Learning more from existing indoors: An investigation of roof lighting within lecture rooms

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ABSTRACT: With regards to daylighting scholastic premises in Algeria, previous literature [1,2] gave clear evidence of the discomfort experienced within classrooms because of an initial inappropriate conception of side windows. With this in mind and upon the basis of a recent research [3] which appraise the efficiency of roof lighting systems within similar facilities, a further investigation (part of an M..Sc. search degree) was undertaken. This tackles a study of roof lighting performance within lecture rooms from the Constantine (Algeria) University Central Campus, designed by the contemporary famous architect Oscar NIEMEYER.
Though, such lighting systems were assumed to provide optimum luminous comfort conditions, a Post Occupancy Evaluation both quantitative and qualitative, showed that under local climatic conditions, roof lighting design does not eliminate totally problems. These were found to be essentially incurred by the glazed areas eastern orientation which appears to be not really appropriate for areas of lower latitudes such as Constantine. One further concern consisted also in bringing attention to how a most clever initial window conception could still bring about indoor luminous discomfort.

Keywords: roof lighting, luminous environment, Post Occupancy Evaluation

1. INTRODUCTION

In previous work [2-4], it was already discussed, the extent of discomfort in the form of inhibition of pupils school work and physical distress because of inappropriate lateral windows design. With this in mind, the current issue tackles a subsequent study in which roof lighting is assumed to be a better alternative design under the same local climatic conditions.

A preliminary survey revealed clearly that the recourse to roof lighting is practically inexistent within the local educational premises. Fortunately, there were the Constantine (Algeria) University Central Campus lecture rooms which were provided with the daylighting systems of interest and were hence retained as a field of investigation. It is also important to recall that their selection was further motivated by their functioning with the regular (or traditional) teaching type similarly to the already studied side lit enclosures [1].

This paper aims to discuss that part of the investigation carried in the form of a formal Post Occupancy Evaluation both quantitative (through measurements) and qualitative (by the means of questionnaires).

Throughout the results, it appeared clear and definite that though roof lighting design does not eliminate entirely indoor luminous environment problems, especially under the local climatic conditions yet, it does alleviate them considerably.

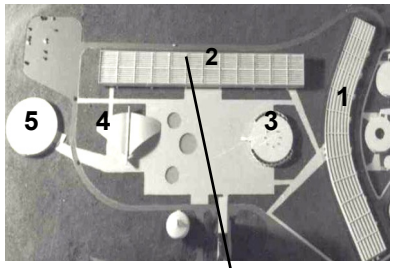
2. BRIEF REVIEW OF THE ENVIRONMENT OF STUDY

The environment of study currently called the Central Campus of Mentouri University [5] was designed in 1968 by the famous contemporary architect Oscar Niemeyer who acted as the principal foreman to see for its realisation.

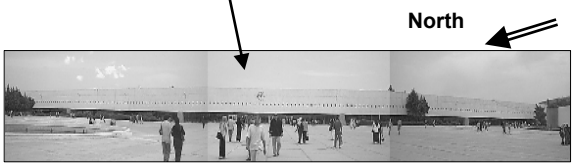
Among a whole series of different daylighting systems integrated to various spaces according to their respective specific function [7-9], a sample of lecture room roof lighting systems was selected for assessment because of the mere reasons evoked above.

In the number of 100, the lecture rooms in question are set on either side along the first floor of building 2 (Fig.1) named currently “Bloc of Literature”. Wide of 40 metres this building extends along 300 metres from South to North.

Oriented either East (-81° from South) or West (+99° from South), all lecture rooms include in addition to their roof lighting apertures, lateral elliptical small openings (portholes like) of 0.19m² in area and 64cm in height each. These were obviously designed to keep some contact with the outside more than to contribute to the required daylight quantity to perform various visual scholastic tasks.



