Studying natural lightning in a hot climate

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ABSTRACT

This paper is aimed to present the analysis made over scale models for a calid climate region on simulated conditions (heliodon, wind tunnel). We analyzed different settings of windows areas proportions, shading devices, and materials at global building designs.

The objective of this research was to consider the architecture user as the main element of the lightning design, preserving his quality of life as a member of a society, and offering an integral comfort where he can perform his visual activities.

Until recently, natural lightning in calid climate received attention due to the rising of electric energy costs. The situation behind this statement is that there are very few clouded days over the year and that during daytime thousands of workers turn on artificial lights at their job place.

According to the evolution of sciences and technologies there is dissociation between building practices and real conditions in natural lightning.

1. INTRODUCTION

In ancient civilizations, and for natural lightning significance in zones considered as tropics, the architecture has been taken into account for dwelling construction. In technical aspects of contemporary architecture, this theme is of comparatively recent origin. On these days and due to the rates increase of energy consumption, the energetic savings idea tends to be at first order.

It is incongruent that currently at daytime working hours, thousand of offices and schools turn on the lights to be lighted up artificially. The great amount of sunny hours yearly that many of the Mexican great urban centers have, allows to omit any electric lightning device in normal working hours, with the simple architectonic elements setting for its proper luminous design and with a minimum investment that in most cases is recoverable.

Lightning Considerations

As a general rule, all constructions standards dealing with the natural lightning theme agree when affirming that the interior lightning level depends directly from the external lightning level. It is under this elemental principle that the interpretation of the sky visible portion from the vault of heaven total through the window is based to. This same amount of sky at a altitude different on the horizon has a quite different luminosity.

2. DAYLIGHT FACTOR

In accordance with proposal submitted by the "Commission Internationale de l'Eclairage" (1955) on "standard cloudy sky" model known as CIE, work is performed with Daylight Factor (DLF), the relationship expressed among the lightning gotten simultaneously within a space of external total and under a sky without obstacles and cloudy uniformly. In other words, of indirect natural lightning (Mur, 1982).

Reference is made by the English Standard concerning DLF required conditions for inner areas. Under normal conditions, DLF index may be acceptable up to a 5 Mt distance from a window. In case that some obstacles are present at external areas, reduction of said index would be

quite significant.

If said obstruction was present prior to the new construction, solutions possibilities would be reduced if instruments needed to control it are not available. The only viable alternative would be reducing the room rear or artificial lightning systems indiscriminate use even in the sunniest months of the year.

To solve this problem, the research development was based on the fact that "Lightning enough can be gotten through an open space between two blocks of an unlimited height and above a fixed altitude on the horizon of a determined amplitude §" (Mur, 1982). In a word, the lightning provided by a window comes from a "slice" of the sky, with fixed amplitude and height.

These orientation criteria, obstacles, window proportion, are not referred to any particular orientation exclusively and are based at the sky covered, without any recommendation to use a specific analysis method.

In Mexico particularly, there are just a few references at a standard level about the lightning conditions that must be taken in consideration in habitable areas. Following this consideration, it was made a research project named "Pilot Project Upon Energy Savings in Educational & Administrative Spaces" in 1998, sponsored by the Science & Technology National Council, proposing a new photographic method of luminous analysis in architectonic spaces.

2.1 Photographic Method

This photographic method was originally proposed by Victor Olgyay (1953) for weather analysis. It was developed to study the sun apparent movement and obstructions present at the horizon, which is the last view in outer boundary. These obstructions will always be reflected, with exceptions in extreme cases as the classic sample of the lent on the upper part of the mast of a vessel at open sea.

For a proper analysis effects, obstructions are no removable objects or blocks that cannot be modified. In architectonic design. It must be taken into account this consideration to modify the sky quantity that may be seen through a window if available a control device at window’s upper portion of sky to protect it against the sun radiation and preventing an intern overheating due to the sun radiation increase present at latitudes closed to tropics.

In this kind of photographs, the horizon interpretation is seen as the last line out of the circle. At the same time, the vault of heaven is obstructed by surroundings buildings. In an initial analysis it can be confirmed that buildings may be interpreted as shady masks on an observation point if photographs were taken during the sun cycle.

2.2 Stereo-graphic Projection

In this type of projection, angle measures gotten when having deformations allow the use of a constant promoting that the projected points are readily measured (Gomez, 1998).

