International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Issue 11, Volume 2 (November 2015) www.ijirae.com

Zero Energy Lighting: Sunlight in every room

Vikram Chandra
Civil,NMIMS

Manish Gandhi
Civil,NMIMS

Aumil Mehta
Civil,NMIMS

Abstract— This research study deals with two primary concepts, i.e. Tubular daylighting system & Fibre optics sky lighting system which captures the daylight or sunlight in transparent domes or receivers, and transfers them into the interior spaces where usually natural light is inaccessible, through tubes and cables. The basic assembly implements a dome, tube and a diffuser for the tubular system and a collector, reflectors, lenses and cables for the fibre optic system. An extensive study and detailing involving the same was carried out which includes various suitable products that comprehend the system for maximum benefits. Also case studies were considered to measure the comfortability and functioning of the structure and to calculate the cost variances. Artificial lighting systems anchored to solar panels can also be embedded, making it a dual system for both day and night purposes and hence enabling it to be a 100 % zero-energy lighting system.

Keywords— Introduction, Tubular Daylighting System, Fibre Optics Daylighting System, Conclusion, References

I. INTRODUCTION

Before the electric light was invented, and for a good while after that too, designing buildings so that daylight could enter interior spaces was a necessity. Humans have evolved under high daytime illuminance levels and relatively low night time illuminance levels. Therefore, people are psychologically accustomed to these conditions and will often feel more comfortable under lower light levels at night. Yet despite a long history of using daylighting as a design strategy, building owners, architects, engineers and lighting designers are only just beginning to understand how to use it effectively. When it comes to lighting, it is very well believed that access to daylight is a human right and that daylight is a light source our eyes have evolved to use efficient day lighting which offers sunlight for indoor environments, through innovative systems that captures and directs the rays of the sun. These systems can be broadly classified into:

1. Tubular Daylighting System
2. Fibre Optics Daylighting System

With only a capital investment and no other recurring costs, this kind of system promises to be totally maintenance free. With such systems, innumerable rooms – deep inside buildings, north facing or even underground – can be illuminated with real sunlight which is the most abundant form of renewable energy available.

II. TUBULAR DAYLIGHTING SYSTEM

A tubular daylighting device (TDD), also known as a light tube, is generally installed at the roof level which transmits light to a focused area of the interior. These somewhat resemble recessed ceiling light fixtures when viewed from inside the interior. They allow minimal heat transfer, as opposed to traditional skylights, because they have less surface area. TDDs harvest daylight through a roof-mounted dome with diameters ranging from about 10 inches for residential applications to 22 inches for commercial buildings. It is made from acrylic or polycarbonate, formulated to block ultraviolet rays, the dome captures and redirects light rays into an aluminium tubing system that resembles ductwork. The device that enables this system into functionality can also be known as a lightpipe. Assembly of a lightpipe device can be seen in the following Fig.1

