

## Study and Analysis of Laser Cut Panel

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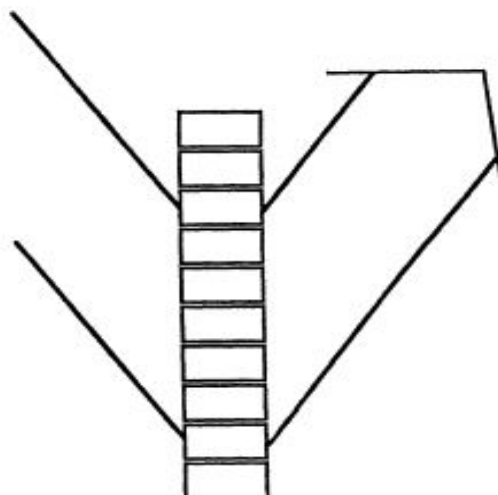
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**Abstract:** Bringing sun light into deep area of office or residential house rooms with simple arrangement of basic windows or sky facing windows is unattainable. To solve this problem light transport framework are important to bring sun light into the profound centres of structures. The main motive of this paper is to upgrade the performance of light transporting media (Horizontal transporting system) and Laser cut panel (LCP) as collector by simulation and study the performance of the various types of LCPs in which cuts are to be made on different angles( $\theta$ ) i.e.  $0^\circ, 5^\circ, 7^\circ, 8^\circ$  and compare the performance of various LCPs of acrylic for South and East façade of the building in CSIO Chandigarh. It is cleared from the simulation that LCPs are location specific and its performance is depending upon the angle of cut ( $\theta$ ), aspect ratio(A), Refractive index.

**Keywords:** Laser Cut Panel(LCP), Mirrored Light Pipe (MLP), Total Internal Reflection (TIR), Aspect Ratio (A).

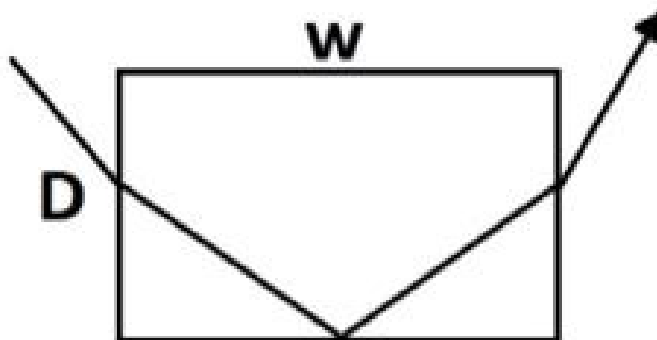
**1. Introduction:** In daylight system collector, horizontal sunlight pipe, and diffuser is used. The natural light provides us great benefits like highly effects on psychological response of human body such as vitamin D synthesis. If a daylight system is developed which can bring the sunlight deep into the rooms like in offices, houses and other commercial buildings which can reduce energy consumption inside buildings (less electricity used, reduced heating effect, and reduced greenhouse effect). The main motive of this work is to improve the performance of the laser cut panel(collector) so that more light can come deep into the rooms. As daylight system is to be installed in very small area so its performance must be high so that enough light can come deep into buildings. So Laser Cut Panel (LCP) is used as a collector in daylighting system. LCP is a light deflecting panel in which transparent rectangular parallelepiped elements are stacked one above the other in a series or array.



**Figure 1: Light Deflecting Panel (LCP) produced by making precise laser cuts in the clear acrylic sheet.**

Formation of LCP with this method is quite laborious. Laser cutting machine is used to make fine cuts in the clear acrylic panel by melting and ablation which produces highly polished internal surfaces which is desirable for total internal reflection. Paul J Littlefair [1] This paper expressed about the various daylighting system and their relative advantages, disadvantages and desired design guidelines. Various innovative daylighting systems like light pipe, Mirror system, prismatic panel, light shelves. Ian R. Edmonds[2]discussed in this paper the fabrication of LCP is done by the laser cuts on acrylic plastic by melting and ablation and produces highly polished total internal reflecting interfaces with in the material. There is periphery on the acrylic plastic sheet in between there are laser cut of insignificant width, the periphery act as a connections of array of transparent rectangular elements. I R Edmonds et al.[3]In this paper the author compared the performance of a MLP and MLP combined with LCP daylighting system. The main aim of author is to reveal theoretically and practically that the combine form of MLP and LCP improve the illumination performance for various angle of elevation below around  $60^\circ$ . Veronica Garcia Hansen at el. [4]expresses the benefit of daylight technology mainly in hollow mirrored light pipes coupled with LCP collectors to enhance the natural illumination of the deep office buildings. Light pipes are processed by testing of two scale models of the buildings, one along with horizontal and the other with the vertical light pipes as daylight devices.