For this method to be applied it is needed its implementation with respect to a stereo-graphic projection type. This is an effective design tool that allows knowing geometric characteristics of apparent sun movement in any place of earth as any movement and hour of the year. Geometrical characteristics above mentioned can be divided basically in 2 types:

- SOLAR HEIGHT (h). Defined as the angle formed by the solar ray and its projection on a horizontal stabilizer.
- SOLAR AZIMUTH (a). Which is the angle of horizontal deviation, formed by the solar ray projection and its intersection with the meridional plane (line NORTH-SOUTH), measured clockwise, of a bearing from a standard direction, as from north to south, indistinctly.

For the conic projection of any body on a plane, a point in the space should be elected. This point is the projection center also known as focus or vanishing point. From each point forming the body, visuals or convergent projections are drawn to the projection center, inserting them on above mentioned plane. Resulting intersections are the body projection on plane.

Similar as Architecture, stereo-graphic projection implies geometrical positions in space. This is the reason to insist in its usefulness for a proper environmental design.

To study natural lightning conditions available, it is required to know the obstruction level at the visible vault of heave. Sun position at sky can be determined by the altitude angle (vertical angle on the horizon) and its azimuth angle (horizontal azimuth, East or West, with respect

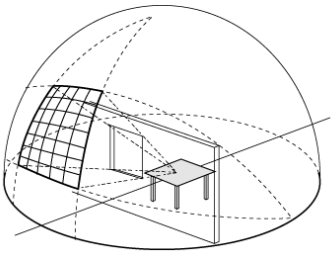

Figure 1: Sky portions with same lightning power from a point of work plane.

to South).

Azimuth angles and solar height are in function of the latitude referred to as well as the day of the year and the solar hour thereof.

It must be noted (since this can be confused), that the sun movement study is denominated under the "apparent" term. It is known that solar projections are caused by the rotation and translation movements of the earth surrounding the sun.

These sun "apparent" movements can be projected through a models series drawn at the vault of heaven (Moore, 1989).

To apply this three-dimensional representation in architectonic terms should be translated to two-dimensional representations. The simplest way to perform this translation is drawing the vault projection plane. Since said projection is equidistant, the solar altitude angles are disposed at similar distances on plane. The equidistant projection will be the most useful tool to determine the shady levels needed at different openings orientations as the natural lightning levels available within the space interior.

Application of processed weather data (represented as spots) in the solar graphic, should determine the day hours as well as the season when the solar control strategies should be required on different buildings facades.

The architectonic element allowing this shady level should correspond to the spatial design and not be "in addition" to the design.

2.3 "Fish-Eye" Objective

In this type of projections (as the stereo-graphic projections) it is considered that the viewer is sited at the center of the photo and obstacles are located at areas surrounding. These obstacles are projected by the buildings or natural elements restraining the solar space or the sky in some points (Arias, 2004).

Conic perspectives projected by the "fish-eye" objective provide an 80º global image limited by the horizon line. To be applied on weather or lightning studies 2 geometrical parameters should be taken into account: First, they provide a 180º global image, limited by the horizon line. To be applied on weather or lightning studies it should be taken into consideration 2 correction geometric parameters: first it should be reveled inverted or if possible, superpose the sun run diagrams inverted. This is due that in said projection the viewer sees the sky while the graphic is a plane projection of solar position conic curves.

On the other side the NORTH exact position with respect to the photographic chamber orientation is a very important data, since this is the only way to superpose graphics, knowing the hour and day of the year where the photograph is taken.

The sky type should be considered at the conic geometry analysis. On images it can be observed that the sky is half covered. In images superimposing a solar graphic, sun position can be estimated only.

Within "fish-eye" projections at interior areas, obstacles scale at sky seen is reduced; walls, roofs and other architectonic elements restrain sunlight penetration and/or the daylight on interest points to be analyzed.

The sun graphic superposition (in this case for a 20ºN latitude) is inverted to correct geometrically impression on negative paper. The viewer point will be the point receiving sunlight at hours and days of the year indicated at the solar graphic. Chamber position at average work level (0.80cm) is the most proper since the floor level finished would have little usefulness.

Proposal developed at the above mentioned research project bases its conclusion applying this technique to the natural lightning analysis, super-positioning "Uniform Sky" graphic and making possible daylight estimates available on specific points of interior space.

This also can be fixed through the use of a graphic known as "pepper pot" (pepper points). This graphic divides each one of the thousand sky areas to a point with a relative equi-lightning. This makes possible a uniform sky with 1000 point sources with the same lightning

power in a horizontal plane. This graphic has not orientation. Therefore its indistinct use should be considered according with the obstruction of direct solar incidence as the weather requirements to get harmony in the environmental comfort (Mur, 1982).

