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Application of Optical Fibers in Residential Buildings

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Abstract Natural light always plays important role in designing of residential apartments in terms of energy saving and health of lifestyle. To find a practical approach for saving electricity energy in lightening of dark places has always been a challenging topic in recent years. Most existing studies on the interior lightening by using sunlight in architectural concepts have focused on position of windows and patio in plans. This paper describes a new application of optical fibers for transferring sunlight into the rooms by conducting an experimental test. The experimental tests indicated that a group of optical fibers can successfully conduct the natural light from the roof of an apartment in to dark spots through walls. Also, from the outcomes it is concluded that the daytime running electricity lamps can decrease in compare with traditional methods.

Keywords: *dark spot, natural light, optical fibers, residential building*

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1. Introduction

From many years ago daylight has been the main interior lighting source in buildings. However, for a short period of twenty years it was replaced by electric lighting and artificial lights. In recent years the cost of providing energy and environmental concerns have heightened the need for designing apartments based on maximum usage of natural light in duration of day [1]. Prokash, et al. [2] demonstrated that sunlight can be an important source in future that is freely available in the world. Franta and Anstead [3] proved that the daylight has significant advantages in comparison with artificial lights in terms of energy efficiency and contribution to the environment.

However, the benefits from solar energy utilization have been much more than energy savings. Not only this perfectly safe source of light contributed to reduction in electrical consumption and utility costs, but also it has provided high quality indoor lighting for building occupants. The usage of daylight can be widely effective in the field of health of lifestyle [1]. Liberman [4] found that people prefer natural light instead of electricity lamps. He demonstrated that spectrum of colors in sunlight is the main reason of this popularity. The full-spectrum of light provides a cool, mild and pleasant interior illumination and increases the eye functions to its highest level [5]. Hathaway, et al. [6] showed that sunlight can be effective for biological functions. Since, it has high level lightening. Base on the scientists’ achievements in the field of day lighting and the human health, using natural light can provide considerable benefits to the human well-being and psychological performance. The use of artificial lighting can lead to physical and mental strains and common problems like oversleeping, over eating, energy loss and work disturbance [7]. Conveying natural light in to buildings to provide interior illumination can contribute to controlling the human body’s chemistry, lower boredom and enhancing occupants’ mood during a day [8]. Franta and Anstead [3] the full-spectrum of the sun light will increase general well-being, mental performance and productivity which results in financial savings and reduces headaches and eyestrain. Day lighting system has been successful such that, nowadays it is used widely in hospitals. It has made the hospital’s environment as a patient care program.

Recent studies have demonstrated that the solar lighting systems which apply optical fibers to transmit sunlight in to structures are more useful than the conventional solar panels. As compared to solar panels which collect sunlight, maintain it as electricity and use a small portion of that to illuminate the buildings, the optic-mechanical day lighting technologies are able to utilize almost half of the solar energy they receive [9]. Apart from their high efficiency, they are able to provide such high quality lighting for building occupants that cannot be obtained by artificial lighting. In addition these systems can alleviate glare and excessive illumination [10].

Recent developments in buildings’ interior lighting have heightened the need for energy saving and supplementing available energy. Many researchers concentrate on the performance of residential apartments in terms of expenses for energy. These developments can lead to i) providing better and safer lighting, ii) saving money and energy and iii) a good solution for environmental safety [11]. Reviewed the literature shows that Himawari who was one of the oldest researchers, developed "Mono-lens Himawari", a sunlight collecting system in 1979 [9].

To find a day lighting device to transfer sunlight from outside of building into dark spots such as bath rooms and stores can be a safe and efficient alternative to and artificial illumination. Sunlight is the main light source of the fiber optic day lighting technology. Day lighting systems are developed in purpose of capturing direct light and the maximum level of solar energy and transmit it through optical fibers in to buildings. Proper operation of these systems chiefly depends on the quantity of sunlight being captured and concentrated on the fibers [12]. Based on the position of the sun during a day from sunrise to sunset, Muhs [9] could track sunlight intensity. Tracking of sunlight can be used for improving lighting system of such rooms lacking natural light. So in recent years there has been a dramatic increase in the usage of optical fibers for providing interior lighting in architectural designs.

The purpose of the current research is to apply the optical fibers for conducting natural light as a viable source of lighting into dark spots of residential buildings and reducing the usage of artificial luminaires.