- View of The project as designed by **O. Niemeyer** [6]
1= Sciences building
2= Literature Building
3= Library
4= Conference room
5=Restaurant



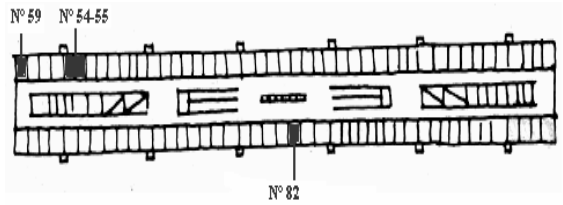
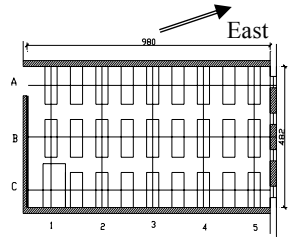


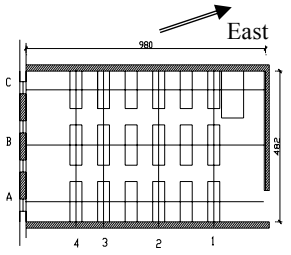
Figure 1: Bloc of Literature (Western View & building layout showing Selected lecture rooms)

As most lecture rooms, the three retained for investigation (Fig.2) have an occupancy rate of around 32 persons seated in rows facing the chalkboard because obviously of the regular teaching type commonly adopted in the place of study.

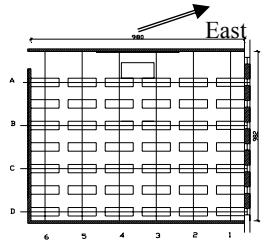
The roof lighting systems of concern take the form of rows of unshaded unilateral vertical glazing (of 1.0m in height extending over 4.75m) oriented towards East.



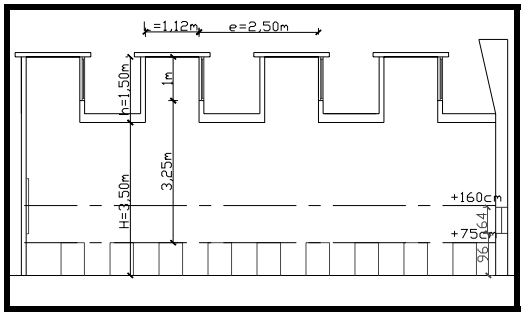
Room 59 (47m²): - *Vertical glazing parallel to chalkboard*
- Lateral apertures oriented east
- Mean Room Reflectance = 0.24



Room 82 (47m²): - *Vertical glazing parallel to chalkboard*
- Lateral apertures oriented west.
- Mean Room Reflectance = 0.59



Room 54-55 (96m²): - *Vertical glazing normal to Chalkboard*
- Lateral apertures oriented east
- Mean Room Reflectance = 0.43



Common geometrical opening features in all rooms

Figure 2: Views & Plans of selected lecture rooms & Roof Lighting Systems geometrical features

3. OVERVIEW OF FIELD WORK METHODOLOGY

3.1 Review of local luminous climate

There is no doubt that indoor daylight is an integral part of outdoor luminous climate. Thus prior to the selection of any investigation method it was important to review the luminous climate characteristics of the city of Constantine.

In some countries sky illuminance data are provided per month and per hour for given localities [10] but such data are merely still inexistent in the place of work. Yet a very recent research [11] has made available a zoning of outdoor illuminance level means under both clear and cloudy sky for the whole country.

More, an analysis of local cloudiness or cloud cover data [12] enabled to reach the conclusion that in the region of study, although cloudy skies are more stable, clear skies are quite frequent throughout the academic year. These latest are also predominant together with partly cloudy skies [4,13]. Additionally, being situated in a Mediterranean region (latitude: 36.17°North & longitude: + 6.37°), Constantine belongs to an area where sunshine probability quite often exceeds 50% of possible sunny hours [14, 15]. Thus, it appeared clear that unless a great care is attributed to fenestration design, frequent incident solar radiations might hardly be prevented from entering a place.

3.2 Method of assessment

More frequently than believed, it occurs that a building technically designed to operate with a great

environmental efficiency is revealed through users' attitudes quite faulty. This is further truer for luminous environments where occupants observation [16-18] has shown merits or inaccuracies of daylighting systems or/and controls.

