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Sunken courtyards as educational environments: Occupant's perception and environmental satisfaction

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ABSTRACT

Sunken courtyard is known as one of the basic elements in vernacular architecture, especially in hot-arid zones. Even though the significant influence of sunken courtyards in energy saving is known for a long time, their suitability for occupants has not yet been precisely investigated. Therefore, this paper presents a detailed analysis of the suitability of vernacular sunken courtyards for modern-day building design. Three traditional dwellings with sunken courtyards, which currently are used as educational environments, are considered in the city of Yazd, Iran. The study is based on open and close-ended questionnaires so as to evaluate psychological and environmental factors that could affect the perception and satisfaction level of the occupants. The results of the close-ended questionnaire reveal that the three sunken courtyards could effectively reduce the traffic noise level. In addition, these spaces have positive impression on the occupants as they find them as comfortable, pleasant, calm and quiet areas. The results of the open-ended questionnaire show that the sunken courtyards are capable of providing a strong link to the green areas, incentives for learning, comfortable temperature level in summers, more concentration and creativity. On the other hand, the sunken courtyards fail in providing sufficient daylight and acceptable thermal comfort during winters. Recommendations will be provided to improve the performance of sunken courtyards in order to meet the requirements for occupants' comfort.

1. Introduction

One of the most significant challenges of the 21st century is to equip buildings with good comfort conditions and less negative impact on the environment (Rezaeian et al., 2017). Earth sheltered buildings are known as one of the effective answer to this challenge. These spaces were ancient underground structures which were originally built for shelter and security against animal attack (Cusido et al., 1987). However, they were mostly applied as a temperature regulator in harsh climates (Alkaff et al., 2016). They are able to considerably reduce the amount of energy consumption which leads to positive economic impacts (Alkaff et al., 2016; Benardos et al., 2014; Derradji and Aiche, 2014; Foruzanmehr and Vellinga, 2011; Hassan et al., 2014; Tundrea et al., 2014; Van Dronkelaar et al., 2014). On the other hand, it is assumed that they are unable to completely support comfort and well-being of their occupants. Indeed, one of the main reasons why people have resisted using underground buildings is the negative feeling towards these spaces (Hane et al., 1991). Entrapment, enclosed spaces, windowless area, darkness and dampness are the negative factors of underground spaces which cause feeling of getting lost, surge of anxiety, depression and a great sense of insecurity (Carmody and Sterling, 1987; Hassan et al., 2016; Lee et al., 2016; Nagy et al., 1995; Roberts et al., 2016). Hence, these negative psychological and environmental aspects have led to the public's fear and avoidance of underground spaces (Ringstad, 1994).

The satisfaction and perception of occupants in different buildings have been considered from environmental and psychological point of view in several research projects. Occupants' satisfaction with visual quality, thermal comfort, noise level and air quality (i.e. environmental factors) as well as their effect on people comfort and well-being are studied in different buildings such as offices (Amasyali and El-Gohary, 2016; Kim and de Dear, 2012; Newsham et al., 2008), residential areas (Amasyali and El-Gohary, 2016; Amole, 2008; Hua et al., 2014), public buildings (Cao et al., 2012; Mostavi et al., 2017) and healthcare facilities (Cohen-Mansfield and Parpura-Gill, 2007; Cohen-Mansfield and Werner, 1995; Marquardt et al., 2014). While factors such as thermal comfort, good visual and acoustic conditions along with good air quality can positively influence the overall environmental satisfaction (OES) (Rehdanz and Maddison, 2008; Xue et al., 2016), the high noise level, local air pollution and the depth of buildings can decrease the

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OES (Frontczak et al., 2012; Leaman and Bordass, 1999).

Analyzing psychological perception, researchers have reported that different types of green buildings such as work places (Armitage et al., 2011; Kato et al., 2009; Pei et al., 2015; Thatcher and Milner, 2014), universities (Hedge et al., 2014; Holmgren et al., 2017), houses and residence halls (Bonde and Ramirez, 2015; Holopainen et al., 2015) have more potential to offer psychological benefits. Furthermore, it is revealed that some positive psychological effects such as feeling of security and safety during extreme conditions are associated with earth-sheltered spaces (Mohirta, 2012). Entrance design, view and orientation, natural light, interior design elements and mechanical systems are introduced as proper design strategies which can improve positive psychological effects of underground buildings (Carmody and Sterling, 1987). Investigating the effect of experience on psychological perception, Kato et al. (2009) stated that in comparison to people who never had visited underground buildings, those who experienced working in these areas were more eager to work in underground environment. On the other hand, results of a photo questionnaire survey indicated that people who had no previous experience in earth-sheltered buildings, showed a positive reaction about these buildings presented in the videos and pictures (Hassan et al., 2016).

The main objective of this study is to measure occupants' environmental satisfaction and psychological perception in "sunken courtyards", as a prominent type of earth-sheltered buildings. Sunken courtyard can be seen in different countries such as china (Golany, 1990, 1992), Tunisia (G. Golany, 1988) and Iran (G. Memarian, 1999). Although there are some studies that had directly investigated the performance of people working in underground spaces (Nagy et al., 1995), the occupants' perception and satisfaction of sunken courtyards are not considered precisely(Durmišević, 2002). Hence, the environmental satisfaction and psychological perception of sunken courtyards in the hot-dry climate of Yazd, Iran, are examined.

