STUDY AND ANALYSIS OF HORIZONTAL LIGHT PIPE WITH LASER CUT PANEL FOR DAYLIGHTING SYSTEM

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Abstract: The utilization of sun light is exceptionally helpful in office structures and residential building because energy utilization can be decreased and working conditions can be improved. It also influences human beings wellbeing and profitability. In any case, bringing sun light into deep area of office or residential house rooms with simple arrangement of basic windows or sky facing windows is unattainable. To solve this problem light transport framework are important to bring sun light into the profound centres of structures. This paper describes the method for transporting sunlight to deeper areas of building structures. The main motive of this paper is to upgrade the performance of light transporting pipe by simulating individual component as well as whole product and minimizing transmission losses of light. In this paper the daylight is transported through horizontal mirror light pipe (MLP) into darker areas of the structure. Here Laser cut panel (LCP) of acrylic material is used for collection of light.

Keywords: Daylight, Laser cut panel (LCP), Horizontal Mirror light pipe (MLP).

1. Introduction:

In deep plan buildings there is lack of natural light at the centre of structure, due to which the usage of artificial light in deep plan areas are more as compared to outer areas. This problem can be solved by a concept of natural light guiding system. Light guiding system is a physical system which works combine as collecting, transferring and diffusing system. For this purpose, a collecting system is necessary which can be of different types such as anidolic collectors, optical lens, glass domes laser cut panels etc. In 1989 Paul J Littlefair [1]expressed about the sunpipe and its construction. Here the Sunlight is collected by a heliostat on the roof and beamed through lenses to a working space. Heliostats which track, collect and concentrate

sunlight have been used in the past for solar energy applications. Before sending the diffuse light through pipe the light has to be focused by using lens and mirror. Here the structure of light pipes is mentioned which are metal tube, optical fibre, solid acrylic, hollow core. In 1991 Ian R. Edmonds [2] has patented laser cut panels. In his paper fabrication of laser cut panel is explained, where he mentioned that the laser cuts on acrylic plastic by melting and ablation produces highly polished total internal reflecting interfaces with in the material. Connection of the elements may be maintained by leaving a periphery of solid material or by ensuring the laser cuts only part way through the material. Here the focus of the study is on laser cut panel collecting system and mirror light pipe for light guiding system. Here again mirror light pipes can be used in two ways vertical and horizontal. After considering the drawbacks of vertical mirror light pipe, horizontal light pipe is considered as light transferring media. L. Shao [3] has discussed transmittance of sunpipe which is calculated by a formula in which parameters such as reflectance, aspect ratio, angle of incidence is considered. Lightpipe performance has been monitored in the field at four buildings in the UK, chosen as representative of four building types: commercial, residential, education and health. Here we also get to know that transmittance of a lightpipe is critically dependent on the incident light angle, reflectance of surface and aspect ratio and the max reflectance achieved in lightpipe is 95%

2. Optics of Laser Cut Panel:

As shown in figure 1 there is an angular range in that range all the light is diflected.when light incident on outer surface of panel its get refracted and falls on extended inner surface. The inner surface and gets TIRed and exits the ray again by refraction through adjecent vertical suface.

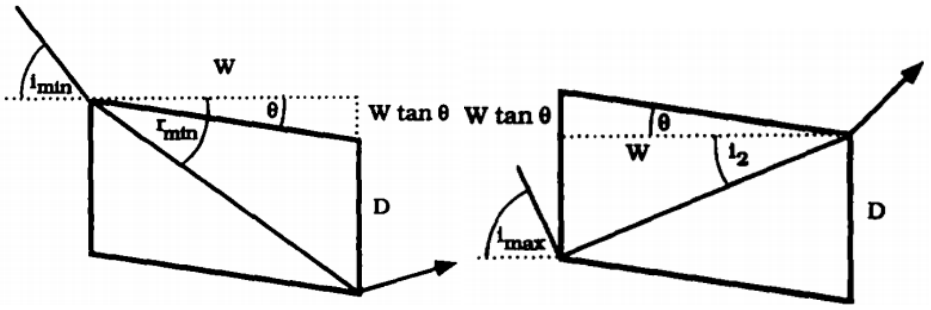

Figure 1: Angular path of Minimum and Maximum
Angle Incident light

For the analysis of ray tracing we used tracepro software. In which we are able to give material properties,type of surface, refractive index etc. so it gives the results in ideal conditions.