In fact, to be faithfully illustrative a daylighting Post Occupancy Evaluation needs to include a technical assessment together with data about users' general attitudes (point of view, behaviour, action) towards their environment [19, 20]. Such evaluation procedures might also be achieved through a number of different methods among which measurements and questionnaires as for the present field work.

Remark: It is believed truly important to precise that within the study environment, electric light was centrally controlled and kept on by all times during occupancy hours (8 a.m. to 5 p.m.). Thus, daylighting conditions were assessed independently of supplemental electric lighting which was assumed to have even effects under various sky conditions.

3.2.1 Quantitative assessment through Measurements

During the academic year 2004/05, quantitative assessments were undertaken essentially in the form of simultaneous measurements (by the means of illuminance meters) of both external and work-plane internal horizontal illuminances (as shown on room plans in figure 2).

Vertical internal illuminances were also registered at the level of chalkboards and on sunny days at the center of monitor roof glazing to allow an eventual assessment of daylight factors (or DFs) under clear skies [21].

Three series of measurements were carried: during summertime period (13th, 19th & 21st of June), wintertime (25th, 27th & 29th of December) and during springtime (22nd & 25th of March and 3rd & 5th of April). For each day, illuminance levels were registered at 9a.m., 12p.m. and 14p.m.

Daylight Factors and daylight factor contours were later established to provide a clearer picture of the potential of light levels within the investigated spaces. Nevertheless, only clear and cloudy skies daylighting conditions are subject to discussion in this paper as they are believed to summarize most extreme possible conditions.

Room, uniformity and glazing indexes [22, 23] were also calculated to check upon the distribution pattern of daylight within the investigated indoors.

3.2.2 Qualitative assessment through questionnaires

The qualitative assessment was carried in the form of a questionnaire addressed to a sample of subjects selected randomly from the three lecture rooms.

- *Selected subjects.*

Over 50 questionnaires initially addressed to subjects (according to the rule of thumb [20]) but 36 only were filled and returned back to the interviewer. This number of respondents was however believed as fairly sufficient and also a reasonably representative sample, especially if one considers other relevant studies or suggestions [16-20].

The group in question formed by exclusively lecturers and students gathered around 60% of males, 80 % of students and 64% of subjects aged between 20 & 25 years

- *The questionnaire form*

Taking into account Steemers & Baker suggestions [19], a questionnaire form was elaborated to collect main *subjective assessment* of a number of aspects inherent to indoor daylighting conditions in both winter and summer.

Also to minimize the interviewer interventions, the questionnaire was designed as a self administrated in which the purpose of the inquiry was put in clear and simple words as the respondents were not bound to be familiar with technical lighting vocabulary.

The main questions could be summarized as follows:

1- *Do you appreciate daylight in your work place? (Answers on a 4 rating scale).*
2- *Do you assess indoor daylight as sufficient in summer/in winter? (Answers on a 4/5 rating scale).*
3- *Do you experience incident sunlight upon your work-plane? (Answers on a 3 rating scale).*
4- *Are you keen for some solar controls in this work place? (answer by Yes/No)*

4. RESULTS AND DISCUSSION

The results extracted from both quantitative and qualitative assessments provided clear and precise data about the investigated environment daylighting general conditions.

4.1 From quantitative assessment

The illuminance levels registered were:

4.1.1. Under Clear Sky

- *During summertime:*
  - Mean illuminance levels were fairly high in the morning (exceeding 3000 lux) within the 3 lecture rooms (Fig.3).
  - Because of the eastern orientation of the glazed areas, solar radiations were incident upon work-planes during morning time (one most effective working day period). Chalkboards were not also preserved from this problem in the contradiction of the regulations [22, 23] which stipulate that direct sunlight should not be falling upon all work-plane types.
  - Uniformity of general illuminance distribution was permanent in room 82 (uniformity index higher than 0.8). In rooms 59 & 54-55 illuminance distribution uniformity was never ensured because probably of lower surrounding reflectance.
  - During afternoons illuminance levels got much lower but remained at acceptable levels (Fig.3).

