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Effects of Sun Controls on Buildings Interior Lighting and Thermal Environment in Hot Arid Regions

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Abstract – *It is important to be able to determine the optimal window shading system because shading of windows in summer in hot climates is among the most important design parameters to achieve good indoor climatic conditions, to let in quality natural light but exclude undesired glare and control contrast ratios with minimal energy consumption. Over shading of the windows reduces daylighting, which results in an increased energy use for artificial lighting. This article investigates the impact of overhangs on incident solar radiation and daylight quality and quantity in office rooms under specific sky conditions of Algeria. The impact on incident solar radiation is analysed through a computer program written in Visual Microsoft Fortran according to an algorithm reported in reference [1], which is corrected according to the average sky condition of the analysed site. The impact on daylight quantity and quality is investigated through simulations with the program "Leso-D.I.A.L" [2], and evaluated in terms of necessary illumination level on the working plane. For purposes of theoretical study, the considered office is orientated to the south east direction wherefrom considerable quantities of solar radiations are received in summer, and also the day light is fairly diffused in the summer days in the northern latitudes. We use the term "geometrical shading coefficient" (GSC) to express the ratio between overhang and window area.*

Résumé – *Cet article examine l'impact des surplombs d'ouvertures sur le rayonnement solaire incident, ainsi que sur la quantité et la qualité de la lumière naturelle résultante dans les espaces à usage de bureau, sous les conditions climatiques spécifiques à l'Algérie. L'effet sur le rayonnement solaire incident est analysé à travers un programme informatique écrit sous "Visual Fortran" selon un algorithme rapport dans la référence [1]. les résultats sont corrigés ensuite selon les conditions moyennes de couverture du ciel du site considéré. L'effet sur l'environnement lumineux est examiné par un ensemble de simulations utilisant le logiciel " Leso-D.I.A.L" [2], évalué en terme des niveaux d'illuminance nécessaires. Le model de bureau considéré est orienté au sud-est, orientation considérée recevoir des quantités considérables de rayonnement solaires et représenter une configuration lumineuse assez diffuse durant la période d été. Nous utilisons le terme "Geometrical Shading Coefficient" (GSC), pour exprimer le rapport des surfaces surplomb/ouverture.*

Key Words : Overhangs – Buildings – Daylighting – Solar radiation

1. INTRODUCTION

Architects often design fixed shading as an integral part of the building exterior appearance. In most cases they ignore the effect on the interior daylighting environment, insolation of the facades and put the same shading on all windows. Closer examination reveals that usually some of the facades are unshaded, while others are over-shaded. Shades in addition to their architectural appearance, should be functional in controlling radiation and daylight admittance.

The design of shading devices, often treated as a means to reduce solar gain only, is in fact a complex issue. Shading devices also affect the quality and the quantity of daylight admitted into the building, as well as affecting the thermal comfort of the occupants. Buildings functioning as offices consume a sizable amount of electricity even when they are being used eight hours of the day when adequate daylight is available in Algeria. These types of buildings are progressively being air-conditioned for creating work comfort conditions against excessive heat admitted largely through fenestrations. By using sun shading devices, the solar radiations could be reduced to a large extent. The quantities involved in such reductions of solar heat and daylight would give a guideline to the building designers for making adjustments at early design stage.

2. THERMAL EFFECTS OF SUN CONTROLS

The thermal behaviour of utility buildings is dependent on the rates of heat gain associated with occupants the provision of artificial light, business and process equipment and solar radiation transmitted through fenestration. Of these heat gain mechanisms, transmitted solar radiation commonly fosters the greatest cooling need, frequently representing as much as 50 % of the total load for the building [3], causing appreciable increase in heating ventilating and air conditioning system capacities.

The design and use of sun controls to restrict solar heat gain rates therefore, should be able to improve significantly the energy_ efficiency and decrease the assembly and operating costs for buildings constructed with these devices. Sun controls can take many forms and can be used either indoors outdoors or between the panes of double glazing. Curtains, rollers and venetian blinds as examples of internal controls, canopies, roller blinds, louver systems and sun breaks as examples of external controls and venetian and pleated paper blinds as examples of controls between the panes of double glazing. As the contribution of exterior sun controls is much more effective in reducing solar gains (a control inside a vertical window retransmits approximately 80 % of its absorbed heat to the building whereas a control outside retransmits only 3 % of its absorbed heat [4]. Therefore, this investigation will be restricted to the simplest form of sun controls placed in this position: the overhang

2.1. Evaluation of overhang effects on incident solar radiations and on interior daylight repartition

The effects of overhang shading were investigated for a specific location, Batna, (Lat.35°, Long.6°). The routine used for the calculation of solar radiation is based mainly on a method described in reference [5], which allows the calculation of monthly average daily insolation on overhang shaded windows of arbitrary azimuth.

