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The Use of Daylight in Architecture with an Emphasis on Reducing Energy Consumption

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Abstract: The reduction of energy consumption by using daylight in architecture is the main purpose of this study. In general, light is the most visible renewable energy. An important key question is that what are the ways for energy saving specially in lighting. More importantly, how much energy the buildings dwellers should save and how much others should save. Since recently there is very little attention on the use of daylight and solar energy. Now, the question is that whether the natural light of day can be used for different tasks inside of space and daylight can be regarded as a factor for energy saving? The answer is that the natural light of day can be effectively used for different purposes and in the most cases it brings energy saving. In addition, it ends up with satisfaction of the people in their life and work environment. It does not mean that light can be used for any purpose and natural daylight is one of several factors that a designer has. As it becomes popular, it can be used effectively and desirable. Application means "correct use" which it cannot be denied and it forms the basis of this study and in conclusion, it is hoped that in the future, we see the use of natural light in buildings as a quite effective element as our ancestors had done.

Keywords: Ceiling light, daylight, efficiency, energy saving

INTRODUCTION

Light is the source of all existence. By lightening the objects surface, light will donate them a visible environment. Retracting shade behind objects gives depth to them. Objects in the boundaries of lighting and darkness are meaningful, gain their shape and displays it. Their internal relationships are discovered and are connected to an endless such as chains and rings. Light donates independence and autonomy to objects and also limit their dependence simultaneously. We can even say that light can give promotion to any object in the environment where that object is quite clear and it varies with other objects. For early humans, light was considered as a means for time calculation. High-energy beams of light that are reflected from the sun over the earth give the basic form to early human's feeling and understanding of place. This light which was taken into the internal space by some kind of opener, enables the residents who had lived in those places to understand the part in relation to the environment.

Nowadays, technical and technology advances has facilitated artificial lighting. However, by artificial lighting, the human relationship with nature would be faded away and finally will lose that relationship. Natural light can be directed to the interior architecture so that it gets depth and definition and creates a very exciting and stimulating space. Light alone cannot be palatable. There must be darkness beside the light for creating light identification. The darkness brings brightness to the light and reveals the power of light.

The use of daylight is effective in reducing building cooling load. This result, the air-conditioning system load will be reduced. For centuries, daylight was the only efficient source of light available. Architecture was dominated by the goal of spanning wide spaces and creating openings large enough to distribute daylight to building interiors. Efficient artificial light sources and fully glazed facades have liberated designers from these constraints of the past. Advanced day lighting systems and control strategies are another step forward in providing day lit, user-friendly, energy-efficient building environments. These systems need to be integrated into a building's overall architectural strategy and incorporated into the design process from its earliest stages.

Architects began to explore different ways to achieve a better quality of daylight. This coverage was implemented through the application of tooth roofs, roof skylights, faded-color skylights and rooms with two or three strain windows, stained glass and other techniques to bring light to places of interest.

According to Lam (1977), the relationship between architecture and light was profoundly and irreversibly changed a century ago by Thomas Edison's handwork. Continuing refinements in electrical lighting systems have brought architects literally more light than they

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know what to do with. By the end of the 1950s, new glazing materials and advances in building cooling systems combined with electrical lighting to displace day lighting as a mandatory architectural issue. With the limitless resources of electrical light, contemporary architects are no longer constrained by programmatic relationship with the sun and sky. Our electrical light sources are easier to control than daylight and can provide more intense illuminance on a user defined schedule. Theoretically, these capabilities allow fantastic innovations in which sensitively designed lighting fulfils every occupant's needs. The reality has been more prosaic .

Day lighting is an attractive energy conversation strategy for office buildings with their high levels of daytime occupancy and common reliance on electrical lighting. Designers are also rediscovering the qualitative implications of day lighting. Our current generation of architects has always followed building practices that emphasize mechanistic solutions to the physical aspects of building performance. Attempts to break this pattern in the lighting of building must contend with a scarcity of useful information on several fronts. Our collective lack of experience in day lighting is manifest in the difficulty of finding buildings to serve as exemplars or careful demonstration of the few contemporary examples that do exist. In short, there is a pressing need for the development of methods, data and documented examples in support of the new efforts in day lighting design .

As contemporary designers consider the use of daylight, they are faced with a formidable set of challenges. They seek to control a powerful force using skills fundamental to previous generations.