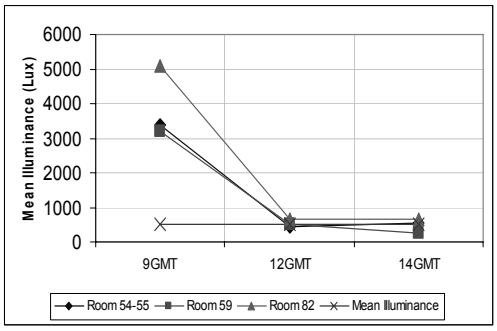


Figure3: Summer clear sky illuminance levels in relation to the recommended mean value.

- *During wintertime:*

  - During mornings, the three rooms illuminance levels were quite sufficient even upon chalkboards (800 to 1370 lx). During afternoons, except for lecture room 82, illuminances were found to decrease below acceptable levels (Fig.4]. More, illuminance levels upon chalkboards remained low within the three enclosures.
  - Because of sun lower altitudes, solar radiation incident indoors were restricted to upper areas where they were of no unwanted effect upon occupants' visual tasks.

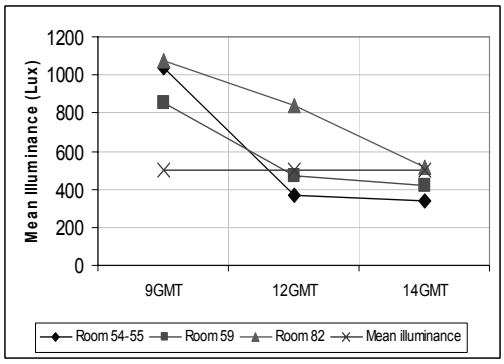


Figure 4: Winter clear sky illuminance levels in relation to the recommended mean value.

4.1.2 Under Cloudy Sky

Within the three investigated places, by all day times under cloudy skies, illuminance levels were fairly insufficient and remained below acceptable levels or more precisely below the recommended mean Daylight Factors (Fig.5).

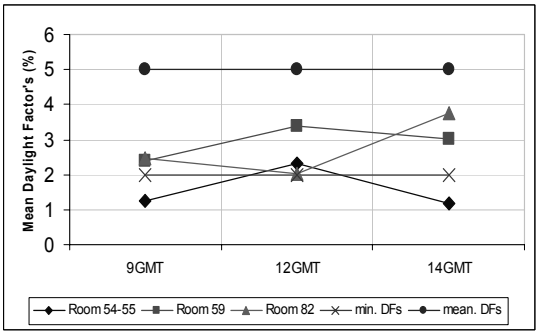


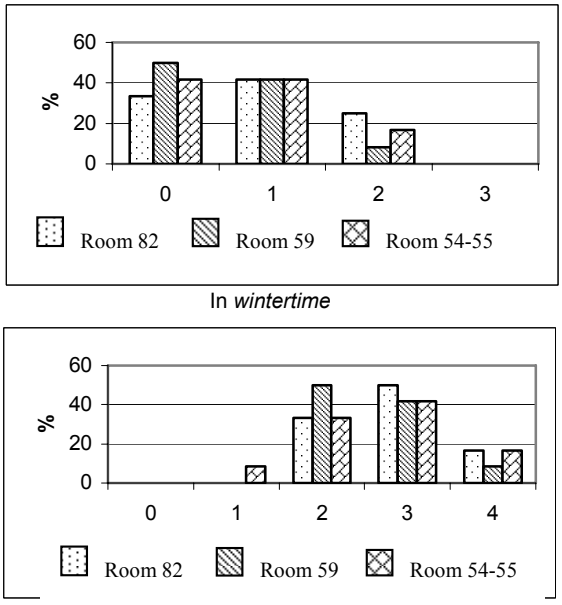
Figure 5: Cloudy sky Daylight Factors in relation to the recommended mean and minimum values.