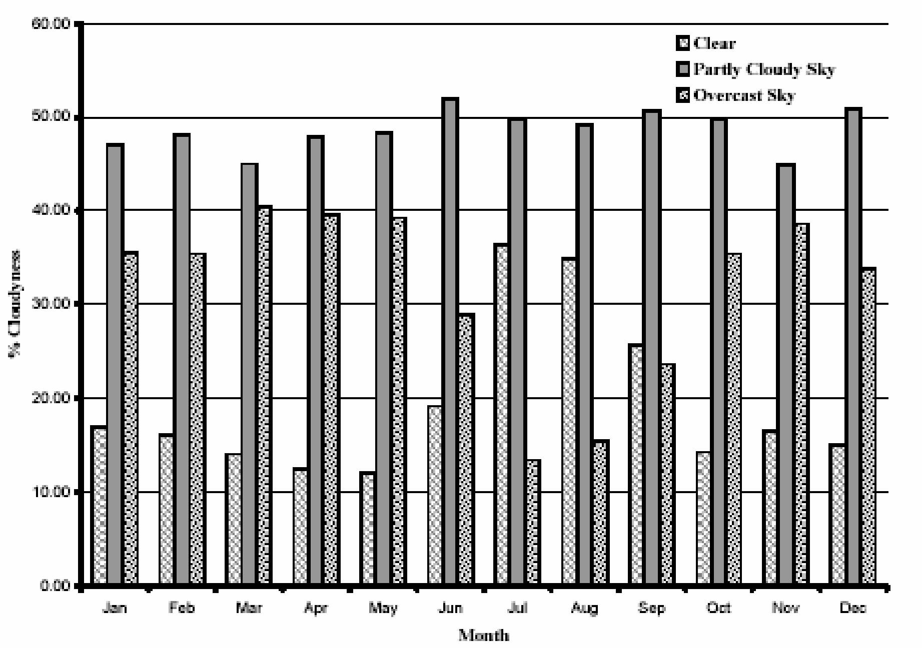

Fig.1: Monthly average cloud cover for Batna in %

The average daily insolation on a horizontal surface for each month and the separation of total radiation into direct and diffuse components were computed as described in reference [1]. The principle of the calculation is to compute solar radiations for clear sky conditions and overcast sky conditions which are then corrected according to the percentage of monthly average cloud cover given in figure 1.

Whereas the daylight illuminances on the working plane of the examined office are calculated according to average sky condition given, in the next section. Calculations were achieved for one characteristic day of the year (21 June) supposed to represent the design day and calculation hour is determined as 09:00 h as it is beginning of work-hours and symbolises a great part of the daylight variations. An office room of 4m x 3m x 2.80 m has been considered(see figures 2,3 and 4.)

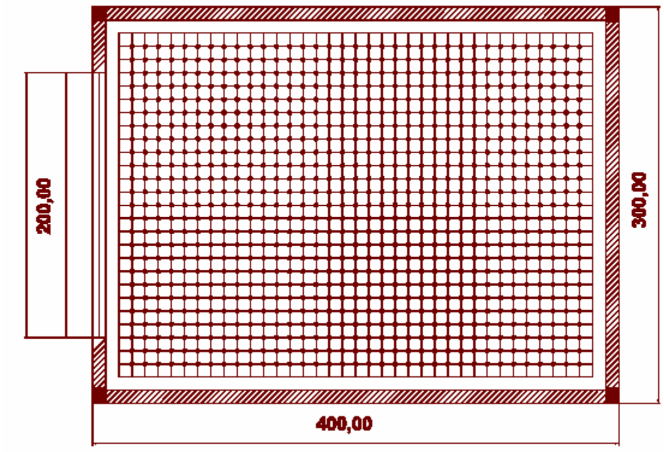

Fig. 2: Plan of the office room model

The fenestration area is located in the shorter wall, and the room is orientated to the south east direction wherefrom considerable quantities of solar radiations are received in summer, and also the day light is fairly diffused in the summer days in the northern latitudes. A grid system, sampled in figure (2) is used for the reference points to determine the illuminance distributions on the working plan. The overhang area to window area is then made to vary from 0 to 1 (GSC=0,1/3,1/2, 1). The light transmittance of glasses produced and used widely in Algeria is taken into consideration. The situation with obstruction opposite to the building that the room is located is examined.