By considering the above background, this study is going to emphasize whether the use of daylight can pave the way for decreasing the use of energy as far as architecture is concerned.

THE HISTORY OF THE USE OF NATURAL LIGHT IN IRAN'S ARCHITECTURE

Knowing the trend of the sun light use is essential like the size of the materials formation trend and different types of building infrastructure for designing. The first history which we know about it was related to the third century of the fourth millennium B.C. which at that time, making a level difference in the external walls was used for acquisition of light and shadow. In the burned city, in the third and second millennium B.C., it can be concluded from the wall to the roof of the left ruined house that each room was connected to the outside through a door and had no windows. In Elamite era around 1300 and 1400 B.C., a sample of glass windows is also obtained which involves tubes of glass paste and occurred beside each other within a frame and certainly was used to illuminate the building interior. Among the oldest documents and windows and doors examples in Iranian architecture, it may be found in the material castle feature in the works of the Sharoukin era.

Holes made on towers can be found from Assyrian reliefs. In Achaemenid dynasty, the door status is clear and most rounded heels remain in Persepolis. Also, there were holes and glass windows at the top of the doors and even the roof of these Palaces; otherwise, how it sheds light such a great and close space by a few pairs of doors that have often been closed?

One of the principles of Persian style properties is building awnings and reasonable and necessary visor for buildings. At that time, level difference rule was used for light absorption into the space. According to the research done by Professor Volfgang, it was found that the deviation angles of monuments of Persepolis is based on the foundation that determination of the first day of year and any season is possible by created different lighting and darkness and this deviation led Iranian architect to build places for living in such a way that every house gets enough amount of sun and light in each season. There is little information about Parthian buildings skylight but Sir Percy Sikes says about Hatra palace like this:

"The halls were all set with wooden roof. Halls height was various and light was obtained by the arc, which was open to the east. According to reconstructed image of the Nesa, skylight was based on the roof truss and this may prove that the Parthians were using this method to skylight"

Sasanians have tended to show the contrast between shadow and light and this is evident in their buildings. The tips of the four arched openings dome have changed into holes because they needed them to have a fire. Karkheh Terrace in Khuzestan shows the way of light absorption in a room for the first time. However, in beat arched buildings, usually providing the light is on the shoulder of those parts that have a flat roof.

Using method of the cradle arch - a Sassanid-era building arch-allowed the architect to embed a window between the distance the two arch and to provide the illumination. As it was mentioned before, the way of light absorption by cup home skylight, after the great Achaemenid dynasty was changed into a tradition. In Sassanid era, the use of dome was accepted in normal range and was a feature of this architecture. There were pores with holes in the dome which they were probably covered with glass. Since Sasanian used carrier walls for load-bearing dome, building light was supplied by a hole in the middle of a dome or pores embedded on it. But, when the domed roof arches were carried on pier, some skylights like crescent could be built in some parts of dome body.

The benefits of natural light use: There are many reasons that necessitate most use of natural light. Comfort and safety, economizing and energy saving, no disturbances on the basis of environmental impact due to the minimal use of fossil fuels and the result of that release greenhouse gases into the atmosphere are strong reasons to use natural light (Heydari, 2009).

The utilization ways of natural light: Natural light comes into confined spaces through openers. Windows are in a variety of made-to-market but in the choice of size and shape, less care and attention is paid on the amount of light that passes**.** Aesthetic aspects and particularly visual feature of frontage is important for designers**.** Even if we consider window as a source of energy consumption, the role of heat will get the main issue. The argument here is that we should not consider only these two aspects. Others aspects should also taken into account. According to Heydari (2009), due to the closed internal spaces, lighting is important (p.48). The most rational use of natural light is using windows due to compliance of other problems**.** Windows can be installed on one or more sides of the cube space. Most of the windows are used on one side or maximum on two sides. The architect designs window from a special point of view. Frank Loyd Wright was interested in overall windows which fulfilled one aspect of the space completely. Robert Venturi, sometimes designed a floor plan of the building with four-side glassed. Renaissance architects had shown their interests in more small decorated windows. In the past, Iranian architects were smarter than those in other countries because they designed window according to climate.