This paper continues by presenting an overview of sunken courtyards in Section 2. The characteristics of the investigated field as well as the features of the three studied sunken courtyards are described in Section 3. In Section 4, the methodology which is applied to analyze environmental satisfaction and psychological perception is explained. The results and conclusion are presented in Section 5 and 6 respectively.

2. Sunken courtyard

Underground buildings were popular in many countries throughout the world such as Libya, Tunisia, Iran, Turkey and China (Abd-el-Hamid, 1990; Rudofsky, 1964). However, traces of traditional sunken courtyards were found in few countries like China, Tunisia, Iran and Turkey (Alkaff et al., 2016; Boyer and Grondzik, 1987; Golany, 1990, 1992; G.S. Golany, 1988; Khair-el-Din, 1984; G.H. Memarian, 1999b). Sunken courtyards located in Matmata (Tunisia) were probably the most primitive ones (Schoenauer and Seeman, 1962) which were mainly used for protection against heat during days and coldness during nights in the hot –arid climate of Matmata (Porras-Amoreset al., 2011). Vernacular Chinese houses in Shanxi, which were influenced by Yin and Yang, are another type of sunken courtyards (Cao et al., 2011; Liu and Zengfeng, 2007; Rudofsky, 1964). In Iranian vernacular architecture, central courtyards, which were built very deep and under the ground level, are called sunken courtyards (Saljoughinejad and Sharifabad, 2015). Although there are some differences in the forms of traditional sunken courtyards in China, Tunisia and Iran, the overall basic designs have remained similar (Al-Mumin, 2001; Taleghani, 2015). Sunken courtyards of Matmata are semi-circular and their dimensions vary from 5 to 10 m. In China, the shape of sunken courtyards is square or rectangular with dimension of approximately 9 to 13 m. Both mentioned courtyards have 9 to10 meters depth (Golany, 1990, 1992; G.S. Golany, 1988; Shi and Li, 2013). The average depth of sunken courtyards in Iran is 3–4 m underground and their shapes are square or rectangular (Saljoughinejad and Sharifabad, 2015). Few dwellings in Yazd have two floors under the ground level and the depth of their sunken courtyards is about 10–11 m like Oloomi and Olia houses.

In China, the conventional method to build a sunken courtyard was digging a deep pit like patio under the ground level and then hollow out rooms on the pit walls (Shi and Li, 2013; Wang, 2012). The construction method of Iranian vernacular sunken courtyards consisted of excavating the ground, building the supporting piers, constructing the rooms in the basement and setting up the sunken courtyard (Majidi et al., 2014). Terms like pit yard, underground courtyard, cave dwelling and "Godal baghcheh" (in Persian) are alternatively used as synonyms for sunken courtyard (G.H. Memarian, 1999b; Wang et al., 2016).

2.1. Advantages of sunken courtyards

Locating under the ground level on one hand and facing a courtyard on the other hand provide high thermal comfort zone for the residents. In fact, a sunken courtyard has the ability to combat the harsh climate and decrease energy consumption by 25–35% (Al-Temeemi and Harris, 2004). Studying thermal comfort of sunken courtyard in a hot-arid area (Matmata, Tunisia), Golany (G.S. Golany, 1988) showed that "the temperature of the rooms facing the sunken courtyard was about 17 °C cooler in mid-summer and 9 °C warmer in mid-winter than the maximum and minimum outside dry-bulb temperatures respectively". Also some experts discussed the thermal advantages of these structures both qualitatively and quantitatively and recommended their implementation (Brown and Novitski, 1981; Wang and Liu, 2002).

One of the main advantages of sunken courtyard is that their central yard can reduce noise levels from the buildings in the neighborhood and the surrounding streets (Taleghani et al., 2012). Thus, the central yard as one concept and underground as another, can perfectly reduce disturbing sound from outside (Hassan and Lee, 2014). Furthermore, many occupants of earth-sheltered buildings suffer from lacking access to natural light. However, sunken courtyard can bring more natural light to the rooms located under the ground level, whereas the appropriate ratio of soil and plants to the total area of the courtyard can provide suitable shading or sunlight during different seasons (Soflaei et al., 2016). While other types of earth-sheltered buildings have limited connection to the outside, a sunken courtyard provides strong link between indoor environment and nature (Al-Mumin, 2001; Heidari, 2010). In addition, trees and plants in most sunken courtyards enhance the air humidity (which is crucial in hot-arid regions) and make the indoor spaces more pleasant (Khalili and Amindeldar, 2014). They are also economical in terms of using the local materials. Building a sunken courtyard with the materials gained by digging land would decrease the cost of transforming materials to the location and construction (Ahmadi, 2005; Barzegar and Mofidi, 2011; Hassan and Lee, 2014). The main reasons for applying sunken courtyards in Iran were shading and cooling the air during summer days. It also enabled residents to have access to subterranean canals which provided sufficient amount of water for plants in the house. In addition, Moradi (2005) indicated that sunken courtyards make easy access to other spaces and provide a suitable environment for green areas.

2.2. Contemporary sunken courtyards and their future development

Despite the mentioned negative feelings of people about underground buildings, their significant role in moderating climate leads to