The equi-lightning surfaces are formed by the points and its situation is alternated, depending on height. This is performed so the reading mistakes by defect can be compensated by other points with the same lightning power.

This aesthetic lightning distribution is applicable to a uniform sky without azimuthal variance as already mentioned, and without fixed orientation on its stereo-graphic.

The points number screened for an end is practically the same as the points number appearing through the sky opening "seen" if graphic is indistinctly turned on its own center, keeping the diagram reading constant on sky without obstacles.

3. UNIFORM SKY

The "Uniform Sky" is the most proper diagram to determine Daylight Factor (DLF) available in an internal space. This is valid if measures instruments are not available or lacking of a deeper analysis on physical models (scale models) in simulated environments (Arias, 2004). Even though and as already explained, this model can be used in scale models due to reading scale is unclear.

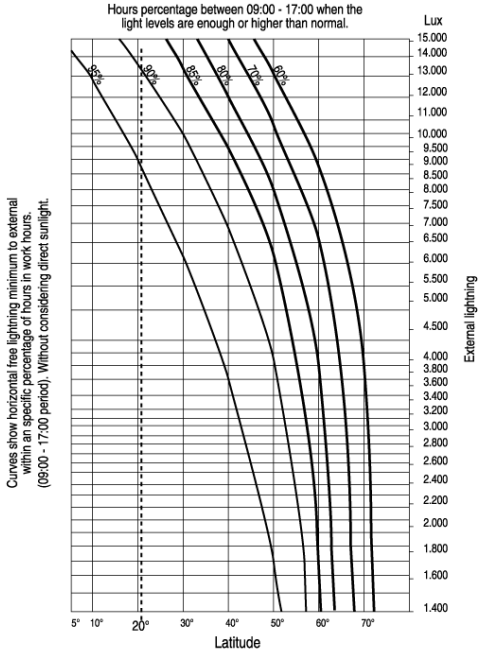

Figure 2: Dresler graphic.

Sky uniform portion that can be seen from the interior is delimited either by horizontal lines projection (as "slices"), and by vertical lines (as radial concentric manner). Through "pepper pot" graphic superposition, equi-luminous points number are computed from a 1000 total, having 9 luces falling as average on each point (in a 20ºN latitude).

On the other hand, the higher the delimited area is, the higher the points number to be accounted. Points maximum concentration is at the circumference zenith. This may be proved if taking into account that the zenithal lightning has the higher quantity.

Likewise, it has to be taken into consideration both the obstacles that may be present visually as the reflection area that may be supplemented to interior finishing materials.

For this method type to be used in other latitudes, it is needed to make reference to the DRESLER Graphic where the DLF is required for different visual activities as: needed lightning for the same, place latitude and daytime schedule percent that may be determined.

DLF values and lightning levels recommended are related with the value of 10,000 lux and taking latitude 20ºN as a constant:

$$DLF = \frac{\text{lightning needed level}}{50}$$

Sun Control Devices

In a warm climate, external devices for sun control and incorporated to the building architectonic design are needed to be installed. The main objective of these elements is sun penetration restraining. Even if visual penetration is

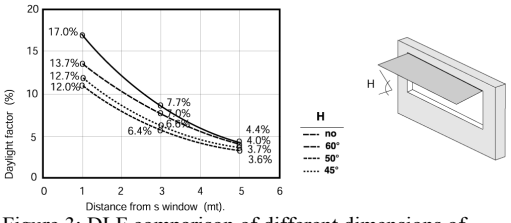

Figure 3: DLF comparison of different dimensions of control devices.

reduced from the interior (visual opening), admitting just a natural light portion. Undoubtedly horizontal sun control devices are more effective for South facades in warm climates of latitudes close to the Cancer Tropic. Another control devices advantages are that may be designed to protect and at the same time, to diffuse sun incidence and introduced into the building interior. The efficiency of these control devices had been analyzed in scale models at simulated environment. As well as the "fish-eye" photographic method, and taking into consideration the facades different orientations. Therefore, it is concluded at the graphic of Figure 5 (Olgyay, 1992).

It can be noticed the observation that efficiency is measured at the window edge; it is not take into account neither surrounding areas nor reflection that can be produced. Due to the foregoing, it is needed to consider wider factor series implying the following criteria:

- Devices Orientation;
- Interior Finishing Materials;
- Position of work level with respect to the window;
- Window size.