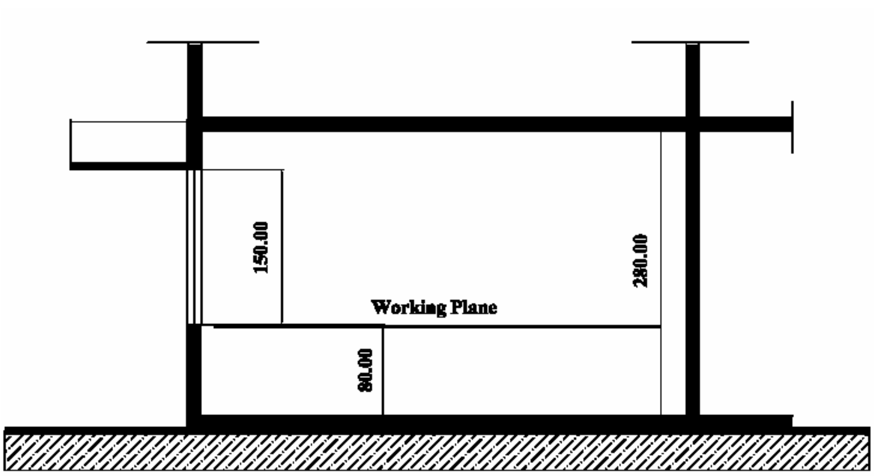

Fig. 3: Section of the office room model

The heights of the office building and obstructions, and the distance between buildings (street width) are determined in accordance with the data of ‘‘Municipal Type Town Planning-Code’’ valid for Algeria [6]. For full description of the assumptions used in the study refer to table 1.

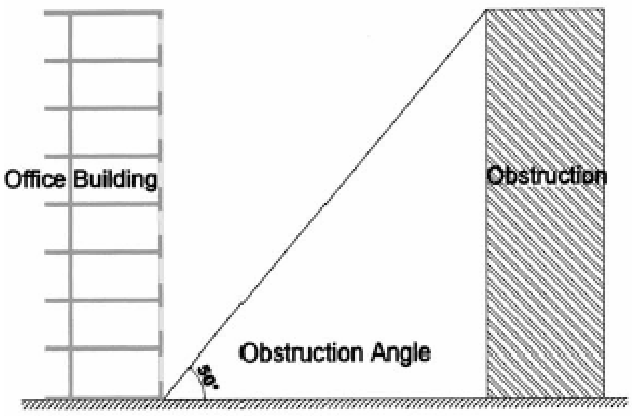

Fig. 4: Office room model situation and obstruction

Table 1: Model description

Assumption	Description
Obstruction angles	50°
Obstruction distance (street width) (m)	19
Obstruction features	Continuously and parallel to the window wall
Obstruction height	Equal to the office building height
Obstruction reflectance	0.30
Dimensions of the rooms (m): width, depth, height	4 x 3 x 2.80
Window (building) direction	South East
Window dimensions (m): width, height	2 x 1.50
Window type: Light transmittance, Reflectance factor	0.75, 0.16
Light reflectance of internal surfaces	Ceiling 0.80,Walls 0.60, Floor 0.20
Reference points height (m):	0.85
Calculation (Batna) Latitude, Longitude	35°, 6°
Average Sky cover	34.38% in June
Days & Hour	21 June, 09:00(h)

3. ESTIMATING THE EFFECT OF OVERHANG ON INTERIOR DAYLIGHTING DISTRIBUTION

There are several computer programs that model daylighting. Leso DIAL[2], adapted for the personal computer, is one such program that can model complex geometries, such as trapezoidal windows, external window overhangs, external obstructions and, angle of incidence for the reflectance of window glass, the aim of ”Leso-DIAL” is to give architects relevant information regarding their daylighting choices at the very first stage of the design process.