In this paper work is done on a collector. Laser Cut Panel (LCP) is used as a collector having dimensions of 502 \* 612 \* 8 mm (prototype model) and aspect ratio of 0.5 and cuts of different angle i.e. 0°, 5°, 7°, 8° are drawn into it. Separation-to-thickness ratio or aspect ratio is the ratio between height(D) and width (W) of the transparent rectangular parallelepiped.



**Figure 2: Aspect Ratio**

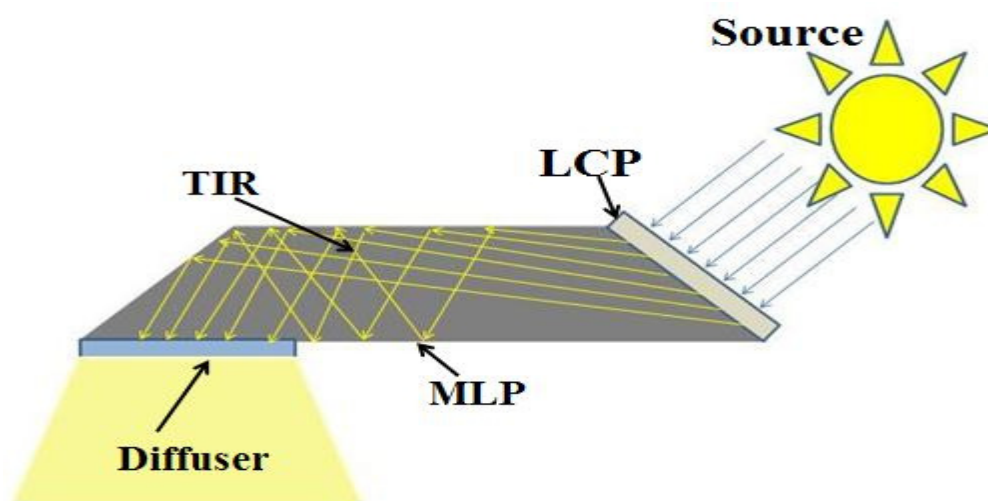
Aspect Ratio also play an important role in the designing of the LCP, it also defines the path of the ray from the entrance to the exit of the panel. LCP is mainly works on the concept of Total Internal Reflection (TIR) as shown in the figure above. So in this paper the main focus is on collector which are installed in the passive type daylight system. Collector is device which gathers the light and focuses in a particular direction in particular manner.

Most of the collector used for light guiding systems is made up of transparent material such as Clear Acrylic, Glass, Polycarbonate etc. In this proposed paper LCP as a collector is used. LCP is a simple optical material that due to its light directing properties can improve daylight collections for mirror light pipe. LCPs is a transparent acrylic sheet and forming a series of parallel cut in this sheet of acrylic with a Laser Cutting Machine. A laser cut panel can be fabricated using laser cutting machine and CNC laser cutting machine. Different types of LCPs are developed at various cut angle i.e. ( $\theta$ ). From the paper of Ian R. Edmonds [2] various calculation is derived and final results are used to improve the efficiency of LCP.

In 1993 I.R Edmonds[2] discussed that LCPs cuts at zero degree has less performance than those which cut at 7 degree. In this paper the simulation is done on the LCPs having angle of cut ( $\theta$ ) i.e. 0°, 5°, 7°, 8° and compare them with simple acrylic sheet. when a sunlight passes from LCP, it redirects the light. It follows the principle of Snell's laws when light incident on outer surface of panel, it gets refracted and falls on extended inner surface. On the inner

extended surface, the light is Totally Internally Reflected and exits the ray again by refraction through adjacent pattern of surfaces.

**2. Working Principle:** The following figure illustrates the phenomenon behind the working of the LCP. In which there is a smart use of Total Internal Reflection and Snell's law. Collector (LCP) 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 having refractive index of 1.49. When light incident on any surface either of three phenomenon will be happen i.e. Absorption, reflection and transmission [5]. Light pipe works on principle of reflection. Light pipe is a light guiding component in which its inner surface is having mirror finish to transfer light by specular reflection through it. Specular reflection is mirror like reflection in which angle of incidence and angle of reflection of single ray is same. 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.