<u>Remark:</u> To give a most accurate picture of the effective work-planes lighting conditions, results are presented in illuminance levels under clear skies and in Daylight Factors under cloudy skies. In fact, for DFs calculation under clear skies [21], it was noticed a great discordance between acceptable levels of illuminance levels and their respective DFs. For instance a mean interior Illuminance level of 2518 Lux (well above the general recommended 500Lux) would correspond to a DF mean of 3.47% (quite below the general recommended values)

4.2 Qualitative assessment

Results from the qualitative assessment revealed the effective extent of occupants' dissatisfaction with the overall indoor luminous conditions (Fig.6). For instance:

- 83 % of subjects judged indoor lighting as rather insufficient in wintertime and generally sufficient during summertime.



<u>0 = Insufficient , 1 = Quite sufficient, 2 = Sufficient</u>
<u>3 = Very Sufficient, 4 = Excessive</u>

Figure 6: Subjective assessment of daylight quantity within the 3 rooms

- With regards to incident sunlight around 50% confirmed to be always exposed to incident solar radiations among which 36% declared to be seriously indisposed by such a situation (Fig.7). Whenever this occurred, the subjects undertook actions such as shifting to other shaded places wherever possible.

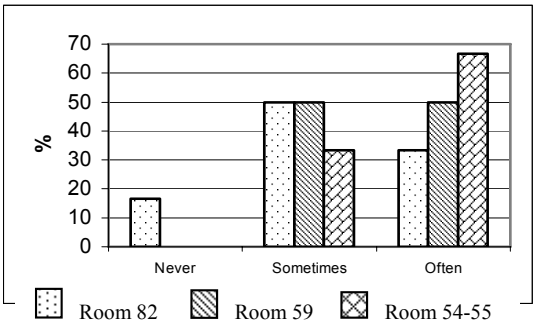


Figure 7: Rate of irritation by incident sunlight

- Around 80% of the subjects declared to be in favor of the use of sunlight protections no matter their form (Fig.8). Such attitude was believed to be further initiated by the experienced discomfort due to overheating as confirmed to occur (during even reasonably warm days outdoor) by around 70% of the whole respondents.

- Except from 19% of subjects, all others declared to be irritated by incident sunlight radiations over chalkboards. Main glare effect sources were named to be incident solar radiation, roof glazing (especially for lecturers) precisely during morning times.

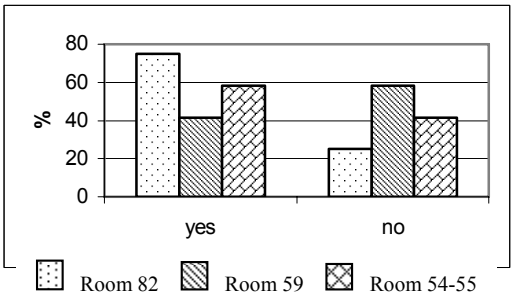


Figure 8: Ssubjects' desire for solar protections

5. CONCLUSION

Throughout this quite elementary investigation, roof lighting design was found to effectively alleviate problems registered while studying side lighting but it did not eliminated them entirely. For instance during summertime periods, high solar altitudes were provoking visual discomfort among around 2/3 of the subjects. Obviously, no similar problems were encountered during wintertime when sunrays are naturally kept beyond areas housing critical visual tasks. Yet, illuminances on work-planes were found quite below acceptable levels.

The issue of this search would have never been opportune if the potential of outdoor illuminances was not so considerable[11]. Beside, it seems just too inappropriate in the place of study to see working places (educational or others) doing with such a wasteful use of electric light.

It is also very important, to precise that at no one time and by no means this paper considers criticising the architect. On the contrary, admiration for the Central Campus design has never lessen among locals (architects, highly educated or others). Nevertheless, the lame number of post occupancy daylighting evaluation studies [7, 9] has at each time revealed problems inherent essentially to either a lack or an excess of dayllight, a critical indoor daylight distribution [7] or to discomfort due to direct exposure to solar radiations.

Actually no problems were attributed to a lack of skill during the construction as it was under the control of the architect himself. Thus, a mere assumption could be that during 1968-69 energy consumption was not at all of a problem and designing with in mind the effective environmental potential of local climates was certainly not considered as a major priority.

For our young researchers, no matter the reasons for more or less faulty luminous interiors, the merits of daylighting post occupancy evaluation helps to raise constructive disputes among local building designers for what need to be avoided within future places.

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