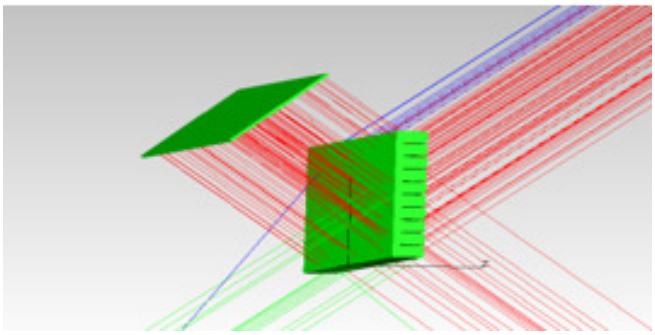

Figure 2: Trace pro simulation of LCP

The figure 2 cleares that the collimated beam of light is majorly devided in two portions i.e. deflected rays which are large number of red rays on right hand side of LCP in upper direction and undeflected rays which approximately follows same path as input collimated beam. The dimension used for this laser cut panel as D=4mm and W=8mm and aspect ratio (D/W)=4/8= 0.5.

Total internal reflection is optical phenomenon in which, two requirements are necessary (a)the light must enter from denser medium to rarer medium (b)the angle of incidence must be greater than critical angle. The critical angle is defined as the angle of incidence that provides an angle of refraction of 90-degrees. For the pair of acrylic and air the critical angle can be determined by Snell's law:

$\sin\theta_1/\sin\theta_2=n_2/n_1$; $\theta_{crit}=42.15^{\circ}$

For effective working of laser cut panel the incident angle of light should be greater than 42.15°.

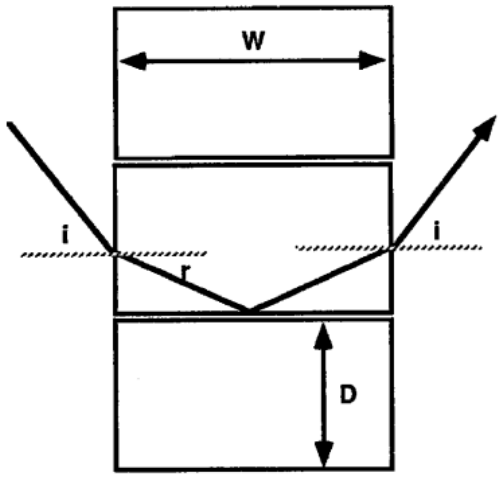

Figure 3: Geometry of laser cut panel [4]

The geometry of cuts is also shown in above figure in which D is distance between the cuts and W is cuts extended from sheet.