**Figure 3: Working of LCP**

**3. Methodology:** In 1993 Ian Edmond [2] explain in his paper that reveals that the deflected light is spread to some conditions that was tested on a scale model room provided with a luxmeter to measure illumination levels and tells in a graph that the aspect ratio 0.5 provide good performance.

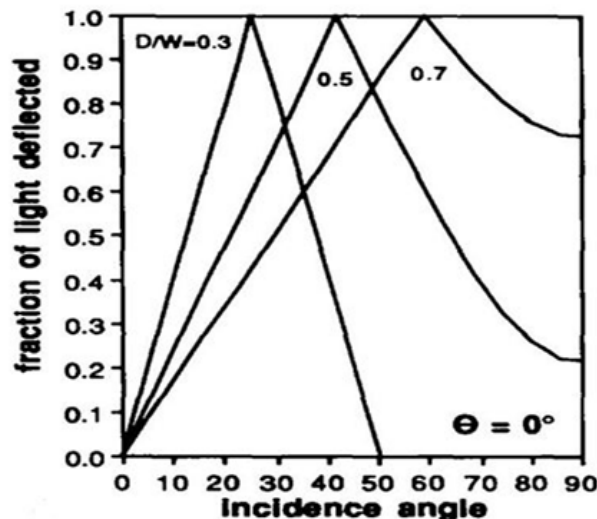


Figure 4: Fraction of light deflected Vs incident angle

So according to Edmonds study some aspect ratio are simulated on solar emulator in TracePro for the location of CSIO Chandigarh, India and following graph are obtained.

Now the main point is that we are investing fabrication cost on cuts of acrylic sheet by laser cutting i.e. LCP grooves. Either it provides good results than the plain acrylic sheet or not. So a comparison of LCP (D/W= 0.5) with plain acrylic sheet are shown in the following graph.

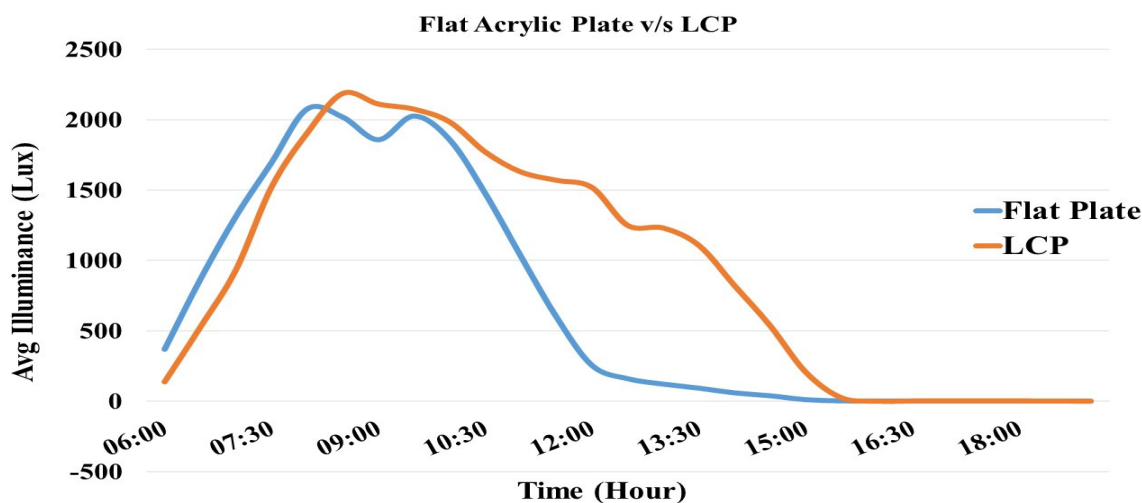


Figure 5: Flat Acrylic Plate Vs LCP

Now after comparing the LCP with the Plain Acrylic sheet it clearly shown in the graph that the LCP possesses good light throughout the day. After this with the common aspect ratio i.e. 0.5, different LCPs are designed for different angle ( $0^\circ, 5^\circ, 7^\circ, 8^\circ$ ) which are suitable for

different facade either North, South, East and West. But according to my objective my main focus is towards South and East facade. Because the room for which the LCPs are designed having facade towards South and East. So simulation is done for these two directions. For East facade the various LCPs are designed at  $0^{\circ}$ ,  $5^{\circ}$ ,  $7^{\circ}$ ,  $8^{\circ}$  angles and their relative comparison are done on the solar emulator in Tracepro software which gives value for a particular day in the month of June and December.

