Optimization of the solar control devices in windows for hot climates

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ABSTRACT: A method for searching the optimum shading coefficient for given window is presented, taking into consideration the energy consumption of the building for heating, cooling and daylighting. A comparison between the performance of different shading devices like glazing materials, external and internal shading, is accomplished. The method is demonstrated on a case study for which diagonal shading devices were found to be the best solution.
The problem of optimal window shading arises in regions with hot climates. In many cases, energy saving in summer is dominated by the shading parameter more than by other design parameters, due to the reduction of cooling load during the summer. On the other hand, window overshading reduces the amount of daylighting. Also, the additional artificial illumination may increase significantly the cooling load in summer.
The present work analyses the climatic and light conditions of the different options in solar control devices for windows. Taking in consideration the consumption of energy and the comfort of the occupants, the variants used in the diagnosis are studied using scale models and comparative with computer available programs, with the principal aim to demonstrate in didactic way the concepts used to the students of the career of architecture.

Keywords: Shading devices, daylighting, comfort, bioclimatic approach.

1. INTRODUCTION

The regulation legal conditions for the devices of control in the openings will have to be stipulated in agreement to a bioclimatic study. For effects of the above mentioned study there are contemplated the climatic and light conditions of a specific region. This will serve also for his application in all kinds of buildings.

In the above mentioned environments there is known the need of protection from the solar direct effect during the summer season, nevertheless it will have use it during the winter to obtain a thermal suitable comfort.

Only it is necessary to adapt correctly the devices of solar control according to his orientation and to adapt them to the architecture as another element more. To regulate the solar gains is the first rule of design to continuing in a semi-templated climate: the solar radiation must not penetrate inside the space, therefore the protection will be necessary in the exterior.

2. CLIMATIC CONDITIONS

2.1 Solar control devices

The produced shading characteristics are independent from the scale of the device. The depth of this device and his suitable dimension in the wall is a determinant factor; this one expresses in angles that they show his radio of action in the normal plane of the wall. This way the effect of shading and of the protection mask they depend on the angle of effect.

The example of the Venetian blinds they show clearly this affirmation; the protection angle is the same that of horizontal shading devices, only it changes the scale of the above mentioned protection. This makes possible to classify the protection systems of agreement to his form and not to his size, though simply it could be said that they are in two places at the same time in three: Horizontal, vertical and mixed.

2.2. Shading conditions.

The method that develops later is a variant of the offer of Victor Olgyay as response to the need of solar protection of several buildings in the E.E.U.U. This tool of work has to of be considering as such, being the imagination of the designer that adjust the protection parameters needed in the different orientations. These parameters of protection come given by the climatic analysis realized in the previous chapter. The method is simple enough, if there are had the basic knowledges of spherical geometry; the information of position that intervene is those of solar height, azimuth solar, as well as of the solar positions during the year that they need to ventilate or to protect of the solar direct effect.

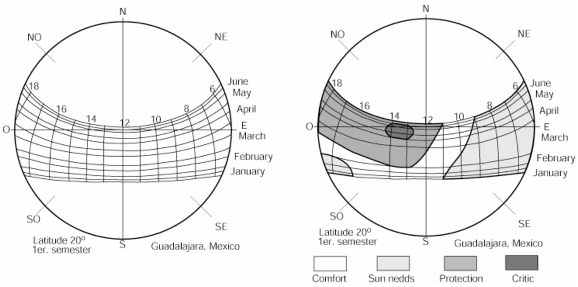
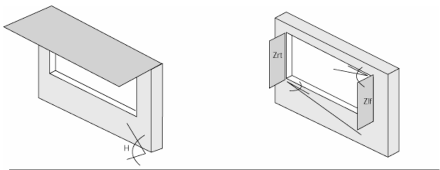


Figure 1: Solar chart, 20º N.

2.3 Horizontal and vertical devices.

The bioclimatic analysis of this region in concrete shows the diverse needs of solar protection in the different orientations, whereas in critical orientations West, Southeast, Southwest (inclusive one is necessary the utilization of lattices), big dimensions are needed in the protection elements, in the orientations North and East exists a requirement of solar direct effect to warm the interior. In the South remaining one of the orientations, Northwest and Northeast the protection angle is average, that is to say mixed, since the solicitations are of the bioclimatic order to warm, comfort and according to the case, to protect and to ventilate.



