Research Article

The way of using daylight in the process of historic buildings reconstruction via new construction technology (Case study: Safa Bath)

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Abstract: Nowadays, the development of modern architecture has led to a more favorable attitude in reconstructing and repairing abandoned and destroyed historic buildings in Iran. Regeneration of these buildings using modern construction methods, which are fit to Iranian architectural patterns, is one of the best ways to restore their forgotten values. On the other hand, since natural light is the just light source for architects, improving the quality of natural light emission inside this building by technical methods was considered as the main objective of providing the design strategy in this study. Evidence has been shown that the quality of light emitted indoors via hornos is the principal challenge related to the Safa Bath. Accordingly, light conditions were simulated in the present study using Ladybug, Honeybee, and DesignBuilder software. Then, the required lights were directed inside this building to improve the quality of their diffusion using optical fibers and the HSL solar system placed on the dome. Results revealed that the implementation of the proposed idea improved lighting situations by about 40% in summer to 80% in winter and about 42% in municipal electricity consumption. It should be noted that the obtained plans and diagrams were qualitatively analyzed and assessed at the end of the research.

Keywords: Historical buildings, New manufacturing technologies, Regeneration

1. Introduction

Sustainable architecture, one of the principal courses of contemporary architecture, is a logical reaction to the issues related to the industrial age. The industrial revolution and technical-technological advances in the field of architecture led to the oblivion of architecture in different parts of the world and the emergence of modern architecture. In general, improving quality in sustainable architecture is done to achieve comfort. Sustainability and environmentally friendly design are among the latest issues in architecture. Sustainable architecture is a logical reaction to problems related to the industrial age and its quality is in line with achieving comfort (Zeinlian, 2016). Many architects focused on natural resources, clean energies (inexhaustible energies), and natural light in various ways. The latter item in traditional Iranian architecture has been studied from two aspects of light controllers (e.g., canopies) and skylights (Mohammadzadeh, 2004). The first group is responsible for regulating the light entering the building, which is divided into two groups: structures that are part of the building (such as porches) and structures that are added to the building and sometimes have decorative modes (e.g., curtains). In contrast, some elements have the role of controlling light and regulating it to enter the building, including porches (Nazif, 2013).

Overall, the necessity of reviewing this research has become due to the misuse (inappropriate use) of technological advances and forgetting the techniques used in vernacular architecture. Iran has more than seven thousand years of urban history, which has a very diverse topographic and geographical status and is considered a treasure trove of world architectural history. Climatic diversity and a long history of habitation in Iran have led to a variety of valuable achievements in the field of architecture and urban planning in this land, and the most important of plans are different techniques of natural lighting in buildings and urban spaces (Tahbaz & Mousavi 2009).

Concerning that the main issue for the Safa Traditional Bath is the negative effects of undesirable light and glare rate at the horno site of domes (as the only way light enters the building), improving the quality of lighting inside the building using some Solar technologies were examined in this study.

Sunlight converters in historic buildings allow the maximum use of light potential received by the outer wall of the building. Besides, the installation of smart solar fibers on the inner walls of the building based on the standard lighting requirements/needs in each space leads to converting solar energy stored by the HSL device into an electrical current, improving the quality of interior lighting, and saving electricity consumption in urban areas. Accordingly, the present study aimed to enter the required lighting into the historical building of Safa Bath during sunny days using optical fibers and solar technology (hybrid system) that can ultimately achieve a homogeneous and uniform light in the space and stability in energy consumption.

2. Theoretical Foundations and Literature Review

Traditional architecture in Iran has been constantly affected by various climatic factors. In this regard, the sunlight can be assumed the most important climate factor affecting urban fabric and traditional building formations that lead to spatial organizations and establish appropriate strategies for monitoring and controlling natural light due to its location and intensity on all of Iran's climate areas (Hanachi).

In recent years, theoretical studies and field surveys relevant to daylight computing and natural lighting conditions have been performed in Iran's educational or office locations due to the development of scientific knowledge and the interest of some students on projects related to natural lighting in architecture (Sanati, 2004; Feyzmand, 2006; Tahbaz, 2011; Kazemzadeh, 2011). Also, establishing the Iranian Association of Lighting and Lighting Engineering is another positive step in this field (Tahbaz, 2012). Studies related to daylight and its optimal use have been significantly analyzed in some developed countries (e.g., CIES American Lighting Association, IESNA European Lighting Association, CIE, and so on). In this regard, some international associations (e.g., the Indian Lighting Association, ILSE Chinese Lighting Association, and other scientific and research associations in Australia and Canada) are also responsible for conducting research related to natural and artificial lighting and presenting relevant standards.