2. Optical Fiber Characteristics

Optical fibers are defined as light-guide channels. In its most basic form, an optical fiber consists of three main parts: i) thin crystal core which is in the central part of a fiber and carries the light, ii) cladding which surrounds the core and keeps the reflected light in it and iii) plastic buffer which protects the fiber against humidity [13].

Optical fibers are made of flexible transparent plastic or glass. String shape with thin diameter is one of the causes of flexibility performance in the fibers. The fiber strings work similar a flexible mirror such that an optical fiber can conduct light from head of string to end of it. The Factors affecting the efficiency of light transmission through optical fibers are the fiber design and the physical environment. Large bends in an optical fiber and small bumps along the core axis which can be caused by the environment shed light rays out of the fiber core [13]. Bending the fiber causes not only increased attenuation, but also the color change of the output light [9]. Figure 1 shows how a light string reflects inside an optical fiber.

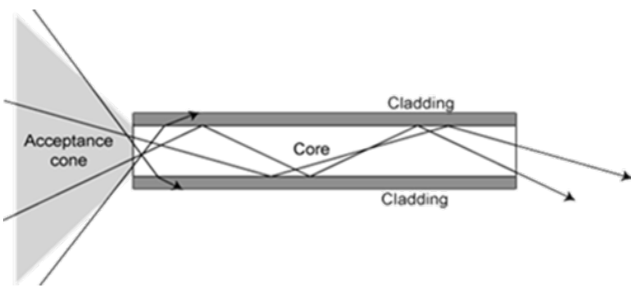

Figure 1. Light conduction in an optical fiber [14]

Light transmission occurs by the total internal reflection. The most common application of the total internal reflection is to keep light in the optical fibers. The light rays are reflected uninterruptedly and travel down the length of the core. The reason of the internal reflection is the difference in the refractive index of the core (n_1) and the cladding (n_2). The material of a core has higher refraction than the outer cladding material [15]. During the light transmission, the reflection may reduce because of imperfections in the core material, so the cladding is used to increase the internal reflection by capturing the light dispersing out of the core [10].

When a light beam passes through an optical fiber and meets the core-cladding interface at the largest possible angle which is called the critical angle, the angle of refraction tend to become 90°. Therefore for light to be trapped in the core of the optical fiber and be reflected with high efficiency, the incident angle should be greater than this critical value which is essential for undergoing the total internal reflection and light ray guidance through the fiber core [15,16,17].

The acceptance angle of the fiber (α) determines which light rays will be guided down the fiber. Furthermore when a light ray makes an incident angle (α) with core of an optical fiber, gets reflected and meets the core-cladding interface. Any light beam making an incident angle greater than (α) with the fiber core, will not be accepted in to the core [16,17,18]. Figure 2 shows Snell's law and refraction of light in an optical fiber.

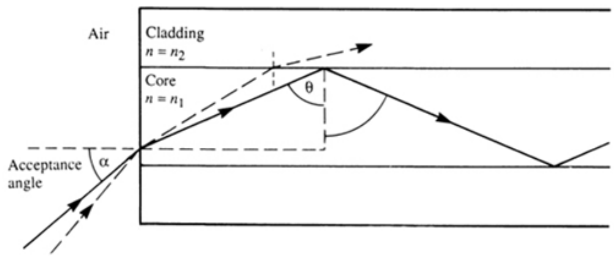

Figure 2. Refraction of light in an optical fiber [18]: n_2 is the refractive index of the cladding, n_1 is the refractive index of the core, α is the acceptance angle of the fiber, θ is the angle of incidence

The diameter of the core plays significant role in the transmission of light rays. An optical fiber with larger core is able to transfer more light intensity. In terms of light-ray transmission, optical fibers are used in two categories: i) single-mode and ii) multi-mode. A single-mode fiber has a smaller core diameter than a multi- mode fiber [15].

3. Experimental Study

In this paper an innovative method is used to conduct sunlight from out of a residential apartment into dark places. Therefore, an experimental test was carried out to prove the primary hypothesis of lightening dark spots by optical fibers. Figure 3 shows a sample of the hypothesis of current research for conducting sunlight by optical fibers from rooftop of a four-storey residential building into a dark bathroom. Figure 3 shows how the sunlight transferring system conducts natural light through the flexible transparent fiber string into any dark spots.