Orientation	H	Zrt	Zlf
NORTH	85º	----	20º
SOUTH	60º	----	----
EAST	50º	----	----
WEST	80º	----	110º
NW	----	----	60º
SE	50º	----	----
NE	60º	----	----
SW	20º	40º	---- (lattice)
NNW	85º	----	45º
SSE	50º	50º	----
NNE	80º	----	----
SSW	75º	115º	---- (lattice)
WNW	90º	-----	----
ESE	55º	----	----
ENE	60º	----	----
WSW	30º	80º	---- (lattice)

Table 1: Solar control angles.

North-northwest (NNW) Orientations. For this orientation, there is relatively easy the obstruction of the solar not wished radiation. With double screening: Vertical of 80° and horizontal 20° for every sector (East and West). On the other hand the orientation NNO, it needs of a vertical major protection towards the sector West is of 45° towards the left wings, compared with the North.

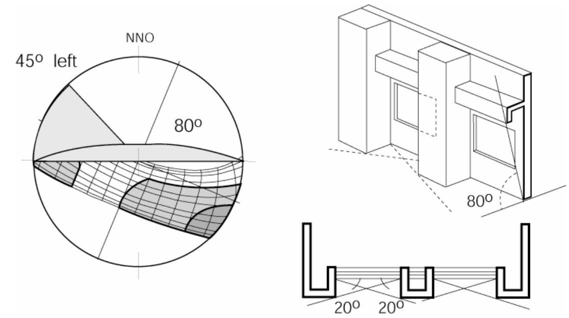


Figure 2: Solar control NNO.

South-southeast (SSE) Orientations. To obtain the suitable protection towards the sector SSE, there is recommended the use of solar control devices, balconies and small interferences, the protection angles needed are indicated in the solar graph similar to that of the South orientation analyzed previously. The protection proposed in both cases, will allow the screening of the solar radiation in the hours and seasons of the year in which it needs major shade (summer) and to allow his step in the moderate seasons.

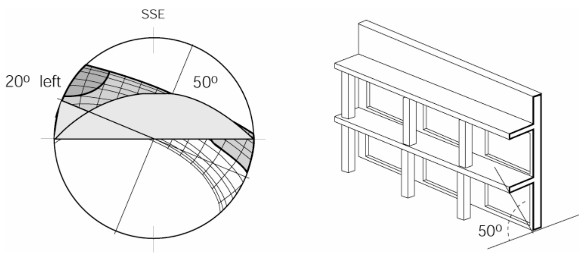


Figure 3: Solar control SSE.

West northwest (WNW) Orientations. In this type of orientations the protection during the warm season, also becomes necessary. For what the use is advisable so much of vertical elements, as of horizontal elements, to block the solar not desirable effect, though it is necessary to allow the step during a short period of the season moderated by the sector East southeast.

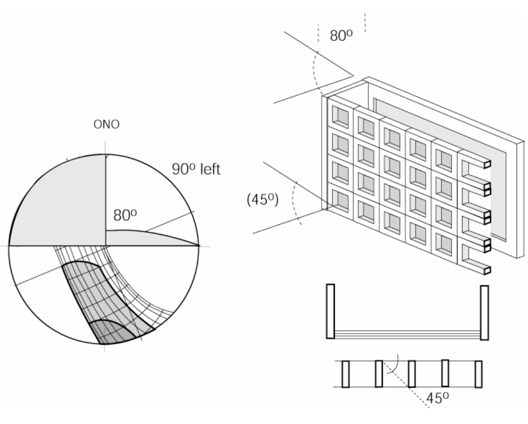


Figure 4: Solar control WNW.

As in the East southeast (ESE) sector, there are recommended the vertical protections that shield the solar effect during most of the year, with the exception of the moderate season, in which heating is needed but only towards the orientation East southeast.

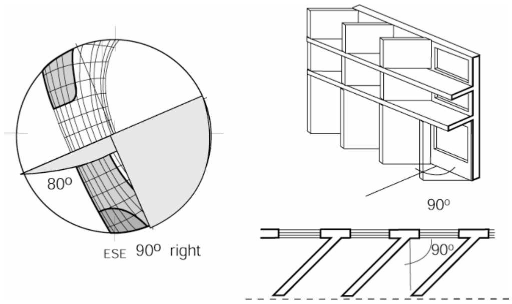


Figure 5: Solar control ESE.

3. LIGHTING CONDITIONS.

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.

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 lux falling as average on each point (in a 20ºN latitude).

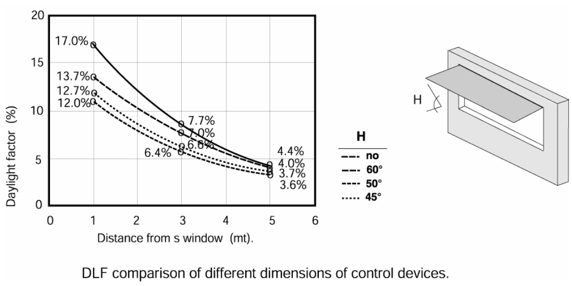


Table 2: Different dimensions of control devices.