Hence, an active lighting system or hybrid solar lighting (HSL), called hybrid lighting, was considered for this purpose. The light absorbed by each of these systems on different days of the year is equivalent to 4000 to 6000 lumens on average, which are directed into the building by optical fibers with a thickness of 3-8 mm. Each three mm thick optical fiber carries about 400 lumens of solar energy. The arrangement of these fibers can also cover approaches for future research by researchers (especially studies related to optimization of forms compatible with a variety of algorithms using artificial intelligence).

Table 1. Hybrid solar lighting systems (Sobhan et al., 2016)

Fabrication	**Light Guiding System**	**Horizontal systems** **Vertical systems** **Parabolic systems**	
Solar Lighting System	Light Transport System	Passive (Inactive)	Combined collectors Parabolic collectors Brilliant concentrators Plate laser cutting Helibas Lighting tube
		Active	Himawari transmits Hybrid lighting system Paran Hoco

Advantages of solar lighting systems

Energy-saving (lighting, heating, cooling, and others) is known as one of the most crucial advantages of employing natural light systems. Light transmission systems are divided into two general categories of active and passive methods (Kahai, 2012). In this study, an active transducer type called hybrid lighting system (HSL) was employed to transmit and release light, which releases light about 15 meters into the building, by hybrid lighting systems. This system can also use urban reservoirs automatically on cloudy days and during 24 hours.

Components of hybrid solar lighting collectors

A hybrid system collector consists of several main components of a plastic dish, two-axis motors, optical converters, optical cable, and a secondary mirror, which are shown in figure 1.

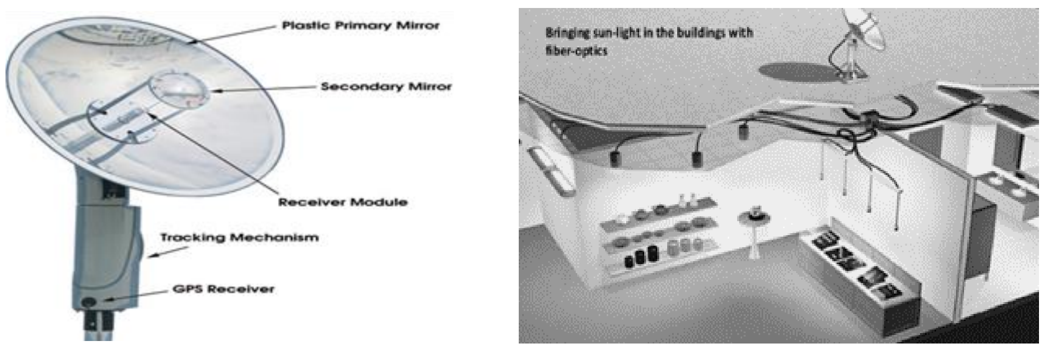


Fig. 1. Hybrid system collector and its components

Table 2. Factor affecting solar system efficiency

The use of solar energy	Active and passive systems

	Direct/indirect passive design
Climatic states and positions of the region	Latitude and longitude Average monthly temperature Radiation intensity Radiation duration Radiation energy level
Position and direction of building and solar systems	Conditions and profile of the environment around the building Location and angles of passive solar systems Location of sidewalls and glazing walls in passive solar systems
Building body and form	The role of the body and form of the building on the received energy and its amount Dimensions and location of glazing walls
Materials and walls	Absorbability of surfaces and materials

Some studies reported the amount of brightness (lighting amount) per unit area on the current conditions of this building at two different times as follows:

In general, brightness amounts were assessed equal to 50-250 and 50-400 lux (one lux= one lumen) for directions of left and right of the plan (12 o'clock in the noon; December 21 and June 21, respectively). It was also reported that brightness values were varied for both directions equal to 50-500 lux under the above conditions. Points to be analyzed in plans including regulating the light intensity and glare rates, shading (the creation of shadows), and the reduction of light at the horno site, which are vary depending on the season, radiation amount, and radiation direction (Figures 2 and 3).

