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Office buildings' daylighting design in hot arid regions: forms, codes and occupants' point of view.

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Office Buildings Daylighting Design in Hot Arid Regions - Forms, Codes and Occupants' Point of View

A. Belakehal, A. Bennadji and K. Aoul

***Abstract*—**In hot and arid regions, contemporary designers need more daylighting related information in order to achieve an environmental friendly and energy efficient architecture design. This paper presents the results of a Post Occupancy Evaluation research undertaken in an office building in the city of Biskra, Algeria. This POE aims to fill this lack by providing practical information. The field work took place during summer in the building of La Caisse Nationale des Assurances Sociales (a major state insurance company). Firstly, the study results presents the different shape and photometric ratios revealed by the field survey and discuss them according to the prevailing norms and design guidelines recommended for buildings under clear sunny skies. Secondly, it exposes the occupants' perception and behavior and their relationships to the shapes, photometric values and relevant standards for the hot arid context.

***Keywords*—**Architectural daylighting, hot arid regions, Luminous ambience, office design.

1. Introduction

Hot and arid regions are characterized by year round clear sunny sky. Such potential should be an enormous advantage in order to achieve an environmental friendly and energy efficient architectural design. However, the situation is another and this makes the hot arid regions presenting a suitable context for daylighting investigations. In effect, contemporary designers from these regions are against a lack of present-day architectural references that let to an adequate daylighting design avoiding overheating and glare problems. Besides, the vernacular apertures aiming to admit daylight and control sunlight are irrelevant when considering the actual users' needs. In addition, the academic research work leading with daylighting has been and is always mainly focused on the overcast sky region case. Moreover, it has been proved that the physical standards for daylighting are culturally variable and couldn't be considered as absolute daylighting design parameters in any regional context.

Hence, a global approach is needed to encompass the complexity of architectural daylighting design in hot arid regions. This approach should take into account the quantitative parameters as well as the qualitative ones. Whilst these latter are human related ones, the former is dealing principally with physical aspects. For, this study adopted the notion of ambience as a main theoretical frame [1] - [2].

2. Luminous Ambience

Daylighting is defined as the practice of admitting natural light into a building in a way which reduces the use of electric lighting. Differently, the notion of luminous ambience provides a new way to investigate the relationships between natural light and architecture. In fact, it introduces the human dimension within this association. The research works on the ambience in the architectural field go beyond the definition of this notion as a situation associating people and the environment where they are localized. They stress on the sensorial aspects emerging from a certain physical stimulus that are taken for signals (sound, light, smell…) whilst they were previously thought as primary human needs [3]. Because this signal would be insignificant if it is not perceived, a focus is made on the users-receptors' behavior. Architecture and the built environment are indeed more seen as an inhabited place than a visual form.

It has also been revealed that inside an architectural space the ambiance is multiple that is to say it is not related to a single signal. This makes characterizing the notion of ambience as inescapably complex. Additionally, the context has been attested as an influent parameter in the characterization of an ambience. The context could act as: i) a physical interior environment with specific formal and spatial properties, ii) a physical exterior environment creating particular stimuli, and/or iii) by means of users dependently of their cultural, social and climatic context. Researchers pay also a particular attention to the built environment (urban as well as architectural spaces). A formal characterization is used because the architectural space remains the study object.

In a previous research work the development of a conceptual model for the luminous ambience has been carried out as an extension of what has been named a the basic model for the notion of ambience[4]. This called integrated model for the luminous ambience consists on hypothetic relationships between [5]: i) the luminous environment, ii) the architectural space, iii) the context, and iv) the user. The components of this model are of very different matters. Thus, they need an appropriate global approach and a set of research techniques in order to

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overcome the emerging difficulties.

3. Research Method and Techniques

In this study, the diagnostic level post-occupancy evaluation method is presented as the most appropriate method to globally approach a complex phenomenon like the luminous ambience is [6]. Its suitability remains largely from: i) its focalisation on the architectural space as perceived by its users (an environmental psychological place centred method), and ii) its ability to enclose several different research techniques. Hence, four of these latter are selected in order to collect the various needed data: i) the questionnaire, ii) the behavioural map, iii) the architectural survey, and iv) the photometric measurements. Because of the complexity of these data and their different natures, the analytical methods of their outcomes require a particular attention. Statistical analysis linear methods for qualitative data (multiple correspondences analysis) are those chosen because most information is qualitative (nominal or ordinal). The data resulting from the luminous environment indicators (photometric characterization) basically quantitative are converted to qualitative (ordinal) ones. This is a suitable manner to associate them to the other collected data in order to interpret them as a whole.