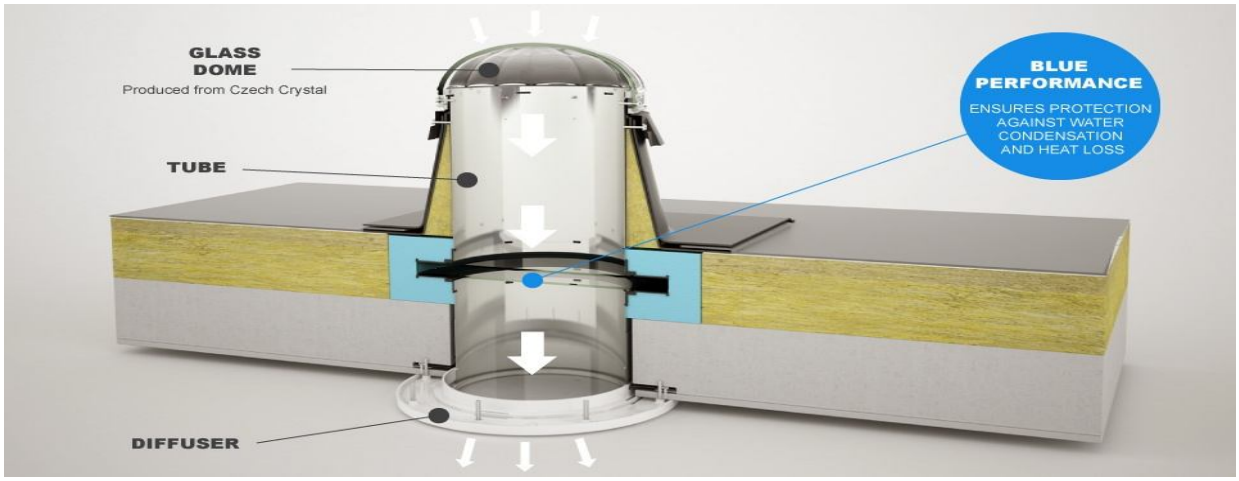

Figure 1

1. *The Dome*

It is on the roof or façade of the building. These light-pipe domes are made of crystal or Plexiglas. Its task is to collect as much light from the sky as possible and send it into the tube. A dome mustn't turn yellow or collect dust. Also it must not alter the colour quality and nature of sunlight even after many years of the light pipe's functioning.

2. *The functionality of the dome*

With light pipes it happens that they aren't capable of delivering enough sunlight even from the very beginning of their service. Then after a few months or years, this is worsened by yellowing of a plastic roof dome, leading to baked-on layers of dust and smog on its surface which rain isn't able to wash away and return the light pipe to a functioning state. That's why it is important to develop a roof dome of crystal or Plexiglas, which restricts the yellowing of the dome.

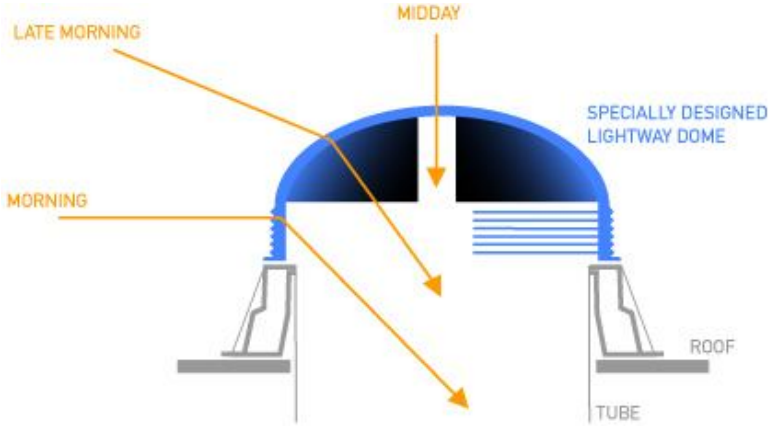

Figure 2

3. *The Tube*

The light pipe tube is a rigid tube which is capable of making turns by using an adjustable elbow. Thanks to its huge directional reflectivity and low decomposition, these pipes manage to deliver sunlight even to a distance of 50 m from the dome. The reflective layer is made of silver and silicon oxides which are fixed by chemical vapour deposition in a vacuum. Its life is around 25 years. The layer mustn't crack or peel or be warped by changes of temperature and humidity. The reflectivity of the tubing will determine how much light we'll get from roof to the ceiling.

4. *The Diffuser*

The light diffuser is in the ceiling or wall of a room. The diffuser's made of sodium-potassium glass or of Plexiglas. It must be ensured that it doesn't distort the given colour of sunlight and mustn't age so that it is continuously allows maximum light outflow. It evenly distributes sunlight across the entire surface of the room.