According to energy consumption and regardless of other aspects, window size must be controlled. Large windows are good in light capabilities but from the heat transmission point of view, it may make the serious problems in buildings. In any case, the use of windows is important for natural lighting. Designer and underwriter are trying to get size aspects for windows to minimize the use of artificial lighting beside each other. In a study conducted in the Netherlands and Germany, more than 80 percent of people working in offices, are willing to sit down and place their tables next to the window. This confirms the fact that the staff prefers working under natural light instead of artificial light. Although there are things that should be considered, the need to create a window with various people from climate to climate is absolutely different (Heydari, 2009).

CEILING SKYLIGHTS

Ceiling skylights are great tools to receive and collect large amounts of light from small openings**.** Even under overcast skies, the brightness ratio of the horizontal roof surface is several times more than the amount that reaches the surface of the vertical window. Roof skylights are effective tools for bring daylight deep into the interior spaces of one-floor buildings and the upper floors of multi-storey buildings**.** They can be used even in multi-storey buildings for the use of daylight in the lower classes**,** through the use of Planium and high wells and reflecting tools although economic conditions in these designs should be taken into account.

Ceiling skylights can be approximately constructed in different sizes and shapes for each specific design. Materials used in those skylights can be clear glass, patterned glass, translucent glass, or various types of plastic, while the performance of ceiling skylights is the same by considering different types and materials used in them. The most common type is plastic domed ceiling skylight which is usually created by one or two plastic vacuumed walls of acrylic and get the dome form and is contained in an aluminum frame. These types of roof skylights are relatively inexpensive, easy to install, anti-precipitation and durable.

Acrylic plastics may be clear, gray, white, smoked or translucent**.** Acrylic plastics have very good vision like glass. They are relatively easy to maintain and lasts 20 to 30 years**.** Some ceiling skylights are dome-shaped, non-transparent and are made by reinforced fiberglass with polyester which are capable of light emission**.** This type of plastic is cheaper but over time the cover will be damaged and must be replaced.

Daylight can be controlled through ceiling skylights by light wells **(**raise skylight from the roof by building a vertical or diagonal wall) and louvers and with the destruction of the low vision Dome, the problem of reflection dazzling will be minimized**.** The use of plastic and non-transparent glass in ceiling skylights for the purpose of decreasing the outside sight cuts off biological benefits of natural daylight.

The use of non-transparent material does not seem very logical. Glass and clear plastic which allowed the direct influence of the sun rays through the ceiling skylight has a proper application**,** but to prevent visual impairment in interior space controlling, light tools should be used simultaneously.

Transparent glass or plastic ceiling skylights cause more heat inside space in comparison with non-translucent skylights due to the radiation energy specifications per specific unit of lighting at work level**.** An outer shield that prevents direct sunlight on the ceiling skylight and allows daylight penetration only through the sky can be used for reducing the thermal load.

Double domes (involve two plastic layers with the air between the space) are recommended as a means to reduce heat loss in cold areas. Double dome has less energy in tropical region which radiant heat gain is more than conductive heat loss.

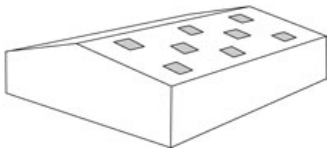
The positive point of ceiling skylights is energy consumption reduction, since there is less need to

electrical lighting by the entry of natural daylight. Also, solar energy gain in winter through ceiling skylights reduces the need of internal heat which is so important.

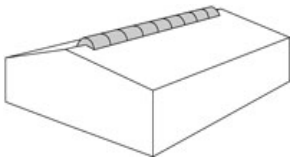
To determine the functions of ceiling skylights from the economic view, analysis in all aspects of climate conditions during all seasons should be taken into account. Proper design of a ceiling skylight (equipped with lighting and heat transfer control system during the day and night) cause good results over years in almost all regions (Owenz, 2000).

Different types of ceiling skylights:

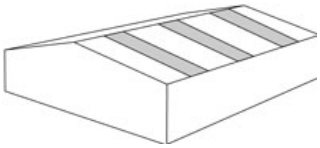
Chess skylights: With optimum light distribution - Most requirements to installation and sealing equipments.