3.1. Single Optical Fiber Test

For primary experimental study it is needed to test a single optical fiber under natural and artificial lights. In the first case of study it was used a torch as a light source at the head of a fiber string. In addition, for evaluating the intensity of light, the location and color of artificial light source was changed. The outcomes showed that the intensity and color of output light depend on the color and distance of light source. Figure 4 (a) shows details of light conduction inside the single optical fiber under artificial light.

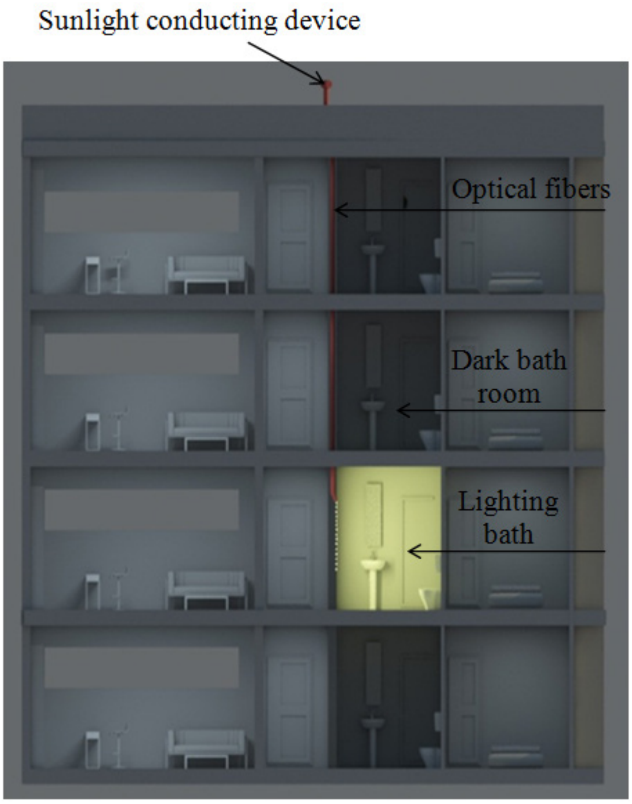

Figure 3. Sunlight transferring system to dark spots by optical fibers

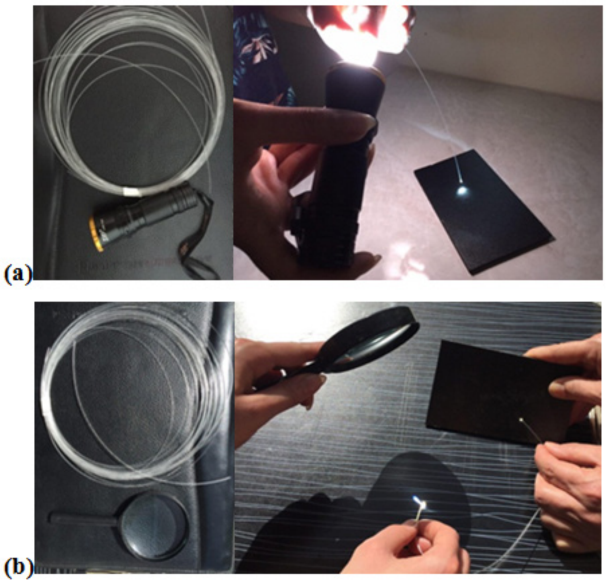

Figure 4. (a) Light conduction in an optical fiber under artificial light and (b) Light conduction in an optical fiber under sun light

In the second case of the experimental test, a lens was employed to concentrate sun rays at the head of single fiber string. Also, in this case the intensity of output rays was depended on the position of lens. The conducted tests exhibited that the single optical fiber can successfully conduct light from head of the string to end of it.

3.2. Sunlight Conducting Device

The primary tests on the single optical fiber indicated that we can use a group of thin strings as a thick wire for transferring sunlight. In the current research two groups of the optical fibers were used to conduct natural light from roof of a residential apartment into a dark bathroom. The length of the optical fibers was set base on the distance between the rooftop to the location of the dark bathroom on the second floor. For concentrating sun rays on the fibers during a day, a sunlight conducting device was fabricated. The fabricated device was installed on the roof for conducting sunlight and illuminating the bathroom during a day. The sunlight conducting device is consisted of three parts: the sunlight collector with three lenses, the optical fibers with supplementary connections and crystal stones on a wall of the bathroom. Figure 5 (a) shows the sketch and Figure 5 (b) indicates the fabricated device for the mechanism of sunlight conduction.