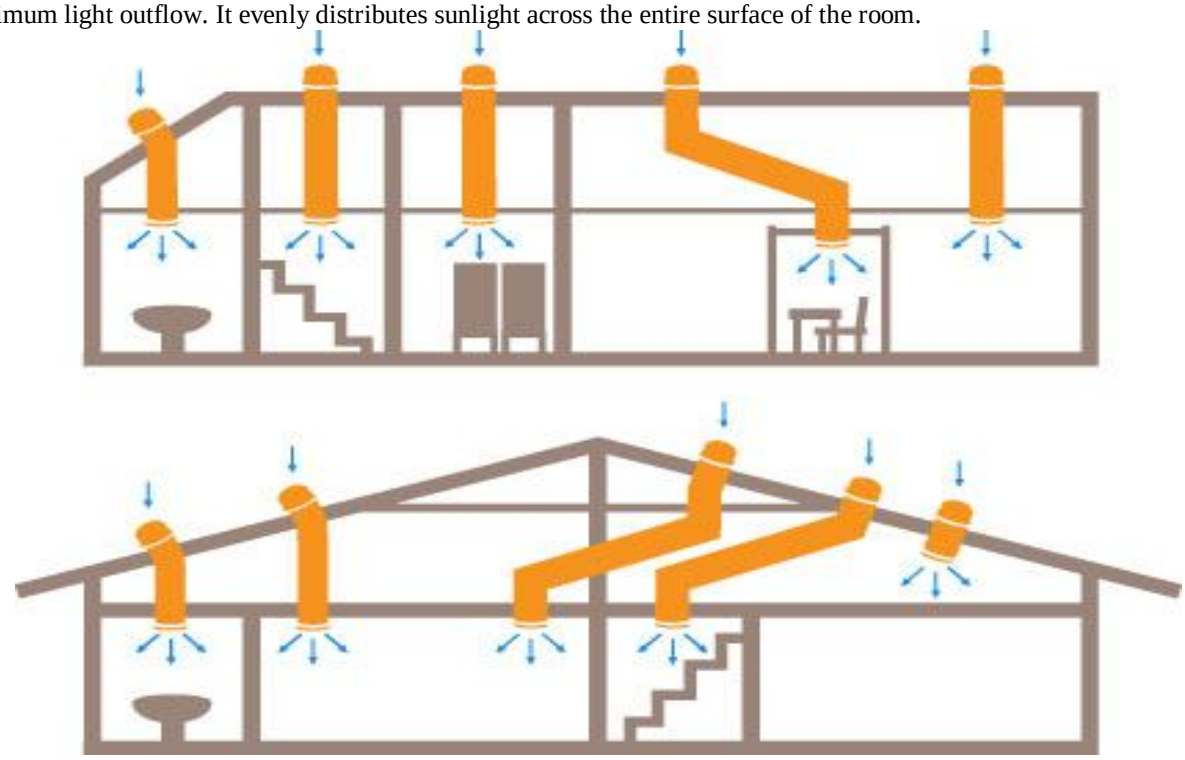

Figure 3

Figure 3 illustrates illumination from the roof to the various rooms. Also in case of urban environment, where the roof is not easily accessible for installation of vertical lightpipe. This system can also be customized into into a horizontal lightpipe system where the sunlight could be transferred from the vertical walls, instead of the roof.

5. *Applications*

Figure 4 - Warehouse

Figure 5 - Office

Figure 6 – Home

Figure 7 – Restaurants/Malls

TDD – Highlights

- The most efficient 10” TDD’s will be approximately as bright as three 100-watt light bulbs (3000-4000 lumens), the 14” TDD will be about as bright as five 100-watt light bulbs(6000-9000 lumens), and the 22” TDD will be like twelve 100-watt light bulbs(13000-21000 lumens).
- Tubular day lighting devices offer many advantages to people and the environment and are an important part of green building design. The most effective TDD’s bring in full spectrum sunlight without the UV rays.
- TDD’s add much less heat to a room than the equivalent amount of electric lights, reducing the cost of air conditioning.
- TDD’s give better illumination and colour rendition.
- Reduction of peak power consumption and dependence on grid irregularities.

III. FIBRE OPTICS DAYLIGHTING SYSTEM

Fibre optic lines, which can be as thin as a piece of human hair, are made of strands of glass that are optically pure. They are used to transmit light signals, and have the ability to carry these signals over long distance. The process of bending a straight line of light is the same technique used to get light through fibre optics. The light is pointed down the core of the cable and makes its way through the cable by continuously reflecting off the interior of the fibre optics. Instead of the mirror used in the tunnel analogy, cladding (which is at least one layer of a material with a low refractive index) is used to reflect the light through the fibre optics cable. This process is known as total internal reflection.

1. *SP3 System*

SP3 is the third generation of the system and can track the sun over the full day, using every hour of sun. Only the visual part of the light spectrum is transported inside - IR and UV radiation are filtered out. That means that much of the heat energy in the solar radiation is blocked and the light does not fade colours and harm materials like UV radiation does. The SP3 consists of a receiver and optical fibre cabling.

2. *Receiver*

The receiver follows the sun over the day to collect its light. Specially designed optical lenses capture and concentrate the optimal amount of sunlight into the cable for immediate transfer to the inside of the building. The system transports the precious sunlight to indoor spaces that would otherwise be impossible to reach.