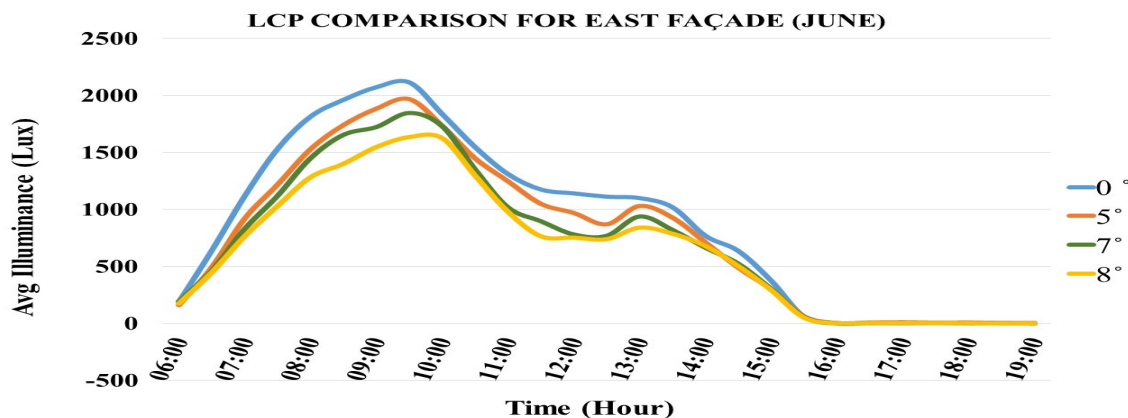


Figure 6: LCPs comparison for East Façade (June)

In the above LCPs comparison graph for East façade in the month of June, it is shown that in east façade zero degree LCPs possesses good results among others. Now for South facade the various LCPs are designed at  $0^{\circ}$ ,  $5^{\circ}$ ,  $7^{\circ}$ ,  $8^{\circ}$  angles and their relative comparison are done on the solar emulator in Tracepro software which gives value for a particular day in the month June of the year.

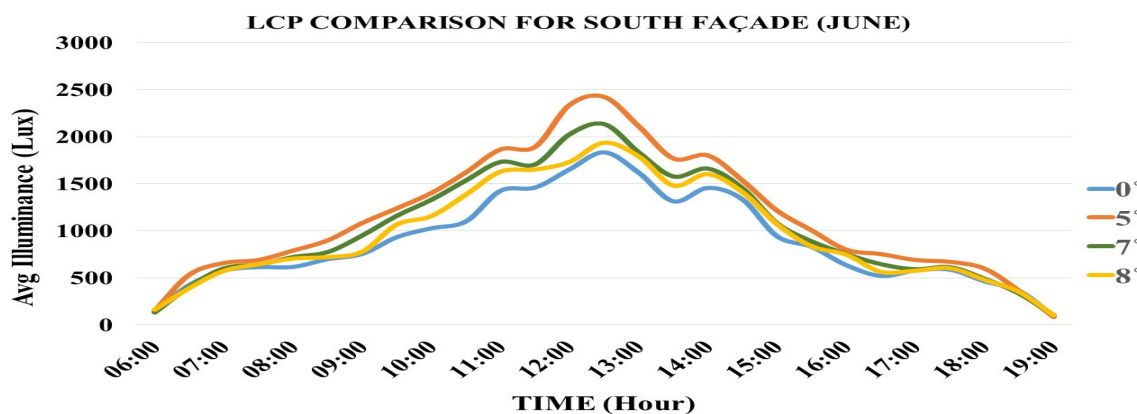


Figure 7: LCPs comparison for South Façade (June)



In the above LCPs comparison graph for South façade in the month of June, it is shown that in South facade 5 degree LCPs possesses good results but in the middle portion of the day i.e. from 11:00am to 2:00pm.