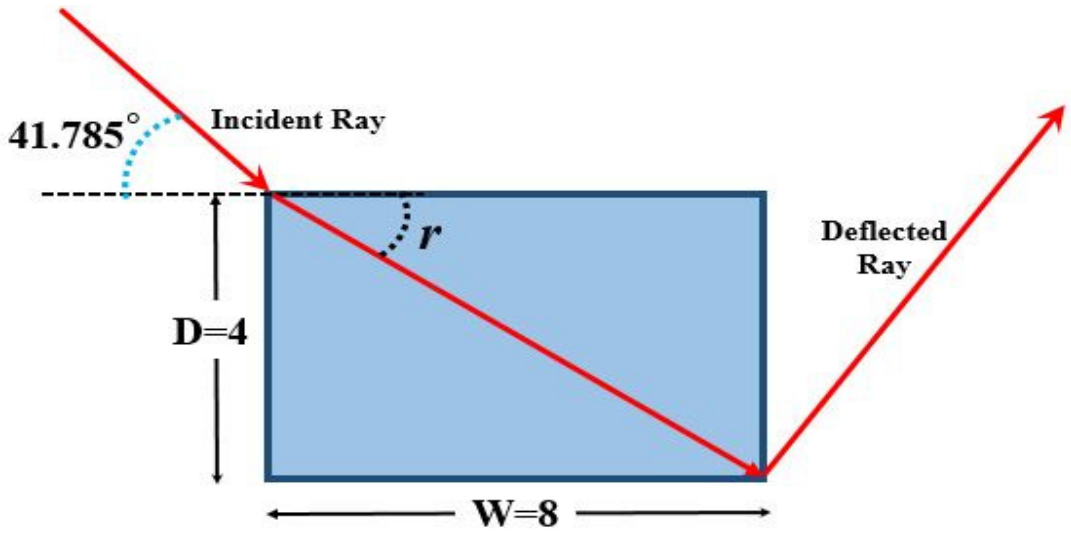

Figure 4: Ray pattern in Simulation

from geometry shown in above figure 3

$$r = \tan^{-1}\left(\frac{D}{W}\right) \qquad \text{Eq}^{n}.\ 1$$

From the above equation 1, "**r**"can be calculated and put the value of (r) in equaton 2

To find the angle at which all the light is deflected,snells law can be used.

$$\frac{\sin i_0}{\sin r} = n \qquad \text{Eq}^{n}.\ 2$$

where n is refractive index of acrylic which is 1.49

$$i_0 = \sin^{-1}(\text{n}\times\text{sinr})$$

From geometrical optics fraction of light deflected can be found for incidence $i > i_{max}$

$$f_d = 2-(W\tan r)/D \qquad \text{Eq}^{n}.\ 3$$

For $i < i_{min}$, the fraction of light deflected is as:

$$F_d = (W\tan r)/D \qquad \text{Eq}^{n}.\ 4$$

To obtain maximum deflected ray output it is found that 41.785˚ and above incident angle gives fraction of deflection 1 which is proved by calculation as well as simulation[4].

3. Methodology:

In this paper various components are design and then simulation is done on the designed components. After simulation, experimentation is carried out on these fabricated design part as a single daylighting system. Various components of daylighting system are discussed below:

I. Collector: Collector is light gathering system which generally takes collimated beam of light and focuses on other side. Laser cut panel is a collector system which is made of acrylic material. acrylic is having refractive index of 1.49. with good transmitivity. Laser cut panel works on the principle of total internal reflection which is demonstrated by fig 1 shown below.

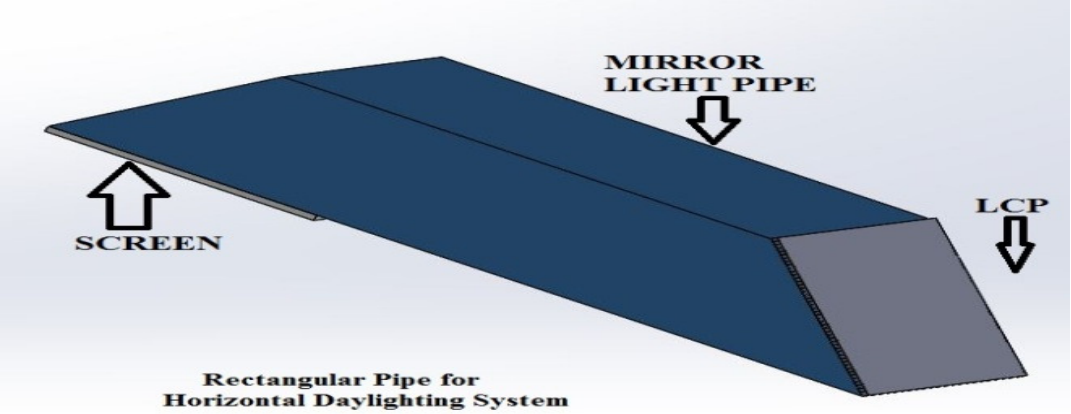

Figure 5: Horizontal Daylighting System with Rectangular Light Pipe

II.Light Pipe: When light incident on any surface either of three phenomenon will be happen i.e. Absorption, reflection and transmission.Light pipe wroks on preniciple of reflection. Light pipe is a light guiding component in which its inner surface is having mirror finsh to transefer light by specular reflection through it.specular refelction is mirror like reflection in which angle of incideance and angle of reflection of single ray is same.