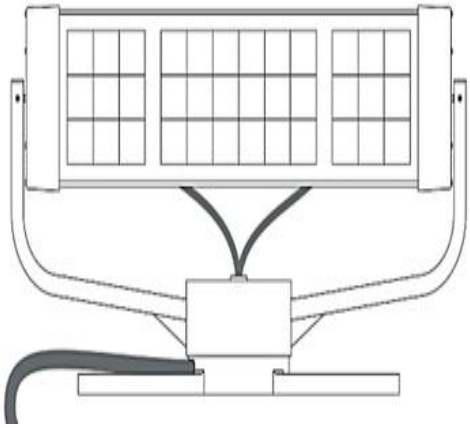

Figure 8

The intelligent system makes the installation simple, as it comes pre-programmed from the factory. On site the unit is fastened, cables are ducted to the inside luminaries, roof and walls are resealed and the system is ready to be powered.

3. Cables

To each receiver, six solar cables are attached. There are four standard lengths at 5, 10, 15 or 20 m – meaning that light can be brought upto two, three, even four floors down. The cables have very good ability to transport light while retaining the full spectrum of sunlight. The cables are thin and flexible, and can transport light both vertically and horizontally, occupying very little space.

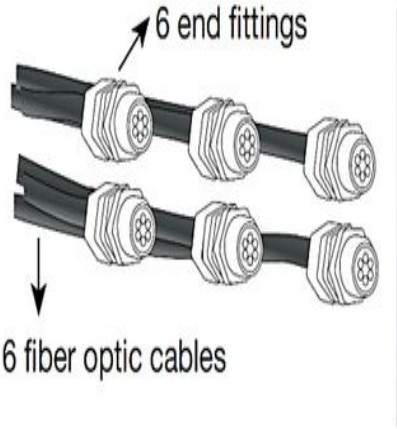

Figure 9

Figure 10

4. Helpers

Mounting Hardware for tin roofs consists of small but sturdy clips are fastened around the folds of the tin roof and make a strong joint without puncturing the roof material. The clip is screwed in place, without drilling, which facilitates the installation. Mounting Hardware for paperboard roofs features a fastening plate that is attached to the roof in a secure way and can then be covered by paperboard in order to seal all punctures to the roof. The receiver can be mounted either directly to the fastening plate, or raised on the extension part.

Figure 11

Figure 12

Table 1- Warehouse with artificial lighting

Total Area	5000 sqft
Total Wattage	5 kW (min. of 1 W / sqft)
Lux levels with 5kW power	Approx. 350-400 Lux
Operating Time	8 Hours
Power usage/day	40 kWh
Effective per Unit Charge	Rs. 7=50 per Unit
Electricity cost for lighting	Rs. 1,09,500=00 / year

Table 2- Warehouse with Light pipe

Total area	5000 sqft
No. of Light Pipes required	11
Lux levels	In the range of 800-1000 Lux Increase of 100% - 150%
Operating time	8 hours
Approx. cost per Light shaft	Rs. 30,000=00 each
Total cost after 80% depreciation in first year	Rs. 3,08,220=00

Table 3- Breakeven point

Electricity cost for artificial Lighting	Rs. 1,09,500=00 / year
Return on investment period	2.81 years

Light Pipe & Sky lighting – Comparison

Figure 13

Figure 14

Without Lightpipe

With Lightpipe

Figure 15 *Figure 16*

The above figures show the difference between lux levels and brightness with respect to same area coverage for an indoor environment.

IV. CONCLUSIONS

In conclusion, its very much evident that daylight is a major light source that is radically underused in modern architecture. It must be believed that a greater consideration of daylight use in the early stages of architectural design would lead to a significant saving in lighting energy. Being energy inefficient doesn't just inflate your monthly utility bill – it could also be the cause of a higher tax burden. An extensive variety of tax incentives are available for businesses interested in improving their energy efficiency, saving a lot of capital. Moreover efficient Daylighting Systems gives better productive and sense of well-being along with proven health benefits.

REFERENCES

[1] Carenegie Mellon University Daylighting Study 2004
[2] California Energy Commission Daylighting and Retail Sales Summary Report October 2003
[3] Dr. Michael Siminovitch Professor, UC Davis, California Lighting Technology Center
[4] Daylighting by optical Fibre, Lulea University of Technology