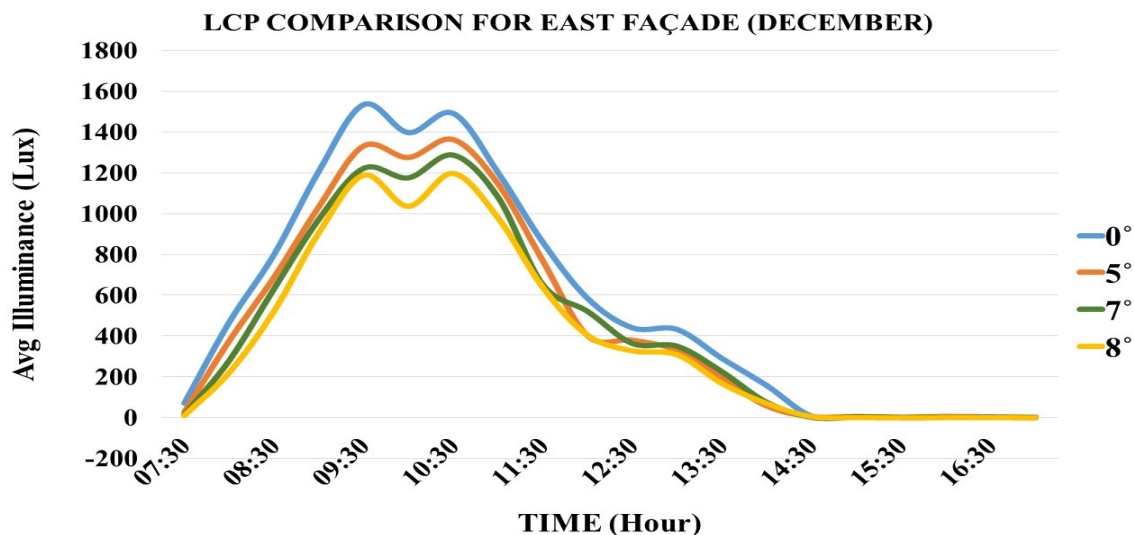


Figure 8: LCPs comparison for East Façade (December)

In the above figure performance of LCPs for December is analysis in which zero degree LCP possesses good results as shown.

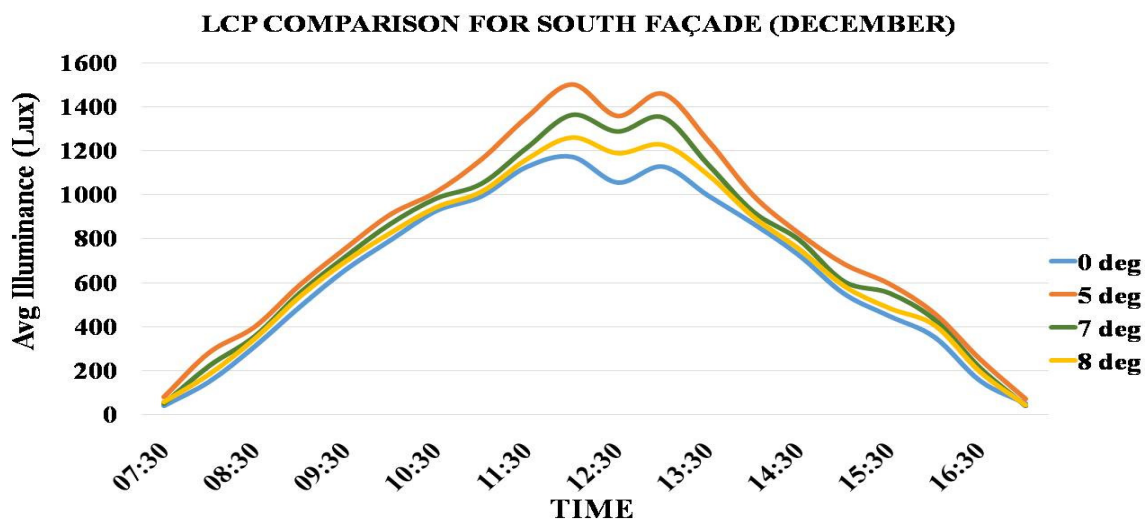


Figure 9: LCPs comparison for South Façade (December)

In the above figure performance of LCPs for December is analysis in which 5 degree LCP possesses good results as shown. After the simulation process it is clear that 0° LCP is

preferred for east facade and 5° LCP is preferred for the north facade of the room which is situated in CSIO Chandigarh, India.

**4. Conclusion:** As we can see from the simulation by Solar Emulator on a particular day of month June and December on different LCPs (adjacent vertical pattern LCPs and adjacent tilted(angle) pattern LCPs) i.e. 0°,5°,7°,8°. LCPs are location specific i.e. for a particular direction a particular LCPs work efficiently. The performance of the various LCPs is depending upon some parameters which are Aspect Ratio, Refractive Index of the material which is to be used, Sun elevation, Refractive Index of the Mirrored Light Pipe, smoothness of internal cuts or slots during laser cutting which effect performance of the LCPs, Width of the cut etc. After the simulation process it is clear that 0° LCP is preferred for east façade and 5° LCP is preferred for the South/North façade of the room which is situated in CSIO Chandigarh, India. So after conclusion and keeping in mind the various parameters we have design the LCPs for East façade (0 degree) and South façade (5 degree) for the room in CSIO Chandigarh, INDIA.

#### 5. References:

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