maintaining the heat balance. Since about 50–60 percent of the energy used today for residential buildings is allocated to heating and cooling systems it is possible that people in cities like Dezful with its harsh weather can reduce their energy consumption significantly using these underground rooms. There is little specific research about this subject but Asfour and Gadi (2008) analyzed the ventilation quality and airflow patterns in arched houses using CFD modeling. Golany and Ojima (1996) divided underground spaces into five groups, which were used in ten different ways. In this research, the effect of using the underground spaces on the natural environment and mental comfort of the humans is studied, and according to the results, using underground spaces has a desirable effect on the both of them. Gribble (2009) studied natural ventilation in Egyptian underground tombs. When in the desert, the outside air temperature drops dramatically in the evening causing a cool air draught to flow into the excavations that flushes out the stale air and dust, and replaces it with fresh air, enabling the workforce to continue working day after day. Bina (2008) introduced Dezful Shavadoons and illustrated their parts. It was determined that the temperature of a Shavadoon in summer is cooler than the maximum temperature and the minimum temperature of the outdoors; the daily temperature fluctuation of the Shavadoon is less than half a degree. In that study, a Shavadoon's temperature was measured experimentally but no simulating models were used. In contrast, this article firstly investigates several types of Shavadoon in shape and their parts and is aimed principally at comparing experimental data and with simulation data in a case study.

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2. Underground living condition

The heritage of underground dwellings can be seen almost in each part of the world. Beside the Mediterranean located regions, significant examples of underground structures used for housing are also found in Asia, where the Yaodong cave houses in the Loess Plateau area (China) have a history of more than 4000 years. The Kandovan rock houses are found in Iran, in the Americas (the Indian village of Mesa Verde in Colorado) and in Oceania (mined houses in Coober Pedy) (Benardos et al., 2014).

Earth sheltered homes have provided shelter, warmth and security for mankind. They have provided a safe haven for people. Protection from predators and climatic conditions, were among the reasons for going underground (Erdem, 2008). The recent quest for energy saving and efficiency in buildings has redirected attention on the earth material not only as support, but also as a thermal mass for passive energy utilization indoors.

Apart from the energy values which the subsurface climate of the earth provides, the other significant characteristics beneficial to earth shelters includes a major goal of recycling surface space by relocating functions to underground. In this way, earth shelters liberate valuable surface space for other functional uses and improves ground surface visual environment, open surfaces for landscaping and thus a more greener atmosphere (Anselm, 2008). Earth-sheltered buildings offer also other benefits, such as:

- lower building maintenance costs (smaller surface area of exposed building envelopes),
- better noise and vibration damping (earth dampens well the amplitude of acoustic waves),
- by definition they are less exposed to weather conditions,
- and often are architectonically very interesting whereby they can become a city's pride or landmark, which is an important consideration for potential investors (Staniec and Nowak, 2011).

On the other side, the underground space is not crowded since it typically has poor access to natural lighting and may suffer from moisture and ventilation problems. These spaces are actually used more often as a storehouse and seldom used as a living room. Today considering high demands for houses and building height limitations in urban areas, these rooms can be used as an accessory along with the remainder of the house in crowded cities.

3. Dezful city conditions

Dezful is located in the province of Khuzestan, in south-west of Iran in +32°, 25′ latitude and +48°, 25′ eastward longitude (Safaee, 2009). Behind this region (Dezful) is the Zagros chain of mountains and before it lies the plains of Khuzestan which extends as far as the Persian Gulf. Thus it has an ecological situation between the central desert of the Kavir cities and the coastal regions of Persian Gulf cities. Temperature in the summer time rises to more than 50° above zero. Since its distance is rather far from Persian Gulf (250 km) the humidity is less. So, it has warm and semi-humid climate. Climatic factors such as the intensity and direction of the sun, heat, weather and favorable wind direction and natural and topographic factors have an important role in the formation and stability of complex old Dezful, This city was built on a type of Conglomerate rising above the Dezz river surface and the river in this city has always had clear and cold running water from the Zagros chain of mountains. Since in Dezful the level of underground water was low, Shavadoon had been built in this city. Fig. 1 shows the location of Khuzestan province and Dezful city in Iran.

4. Shavadoon

Earth temperature in summer and winter is lower and higher than outside temperature respectively, except along the coast of the Caspian Sea and Persian Gulf and Gulf of Oman. Most of Old Iranian houses have basements, and typically household members went to the basement in summer (Ghobadian). Shavadoon is an underground space dug under the buildings in the old regions of cities of Dezful and Shooshtar. Its depth is from 5 to 12 m which can be reached by many different stair cases (Safaee, 2009). Shavadoon has been used for heating and cooling purposes when the ambient temperature is 7 °C in January and 47 °C in July, Shavadoon average temperature is 17 °C and 23 °C, respectively. The suitable Shavadoon temperature range proves the ability of this space in for saving energy. Shavadoon is one of the most innovative types

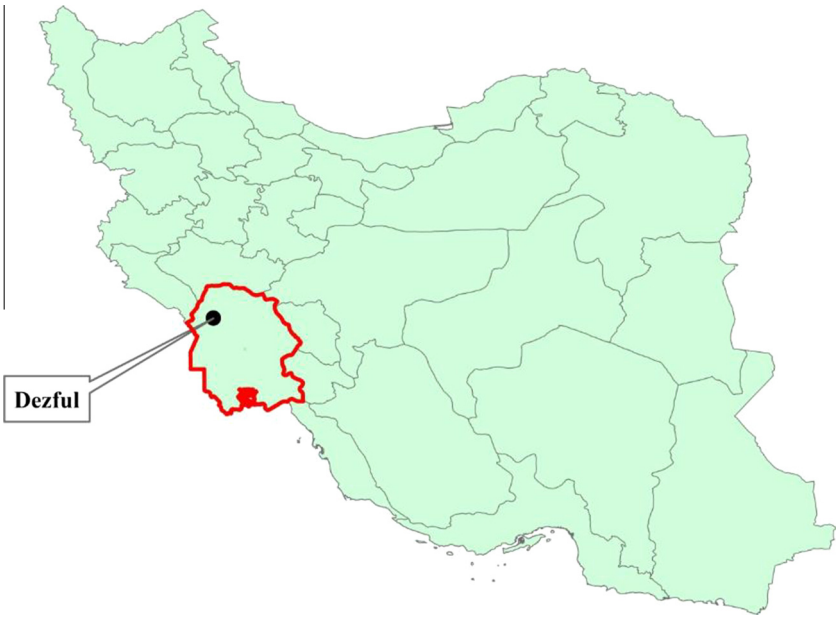

Fig. 1. Location of Khuzestan province and Dezful city.