As we know, most relevant decisions have to be taken at the very first design stage, when the sketches are made. This is the right moment to make the right choice. Most often, only unsound compromises come of later interventions. In actual fact, it is much more interesting to have rough but early information than precise information which comes too late. Unfortunately, the existing simulation tools cannot be used at the sketching stage, because room geometry and photometry are not yet precisely known (computer tools need precise values for each of the description parameters). The idea of "*LESO-DIAL*" is to focus on this stage, and to allow architects to quickly make pre-choices in their own office.

The main program consists of four parts, corresponding to four stages of the design process: Allocation, Description, Estimation and Comparison. The first action is to define the room in order to know the specific requirements the architects' experience. Once the room's allocation is known, the user is asked to describe both geometry and photometry. The principle is to only handle graphic and linguistic items to describe the problem.

3.1. Leso Dial sky model configuration

Sun and sky are natural light sources and basic determinants of daylight. Quantity and quality of daylight are variable related to the geographical, meteorological data such as the altitude of the region, turbidity of atmosphere as well as time. Because of this, the correct determination of the qualifications of the natural sources, which cannot be controlled by the designers and users, is of great importance in daylighting design. If there are no precise data based on the regional measurements about natural light sources specifications, theoretical determinations and approaches derived from various assumptions are used. The "Commission Internationale de L'Eclairage" (CIE) defines five reference skies taking into account the studies made on this subject as follows [7]:

- CIE standard overcast sky,
- CIE standard clear sky,
- intermediate sky,
- average sky,

The meaning of reference sky is ''exactly defined sky (sky model) that can be used in daylight calculation methods overcast, clear and intermediate skies are related to the sky luminance definitions that can be accepted according to the weather conditions. Average and mean skies define the conditions that use to determine the real sky situations.

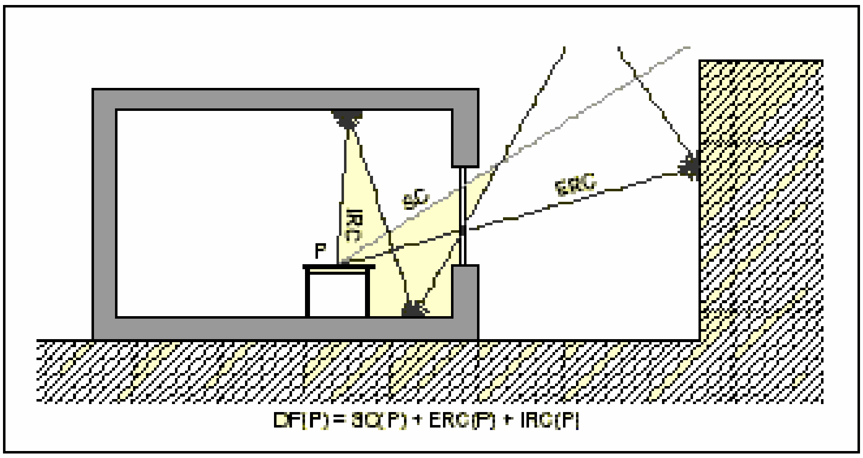

Fig. 5: Daylight factor components

3.2. Leso Dial daylight factors and interior illuminances calculation

- The Direct Component (DC) is obtained using analytic calculation of the sky luminance [8] according to the position of the window(s), light flux coming from the sky is integrated in the corresponding solid angle(s).
- The External Reflected component (ERC) is derived from this analytical procedure, assuming that the sky luminance is weighed by the reflection factor of the obstruction.
- The Internal Reflected component is estimated using the BRS formula [9].

In the present case Daylight factors and Internal daylight illuminances values are all calculated according to the average sky model taking into account the assumptions described in the previous section.

4. RESULTS AND DISCUSSION

Preventing penetration of the sun's rays inevitably reduces the light from sources above the horizon level. Light reflected from the ground and surfaces of the shading device must therefore be employed to greatest advantage. The quantity of light available from the ground is proportional to the sky luminance and to the average reflectance of surrounding objects, including grass, trees, roads and buildings. Consequently the illuminance within a room varies linearly with both ground reflectance and sky luminance.

From the results of the simulation given in figures 6 to 10, it is obvious that in this particular case overhang shading can quite effectively reduce summer insolation without drastic reduction of the winter insolation.