4. Case Study

A field investigation took place in a contemporary office building located in the urban setting of the city of Biskra. It aims to apply the proposed occupant based conceptual model of the luminous ambience. Offices present the kind of buildings where good daylighting conditions are an inescapable issue for the users' comfort. Biskra city is located in the northern part of the Algerian Sahara which is characterized by a semi arid hot climate and a clear sunny sky almost year around. The office building houses a major state insurance company (Caisse Nationale de l'Assurance Sociale). The building is five storeys high organized around an uncovered courtyard and with four facades (Fig. 1). The majority of offices are of a small size. Open plan offices are few but exist in every floor.

Fig. 1 A view of the Caisse Nationale de l'Assurance Sociale Building

A questionnaire was administrated, face to face, to thirty nine occupants (20% of the total number of occupants) in twenty four offices (42% of the total number of offices). Further, the occupants' behavior was observed, particularly their reaction to daylight and sunlight. Along, a photometric characterization of the luminous environment was done for every questioned occupant. This characterization is made in respect to an improved protocol of measurements developed for this research work [7]. Also, an architectural survey was made for every office concerned by the investigation.

5. Openings Morphological Characteristics

The first results of the study concern the openings morphological characteristics and include: i) the window size, proportion and location, ii) the window area to the façade wall area ratio, iii) the window area to room area ratio, and iv) the window head height to room depth ratio. These results are related to the offices occupied by the interviewed workers. The morphological characteristics are studied at the initial condition as the architect designed them. That is to say, the various occultation introduced by the workers, by means of movable solar protections, are not taken into account at this level of the results presentation.

The openings size is of two kinds: i) small windows looking as holes in the wall, and ii) larger openings with various sizes. According to Baker et al classification [8], the shapes of this second openings category vary from vertical to intermediate. No horizontal openings exist in the CNAS office building. The smallest openings have mostly a square shaping. 41% of the interviewed occupants are working in offices with an opening located at the middle of the façade wall whilst 59% of them have their opening near the wall corners.

The window area to the façade wall area ratio (WWR) varies from 4% to 55% in the investigated offices. More than a half (59%) of the interviewed occupants works in offices where the WWR represents less than the quarter (25%) of the façade wall. Nearly the quarter of them (23%) are in offices with a WWR equal to 25%. A small number, but not less significant, of occupants (15,4%) are in offices with a WWR between the 25% and 50%. Very few workers (2,6%) occupy offices with a WWR superior to 50%.

The window area to the room area ratio (WRR) varies from a minimum of 7% to a maximum slightly superior to 60%. The third (33%) and more than a third (38,4%) of the interviewed workers occupy offices where the WRR is varying respectively from 20% to 30% and from 30% to 40%.

The window head height to the room depth ratio (WDR) maximum and minimum values are respectively 1,03 and 4,60. Slightly more than the three quarters of the interviewed employees are working in offices where the WDR is under the value of 2 whilst for 15,4% of them the WDR is between 2 and 3.

6. Photometric Characterization of the Luminous Environment

The second part of the research results focuses on the luminous environment characterization by means of a set of photometric measures. These latter are taken at the office worker eyes level for both micro-visual field and macro-visual field. The former is the field seen by the office worker when achieving his task (looking at the task area).

The latter is the one viewed when he raises his head and looks frontward. The illuminance value at the task level is the measure used in order to characterize the micro-visual field. The maximal luminance value is adopted for the macro-visual field one.

The illuminance values measured at the task level for the surveyed office workers vary from a minimum value of 18 lux to a maximum one of 1078 lux. For 30,5% and 46,1% of the office workers the illuminance value is, respectively, ranging from 100 lux to300 lux and from 300 lux to 500 lux. A few of them are working under illuminance values inferior than 100 lux (10%) or superior than 1000 lux (2,6%) (Fig. 2).