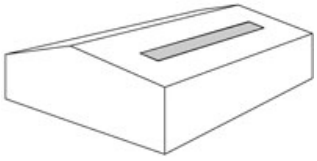
Upper skylight



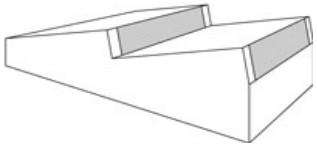
Belt skylights: Proper distribution of light, the minimum required instruments



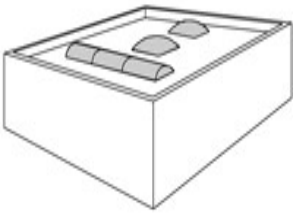
Quasi- belt longitudinal skylights



North-longitudinal skylights: Subsets of Quasi- belt longitudinal skylights



Custom designed skylights



EFFICIENT USE OF NATURAL LIGHT ENERGY

The most effective method of sunlight use is to provide lighting with natural light**.** Even the best incandescent bulb compared to sunlight needs more electricity per square meter to provide certain amount of light and generates greater amount of heat**.** Participation of natural light in every building lighting should also be done to deal with undesirable heat absorption**.**

Optimizing idea for the relationship between shade and directed natural light into the architecture space is possible with new forms. Precast concrete great light crushers, which were set by Renzo Piano in Menil Complex in Houston Texas**,** displayed beautiful manifestation of this newly bugs (Fig. 1).

Another sample is Linz Design Centre in Australia by Thomas *et al*. (1994). In Fig. 2, the system used enables reflecting and neutralizing natural light scattered.

Glass has influenced new medieval architecture strictly. Although the use of this construction material in the 50 and 60 decades of the twentieth century causes some problems, glass is now considered as a guaranteed material with a good performance in solar architecture.

James Carpenter, an architect and designer of glass and light in New York, has used dichroic glass to create optical effects. He has proposed a model for the work in a church, once the viewer is faced with geometric shapes of light, he discovers the importance of this idea. Because this approach does not lead necessarily to optimize the power consumption, it is clear that new methods search are needed for optimizing the use of glass as a building material. Electrochromic glass is an interesting achievement which has been made by adding dynamic properties to a stable material. Electrochromic glass can change to a dull surface by using electrical current for a few seconds. Mike Davis who worked in Richard Rogers Company followed the idea of a fully mobile multi-layered wall which is like a chameleon that can respond to the environment. Mike Davis is a progressive character in new areas discovery of glass technology. Various researches on early samples of multi-skin glazing screens for a research project called Project 218 was one of his various activities.

Fig. 1: Concrete light crusher at Menil complex-Renzo Piano

Fig. 2: Design center Linz in Australia (Thomas *et al*., 1994)

Fig. 3: Lloyd's building in London Richard Rogers Company

Fig. 4: Berlin Reichstag parliament dome skylight

Ventilated cavity wall of Lloyd's of London building outer wall, despite high thermal efficiency is another example in which the stylized natural light is placed into the interior spaces optimally (Fig. 3).

One of the proper areas for study and assessment is reviewing the application of gases, liquids and solids

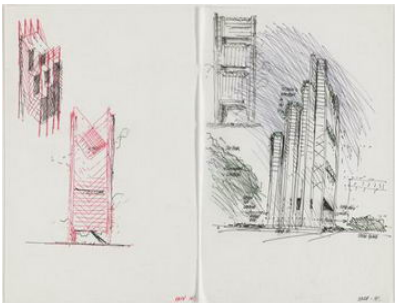


Fig. 5: Conducting light to the lower floors in Hong Kong banks-Sketche (Norman and Partners, 2005)

and even organic matters or materials that can be used between two layers of glass or how to form the glass such as the glass cup is applied in the Lloyd's building of London.

The art of using natural light to create dramatic effects is still one of the issues addressed in architecture. New technologies provide new facilities in this field.

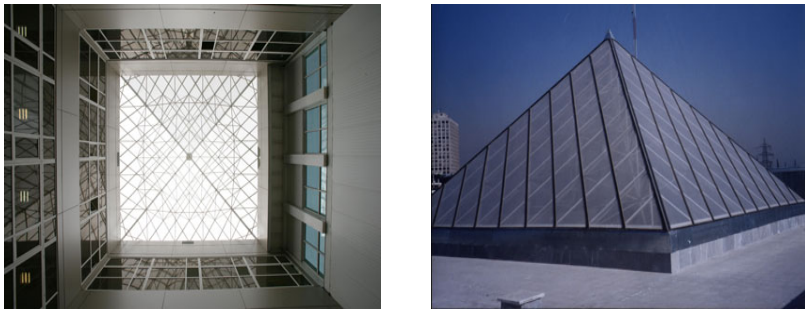
Reichstag building in Berlin is the location of the new Germany's Parliament, which is run by Norman and Partners (2005). The inventive idea for this project about energy issue ended up a construction with exterior appearance above the building with the resulting photoconductivity eventually. This new interpretation of a dome which is the visitors' station**,** reflects natural light to lower part of the building (Assembly) through the hundreds of mirrors forming the middle funnel (Fig. 4).