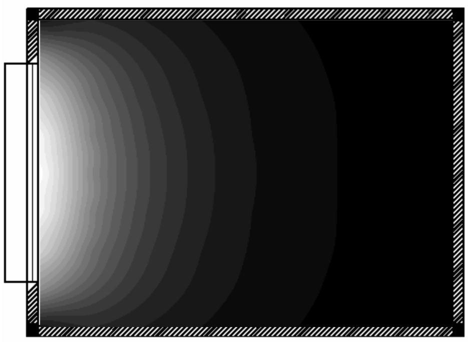

Fig. 6: Daylight levels repartition GSC=0

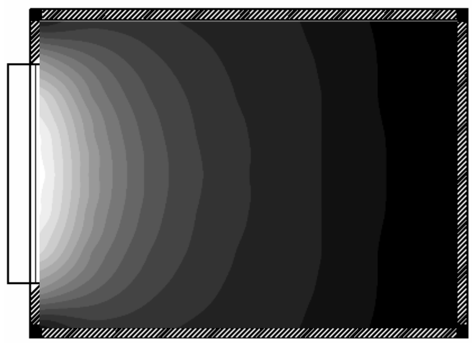

Fig. 7: Daylight levels repartition GSC=1/3

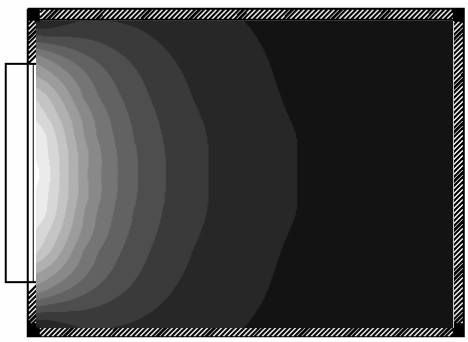

Fig.8: Daylight levels repartition GSC=1/2

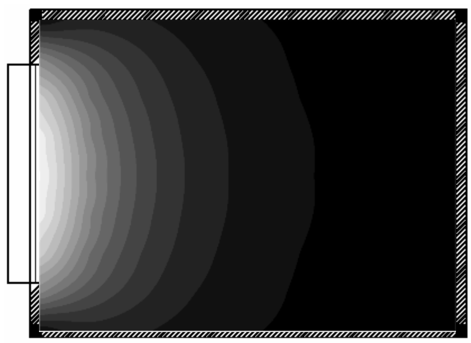

Fig. 9: Daylight levels repartition GSC=1

Illuminance distribution in rooms with shades and in those without is the result of the diminution of the direct sky component in the former case and the ability of the sun controls However the effect on the interior daylight environment is slightly more complicated shading devices act as a source of light; the luminance of which depends on the reflectance of the shading device. and exterior obstruction in diffusing light entering the room. These factors reduce the large illuminance gradient that normally exist in rooms without shade and can therefore reduce the risk of glare that could occur in this type of configuration.

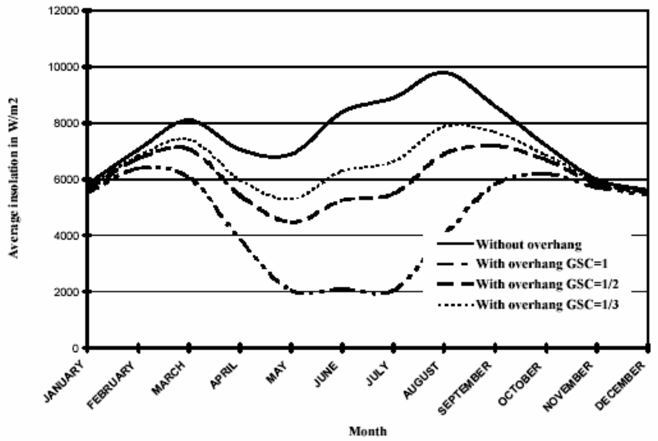

Fig.10: Monthly average insolation on south east facing window in Watt/m^2

5. CONCLUSION

Overhangs can be useful controls for fenestration. In addition to blocking the direct beam from the sun, they will also reduce the amount of sky seen from within a room. thus reducing the amount of diffuse skylight admitted through the opening. Reflected light from the ground or other surfaces can also be caught by an overhang and directed back into the interior of a room independently of orientation. The result will be a lower average illuminance level but a more even distribution of light in the space.

This article indicates that in this latitude and under the specific climate of Algeria, overhangs can result in important reduction of incident solar radiation. From the point of view of lighting engineering overhangs acts as optical devices which diffuse evenly and quite uniformly daylighting inside sidelight buildings and therefore could reduce glare and give more comfortable spaces.

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