On the other hand, the higher the delimited area is, the higher the point's number to be accounted. Point's 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.

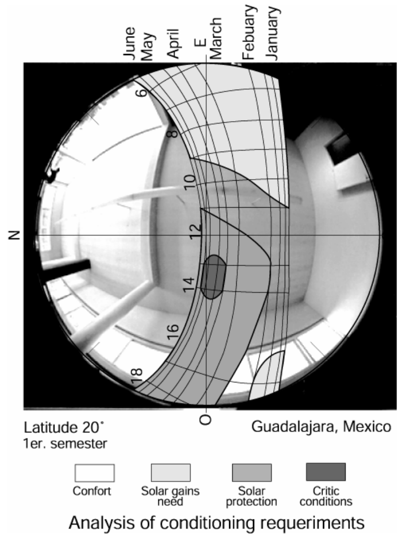


Figure 6: Solar chart and climate requirements.

DLF values and lighting levels recommended are related with the value of 10,000 lux and taking latitude 20º N. as a constant

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

4. METHODS OF MEASUREMENT

4.1 Analyses of models.

The scale model prototypes, developed with the purpose of representing the different types of devices of control, both climatic and light. In the same way is feasible to simulate the seasonal and daily variations, to be able to evaluate the thermal and light comfort according to the occupational use of the buildings.

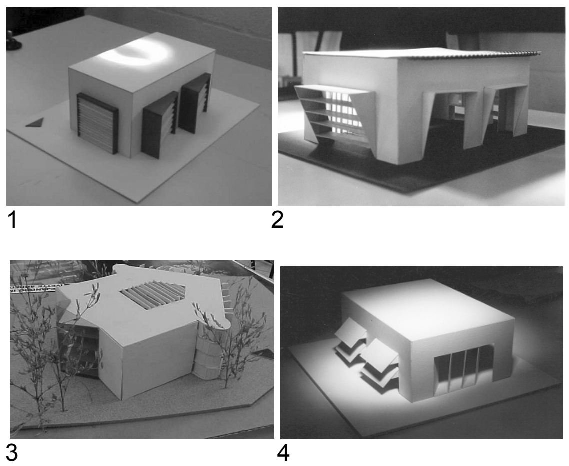


Figure 7: Scale models.

This series of simulations of solar tours on the different stations, orientations and hours of the day;

they lay the foundations to define strategies of bioclimatic design and of natural lighting. All this by means of the screening adapted to control the penetration of the solar direct radiation, which provokes thermal gains ó not wished glare. (1) Is feasible likewise to observe, the quantity of natural lighting that penetrates in the interior spaces, with what the best options of control decide to obtain the light indexes of major adjustment to the different visual tasks. (2)

The utilization of vegetation, to protect or to make way to the solar radiation, is likewise a key element in the environmental design of the buildings. For what they worked different types to diagnose the behaviour so much exterior as interior of the above mentioned buildings. (3) Finally the interior analysis, were observed different ended, types of reflectance, color, etc, to establish the lighting for reflections added to the direct lighting, etc. (4)

4.2 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 sky 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 diurnal period.

4.3 Stereo-graphic Projection

In this type of projection, angle measures taken 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 to know 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 high (h). Defined as the angle formed by the solar angle and its projection on a horizontal stabilizer.

-Solar Azimuth (a). Which is the angle of horizontal deviation, formed by the solar angle 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 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.

4.4 "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 180º global image limited by the horizon line. To be applied on weather or lightning studies two 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 to 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 20º N 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. Photographic camera position at average work level (0.80 cm.) 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 an 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 lighting distribution is applicable to a uniform sky without azimuthally variance as already mentioned, and without fixed orientation on its stereo-graphic.

The point's 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.

4.5 Program GENELUX.

This computer program calculates from the light source in question, the level of lighting in the interior on every wall depending on the building, his length, width, height, the factors of reflection of every wall and the type of used glass. It is necessary to indicate that the information of the natural available lighting is given in agreement to the calculation of the annual available average in normal conditions of the specific region of study.

Elaboration of the files BDG. There were created files that they present of the following way for each of the surfaces;

Surface name:	North wall
Surface color:	White
Surface shape:	Rectangular
Surface position:	(interior, exterior, glass.)
Surface reflection:	Diffuse
Reflection factor:	0.50
Transmisión factor:	0.00

The coordinates of the surface North is given by 3 points of a volume of 6 x 12 x 15, since it appears in the figure.