One of the index components at Foster's office in Hong Kong Bank is natural light supplier atrium in the building. Supply of light in this building has got practicable through light reflection from the surface of two huge mirrors**.** Outdoor sunlight collector screen is composed of hundreds of small mirrors that follow the sunlight track and shine it to the concave mirror on top of the Athrym.

This concave mirror leads light into space and even to the glass bottom floor of the building**.** Norman and Partners (2005) early Askys shows the best way of light led to the underground (Fig. 5).

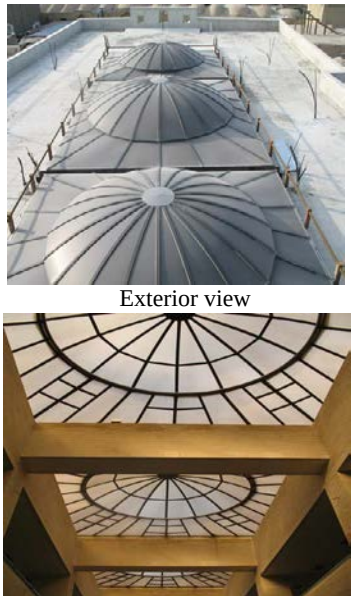
Kimbell Art Museum: This museum is one of the most beautiful buildings in the world which is light-emitted by daylight. Museum Ancient Art lighting has

Kimbell Art Museum Gallery Entrance Hall



Interior view Exterior view

Fig. 6: Arjhantin Shahrvand skylight-Tehran



Exterior view

Interior view

Fig. 7: Carpet museum-Isfahan

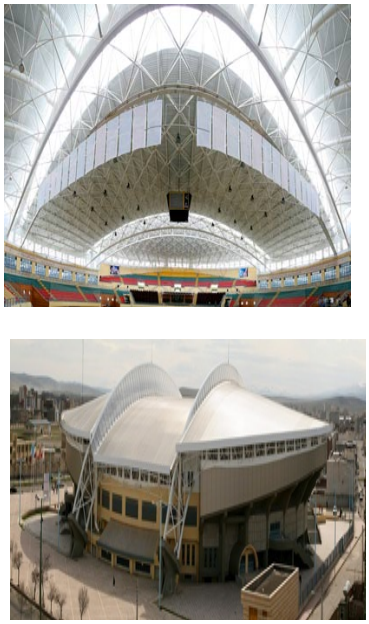


Fig. 8: Reza Zadeh stadium in Adrabil

been associated with great doubts through daylight from the past because ultraviolet rays present in sunlight could have devastating effects especially on paintings. Louis Kahn chose the most modest level of daylight for ambient lighting in Kimbell museum. He expected to satisfy the biological needs by daylight and creates comfortable feeling through knowing information about the time and provide many other states and feelings. This museum is made of a series of circular concrete arches attached to each having 30 meters long and 7 meters wide with a transparent roof skylight along the roof ridges (Owenz, 2000) (Fig. 6 and 7).

RezaZadeh Stadium in Adrabil: In this study, 1600 m^2 sheets of the same transparent polycarbonate having three layers with a thickness of 16 mm was used with sandwich panel (Fig. 8).

CONCLUSION

Based on the performed analysis, we can conclude that the use of artificial light increases the electrical power consumption and the use of daylight decreases energy consumption. Although this issue is important in residential buildings, it is more important in non-residential buildings such as commercial and official ones. However, unfortunately, this issue has been neglected, which itself causes crisis in irreversible energy. Therefore, we should adopt measures to reduce energy consumption in buildings; and in this context, we present the two following recommendations:

- First, we should enhance the general knowledge of people and encourage them not to use artificial light during the day when they do not really need it.
- Second, we should teach future architects how to design optimal use of daylight.

We hope that providing these guidelines will be effective for reducing energy consumption

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