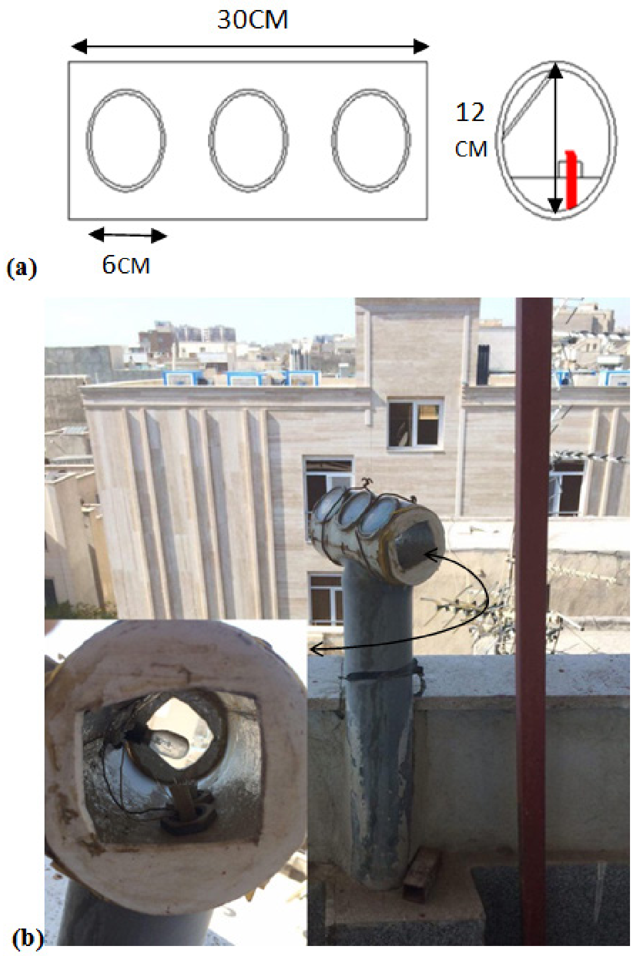

Figure 5. (a) Sketch of sunlight conducting device and (b) Test set

The implemented lenses collect and concentrate the sunlight on the optical fibers which are fixed in front of the lenses in the collector. There are two glasses on the two sides of the system in order to track sunlight that changes its position during a day. When the light enters the collector which its internal surface is covered with Aluminum, inside the pipe becomes like an illuminator. The reason of using Aluminum is to have an internal light reflection and focusing the maximum amount of light entering the collector, on the fibers.

After the sunlight is captured by the optical fibers, it will be transmitted through the fibers which are located inside the wall and guided down to behind the bathroom wall of the second floor. In this project 5 optical fibers were used for each of the spot lights on the wall and we maintained about 40 watt electricity power. When the sun goes down and it gets dark, the lamp which is placed in front of the fibers in the collector can be used as a light source to supply the illumination of bathroom sufficiently.

The outcomes of tests indicated that the sunlight conducting device can transfer natural light from out of a building in to dark spots which prove the primary hypothesis. Therefore, the use of a sunlight transferring system can improve the quality of lighting, psychology health of building occupants and the environment safety. Figure 6 illustrates that how successfully this device could illuminate the bathroom with sunlight. This figure shows the spot lights are applied on wall of the bathroom and each of these spot lights includes of several fiber strings.

Figure 6. Lightening bathroom with natural light by sunlight conducting device

4. Conclusion

The energy crisis that arose in the past and even in the recent years has been one of the primary considerations for building designers, environmental concerns, high utility costs and daytime lighting requirements for large buildings and dark spots have made the sunlight a perfectly safe and increasingly efficient alternative to electric lighting.

The sun is a free source of healthy, high quality and plentiful light. Therefore, proper installation and maintenance of natural lighting systems and bringing daylight into buildings and dark spots, not only alleviate the problems relative to energy crisis, but also result in tremendous savings in money and energy consumption.

This paper discussed about the experimental study on an innovative method of conducting natural light in residential buildings. All tests were carried out base on the ability of optical fibers for transferring light in a long distance.

The primary test on a single optical fiber indicated that the intensity and color of the output light depends directly on the location and color of the applied light source.

The obtained results from tests on the group of fiber strings exhibited that the sunlight conducting device successfully can collect sunlight and transfer sun rays into a dark spot. Therefore, such device can be considered as a high quality and efficient lighting source rather than artificial ones.

Competing Interests

The authors have no competing interests.

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