0.000	12.000	15.000
0.000	12.000	0.000
6.000	12.000	0.000

Representation and interpretation of the results of the simulations. Once carried out the calculations, the file of results (file RES) gives the values of lighting obtained in the different points for every surface of the building. With the values of lighting obtained (given in luxes), the available FLD can be calculated in the different points of the interior.

For practical questions, every graph corresponds to the measurement given in meters by the mesh represented in white lines. Later there appear the results obtained in simulations GENELUX in the openings.

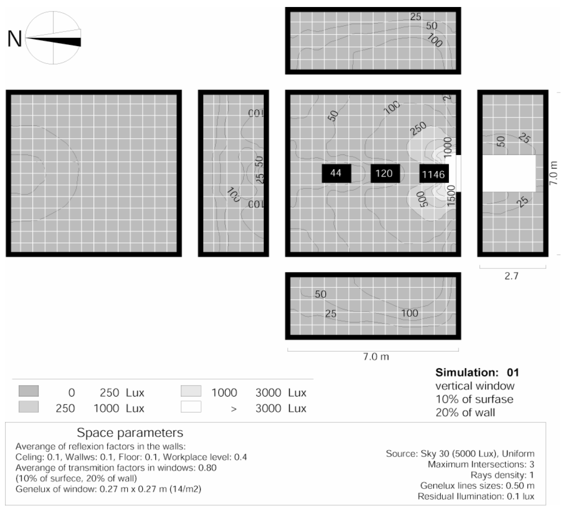


Figure 8: Genelux program.

5. CONCLUSION

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 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 following graphic:

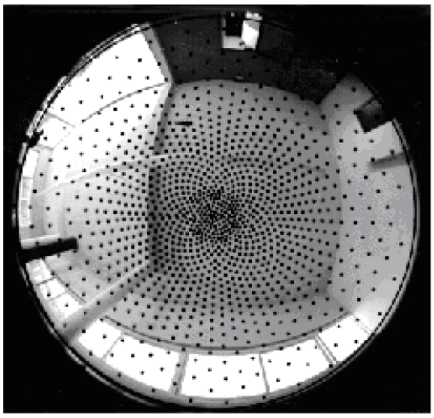


Figure 9: Analysis on available lighting requeriments.

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 solar control device 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.

On the basis of the measurement of models in the heliodon, with the different devices of control a series of results were obtained. With regard to the thermal reduction it is possible to say that the percentages of decrease are sufficient to obtain the thermal interior comfort. For the light requirements, nevertheless that diminishes great percentage, it is indisputable that there will have to be adapted the levels of thermal and light comfort, across mantelpieces of light, which on the one hand it protects from the solar excessive radiation and for other one the direct gains of lighting in the interior.

Exterior solar control devices	Termic reduction	Lighting reduction	Ventilation
Horizontal devices	70 - 80 %	45 %	80 - 100 %
Pergolas	85 %	77 %	80 - 100 %
Vertical blinds	70 - 80 %	45 - 65 %	10 - 50 %
Horizontal blids	80 - 85 %	70 - 80 %	80 - 100 %

Table3: Control devices estimations.

Finally for the estimations of energetic saving it is necessary to consider other factors of equal importance:

The type of materials and finished used in the walls and the interior ceilings, the requirements of visual detail depending on the task, the obstacles, etc.

The use of chimney of light, which can serve to improve the allotment of the natural lighting and to diminish the glare in the points near to the window, by means of the suitable use of diffusive materials that allow to distribute correctly the above mentioned lighting.

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REFERENCES

[1] Arias Orozco, Silvia / Avila Ramírez David. Natural lighting in architecture. Ed. U de G. México. 2004.
[2] Arias Orozco, Silvia / Ávila Ramírez David. Bioclimatic design in architecture. Ed. U de G. México. 2005.
[3] Avouac, Pascale. Bien voir, bien apprendre. Commissiion of the European Communities. European Reference Book on daylighting. 1990.
[4] Fontoynont, Marc. Guide de conception de systemes d'eclairege natural. ENTPE-Lash. France. 1990.
[5] Moore, Fuller. Concepts and practice on Architectural daylighting. Ed. Van NBostrand Reinhold. USA. 2000.
[6] Mur, Juan. Asoleo geometrico. Ed. UPC. Spain 1982.
[7] Robbins, C. L. / Hunter K. C. A model for illuminance on horizontal and vertical surfaces.