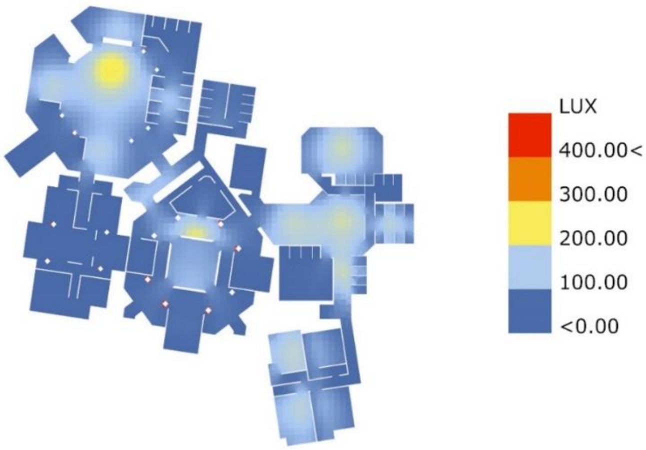


Fig. 2. Analysis of light in the current conditions (12 o'clock in the noon; December 21; Reference: Authors)

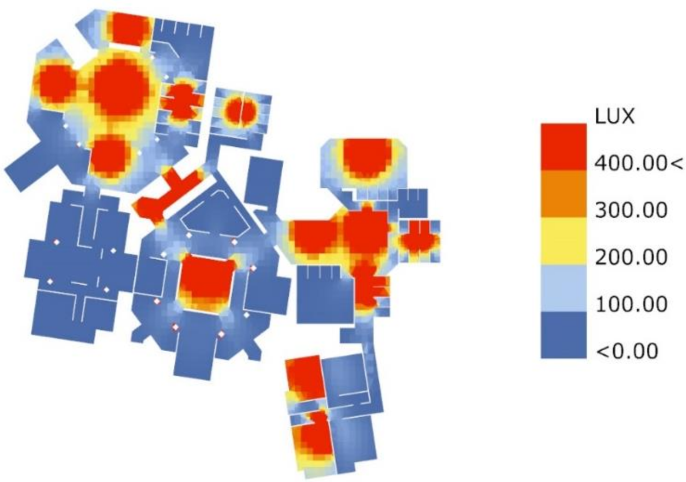


Fig. 3. Analysis of light in the current conditions (12 o'clock in the noon; June 21; Reference: Authors)

Some researchers have proposed solutions for the spaces of some land-uses based on lighting standards to reduce glare rate at the horno site so that the required light would be provided uniformly (with better quality) using a solar energy source. Here, considering the ability of hybrid systems to automatically use city electricity and sunlight, we provided the amount of light in each space in accordance with the lighting standard using optical fibers with a thickness of 3-6 mm. It is noteworthy that the transmission power of each optical fiber with a thickness of three mm was assumed equal to 400 lumens. An example of the studied spaces is as follows to better understand.

A lobby, with an area of 106 m^2, needs 250 lumens of light in standard conditions. Figure 2 indicates that the light intensity is in high levels only at horno installation sites while the brightness around them was reduced to 50 lumens. In general, if the required light for the whole surface of this example considers equal to 250 lumens, the number of fibers (with three mm thickness) will estimate based on the following calculations. It should be emphasized that because of the presence of different levels, there were generally about 1.3 lumens of light losses for each space, which was accounted for all statistical calculations of the present study.

$Lux\ 250\ \times 106\ M = 26500\ Lumines$

$26500\ \times 1.3 = 34450\ Lumines \cong 34500\ Lumens$

$34500 \div 400 = 86$

In other words, if fibers with three mm thickness are used in the regeneration process (400 lumens per fiber), eventually 86 optical fibers will provide the standard lighting of the lobby space. Hence, it is predicted that these calculations eliminate the inevitable existence of hornos in the regeneration process of similar buildings.

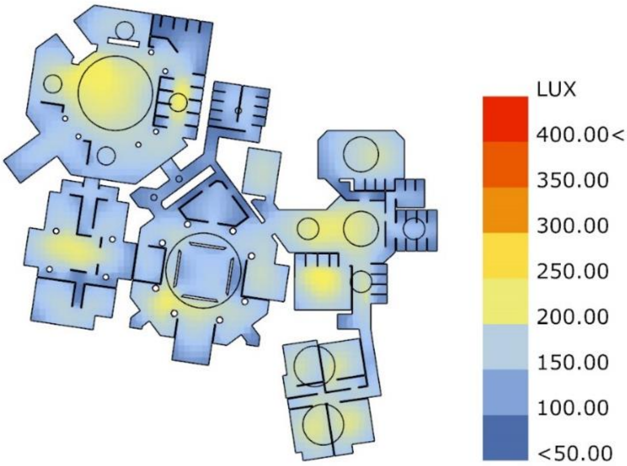
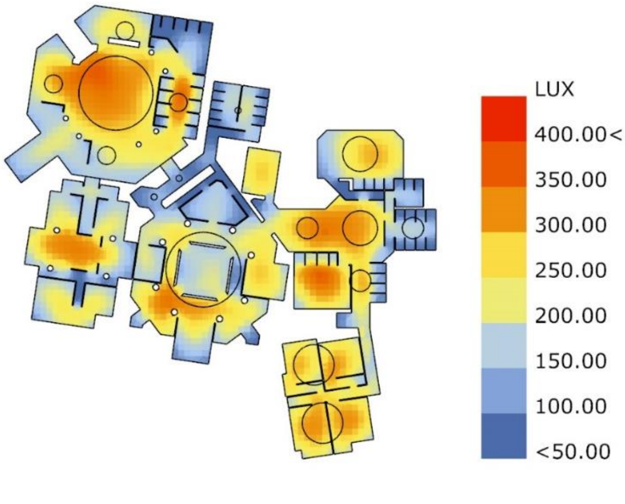