The effectivness of light pipe is primarily depands upon three factors viz,area and geometry of pipe,reflectivity of material,and dirctional property of incoming light rays.from literature survey it is found that new materials are developed such as micro silver and spectralight infinity with reflectivity of 98%. L.O. Beltran [5]has discussed light pipe with their design parameters such as space consumption, geometry and reflectance of pipe. He mentioned four ways of Floor plans of light pipe designs which are (a) base case light pipe, (b) Rectangular section light pipe with central reflectors, (c) Rectangular section light pipe with side reflectors, (d) Trapezoidal section light pipe with side reflectors. These all configurations are related to the horizontal light pipe.

III. Screen: Screen of the model act as a perfect absorber in the simulation process and it may be use as a diffuser in the room. During experimentation luxmeter is used to check the lumens per metre square on the screen.Various types of LCPs:In these LCPs the exact aspect ratio i.e. 0.5 and angle of cut(θ) is (a) 0°, (b) 5° as shown below:

Figure 6: Zero degree LCP

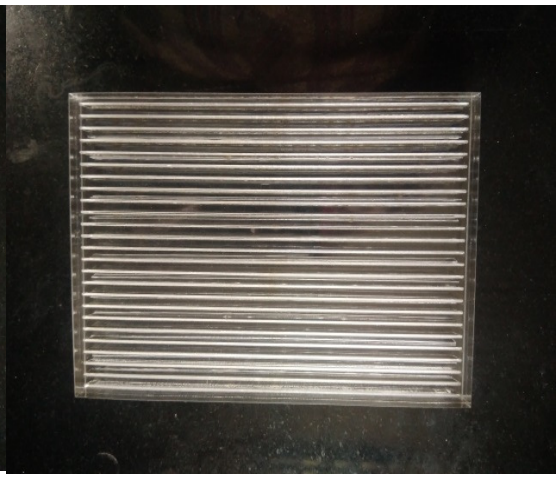

Figure7: 5 degree LCP

For analysis of light rays through mirror finish light pipe a solid work model is created with assembled laser cut panel shown in figure 6,7.This model is then simulated in trace pro with .oml file format.From figure it can be seen that for perticular angular range of source or incident rays the rays change path beacuse of laser cut panel and directly passes through light pipe,due to which we are able to reduce losses due to internal specular refelection.

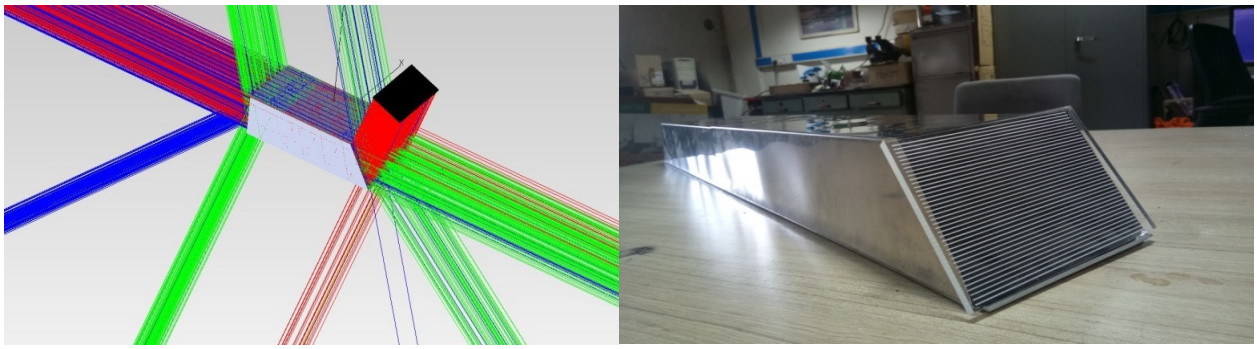

Figure 8: Solid work model and fabricated model of light pipe with LCP

The light rays which are undeflected strikes on the wall of light pipe which is having mirror like surface due to which the rays reflects and travels in forward dirction.Because of striking of light the energy of rays may get absorbed at surface due to which its intesnsity gets reduced and it can be seen as blue colour rays in figure 8.It was observed from the literature survey that the fabrication was done only for 0° LCP not for 5° LCP. However, for throughout good illuminance level in the day is attained from the south façade of the room in both the extreme months i.e. June and December of the year. Therefore, 5 Degree LCP was the appropriate for good illuminance. So only for South façade with five Degree LCP is selected for simulation, fabrication and experimentation. To evaluate the performance of lightpipe a prototype of living area is modeled in design package is simulated with Tracepro along with 5° LCP toward south direction. The results obtained from simulations are compared with experimentation data for standard requirement of light.