Graphic shows light performance results that depends on great measure of the protection element type used. Due to protection requirements (by means of thermal concept), the eave angle with respect to base of the opening of the wall, will increase or decrease allowing the choice to protect with a minor scale. As a sample the use of Venetian blind or a leafy shelter or recess having the same protection angle and providing more lightning rates.

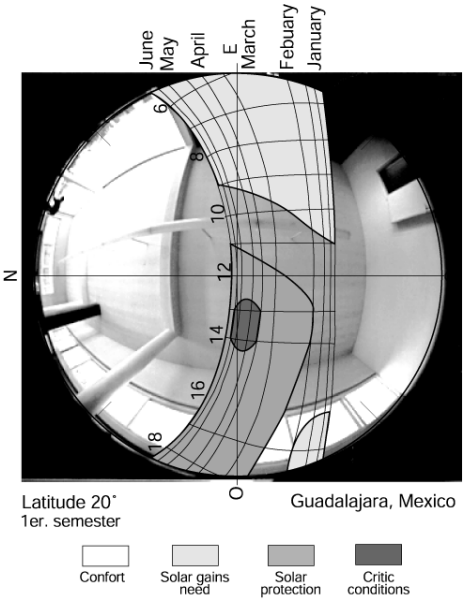

Figure 4: Analysis of conditioning requirements.

4. PROPOSALS

Selection of the components of the step

First, it is convenient to remember the main principles that must guide the concerning steps to the analysis of natural illumination of the architectonical project; it can be observed 3 different objectives:

- To propitiate the reception of diffusion of light;
- Selection of direct sun penetrations according to season;
- Homogeneous distribution of light in spaces of interest.

It can be seen two great groups of natural illumination components; the lateral and zenithal. The available light in a spot in the space depends on the sky type, the horizontal exterior component, the solid angle of the opening and by the cosine of the angle of media incidence of that light over a respected level.

It is deduced, by this relation, that the zenithal openings are more effective in a horizontal plane than the lateral openings, because they

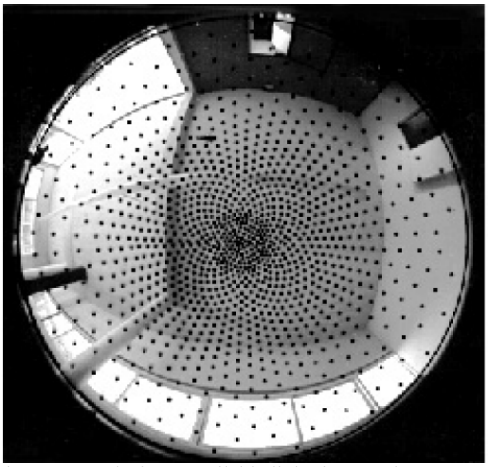
Figure 5: Analysis on available lightning requirements.

produce a high interior illumination over this horizontal surface. Concerning the direct sun incidences (sun light) it can be say that the lateral openings are more favorable because the penetration is selective depending the season of the year, the day and the hour opposite to zenithal openings where incidence in summer is critical and in winter is lower, even though in the case of the classrooms only is contemplated the lateral analysis, of the sky CIE (Gomez, 1998) (covered sky) it means the diffusion of light. It is also taken into account considerations of the control devices of direct solar incidence. The bioclimatic criteria mark the guides to reach this pre-conclusion regarding percentages of window, geometry and disposition in different walls. Even though the proportion is marked according climatic matters, illumination levels than can be reached with this proportions are well accepted to accomplish visual tasks in appropriate facings. The results obtained show that the proportions of original North-South windows only provide 261 lux in position table 1, which are the activity visual requirements in drawing 750 lux.

5. CONCLUSION

It must be noted the fact that natural lightning conditioning is hard to be established. Lightning good development can be gotten gathering element series that jointly can determine the proper environmental comfort. This paper intends to recommend not a minimum lightning rate series to be met, since this idea can conduct to a discomfort promotion, neglecting maximum blinding indexes recommended. Neither is commendable establishing lightning maximum rate, which can drive to a visual insufficiency. It should be proper to set forth commendable lightning rates at marked distances and depending on visual task to be performed.

Likewise, this paper does not intend set forth architectonic design rigid parameters but giving tools to allow designers to create healthier, habitable and efficiently spaces, with respect to energy-savings.

As a reminder, the environmental design influences directly in architecture users development, in mental stage, at working yield. Therefore, environmental factors should be taken into account with responsibility in architectonic design. This is not a discussion point, but an obligation.

The luminous analysis method herein detailed has been developed and patented by the author.

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