Fig. 4. Lighting status caused by the application of solar optical fibers (12 o'clock in the noon; June 21; Reference: Authors)



شکل 5 روبرو اضافه شود

شکل 5-وضعیت روشنایی بدست امده با فیبر های نوری خورشیدی- ساعت 12 ظهر 1 تیر ماه .منبع:نگارنده

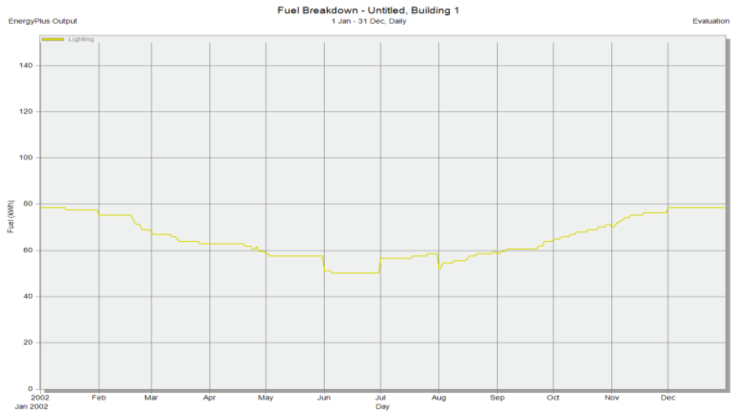


Chart 1. The amount of urban consumption of electricity in the absence of solar technology (equivalent to 23770 kWh; Reference: Authors).

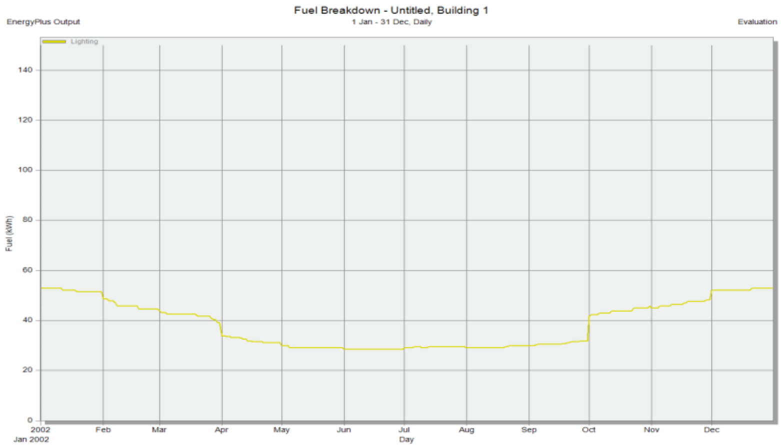


Chart 2. The amount of electricity consumption for urban areas in the presence of solar technology (equivalent to 14010 kWh; Reference: Authors)

The amount of electricity consumption for urban areas (for 120 watts per m^2) is calculated by the following formula:

$$14010 \div 23770 = 0.58 \ (or = 58\%)$$

Therefore, the amount of power savings is equal to 42% using the proposed system (assuming the requirement of 120 watts per m^2 for optimal lighting).

3. Conclusion

Safa Traditional Bath firstly simulated using Ladybug, Honeybee, and DesignBuilder software. Then, its strength/weakness and undesirable points were recognized in terms of the emitted light quality per unit area. Next, a hybrid solar system was installed to improve the current conditions of the building. Eventually, the proposed system was simulated on the Safa Bath to improve the lighting quality, ventilate the interior of the building, and present different advantages of the recommended technique. In general, simulation results showed that the proposed method resulted in improving indoor lighting per unit area (equivalent to 40 to 80%), saving electricity consumption in urban areas (equal 42%), and enhancing indoor air conditioning (about two times).

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