Figure 9: Experimental setup

Now the Prototype model is simulated in the tracepro software and the simulated data is compared with the experimental data. The simulation is done between 7:00 am to 7:00 pm in the month of June for each consecutive hour. Simulated Data is than compared with the experimental data to check the performance of the passive daylighting system. To identify performance of system in real world it is necessary to test on a prototype. Number of combinations used to optimize the system is possible only in virtual environment but the optimized results are how much closer to actual values are able to evaluate by prototype. The simulated data obtained from tracepro software is now compared with the experimental data as shown below.

Table 1: Simulated Data versus Experimental Data

Time (Hour)	Simulated Data (Lux)	Experimental Data (Lux)
07:00	52.68	41.32
08:00	168.18	101.601
09:00	396.894	294.862
10:00	742.122	618.25

11:00	890.996	768.234
12:00	913.658	826.23
13:00	768.788	698.1
14:00	643.916	581.54
15:00	404.718	323.15
16:00	175.348	129.47
17:00	131.339	98.023
18:00	70.007	62.89
19:00	30.235	24.158

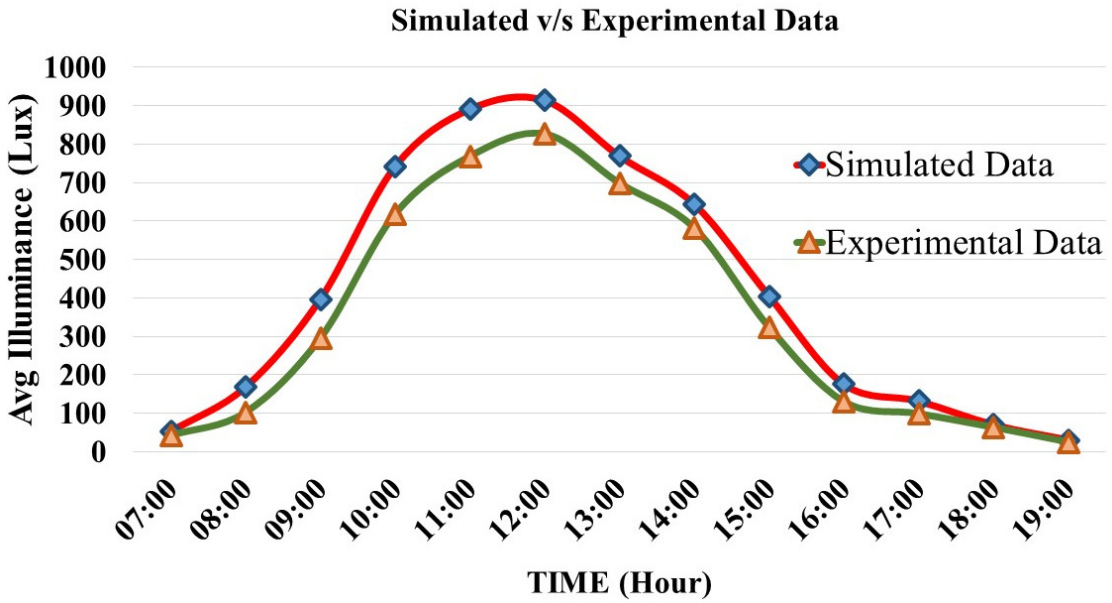

Figure 10: Simulated data versus Experimental data

After comparing the simulated data with the experimental data of the prototype model, it is clear that simulated data is approximately near the experimental data. However, there is 16% lag between the simulated and experimental data. This lag is due various reasons like white paper is used in experimentation instead of white paint, climate condition, little scratches on the surface of Horizontal mirrored light pipe etc.

4. Conclusion:

From above simulation and experimentation, we can conclude that for range of incident light the loss in light transmission is possible to minimize.The ability of laser cut panel to deflect light with minimum loss through it, is very useful to obtain good results then a traditional glass window. Conjunction of laser cut panel with horizontal mirror light pipecan be used for buildings having flat roofs.

5. References:

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