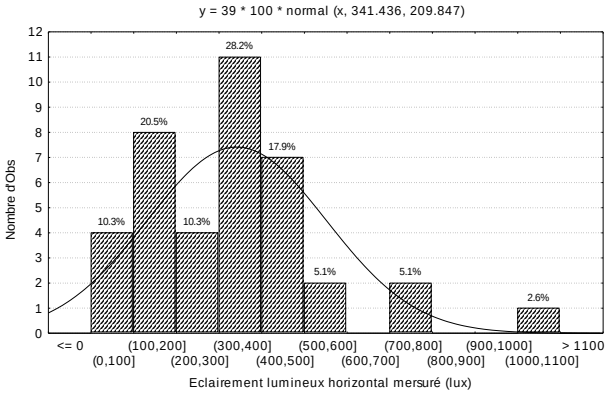

Fig. 2 The measured horizontal illuminance values

The maximal luminance value received by an interviewed occupant from his macro-visual field is 4995 cd/m^2 whilst the minimal one is 7 cd/m^2 (Fig. 3). An important number of the surveyed occupants (71,8%) receive luminance values under 500 cd/m^2. Few of them are in front of surfaces reflecting luminance values of 500 cd/m^2 to 1000 cd/m^2 (7,7%) and 1500 cd/m^2 to 2000 cd/m^2 (10%).

Fig.3 An example of a picture showing the values of the measured luminance in the macro-visual field

7. Comparison with Codes and Design Guidelines

Building design standards could be performing established by ergonomics and building physicians such as illuminance and luminance ratio values. They could be also prescriptive preferred by architects and known by rules of thumbs. However, the Algerian building regulation did not include any daylighting standards for public buildings. Because of the lack of such information, it was decided that the results of the study will be discussed in comparison with current academic daylighting design guidelines. A more attention is paid to those specific to hot arid /clear sunny sky regions.

The result of a previous research work on window size in hot and arid climate reveals the influence of window shape and size on sunlight penetration [9]. It attests that vertical windows are efficient only for the south-east and south-west oriented facades. For a similar wall depth (36 cm), it is recommended the use of windows with a width inferior to 75 cm. From the daylighting point of view, another study focusing on daylighting design in buildings under a clear sky shows that the variation of the window shape from extreme vertical to extreme horizontal did not affect significantly the illuminance values at the horizontal level particularly at more than 2m from the window [10]. However, it is the window area which contributes strongly to the variation of the illuminance levels at the deepest zones of a room. In addition, the vertical narrow opening located at the walls corners is very suitable in regions when clear sunny sky prevails. This should allow a better protection against glare effects [11]. In respect to these findings and to the orientation of the studied building facades, it will be clear that the large vertical windows create some sun penetration problems. These latter should in turn affect the luminous ambience inside the offices. Moreover, their location within the façade wall is not effective for the glare protection.

For Biskra city, the Mahoney tables give a WWR varying from 15% to 25% [12]. This ratio is respected in the offices occupied by 82,1% by the interviewed workers. Three values are recommended for the WGR: i) from 10% to 12% [13], ii) 8% to reduce to 6% for the case of extreme desert regions [14], and iii) a minimum of 6% [15]. Only one, among all the investigated offices, has a WGR which is respectful of the recommended ratio for similar climatic regions. Recently, the efficient daylighted zone has been extended from 1,5 to 2 for the case of a sidelighting room [16]. According to this value, the window head height to the room depth ratio of the studied offices shows that 75% of their occupants are working within the efficient daylighted zone.

The recommended illuminance values for the micro-visual field (at the task level) in an office are between 200 lux and 600 lux [17]. For the case of the macro-visual field, Baker et al [8] assert that a luminance value superior to 500 cd/m^2 has to be considered as glaring when the room is daylighted. The same value is confirmed by a different author for the case of the luminance reflected from a big size zone like a window or a wall [18]. In addition, he specified that for the luminance of sky perceived through the window a value of 2000 cd/m^2 is inconvenient. The measured values at the work stations reveal that those exceeding 2000 cd/m^2 represent only 7,8% of them. Also, they show that among 39 analyzed macro-visual fields, only two includes values superior to 500 cd/m^2.

8. The Occupants' Point of View

The interviewed occupants have been asked about the luminous environment of their offices. The windows

occultation by means of movable solar protections (curtains) has been also analyzed which led to new ratios.

About the luminous environment on their desks (micro-visual field), a pilot study reveals that the suitable question form within concern to this matter should be related to their eyes fatigue where they are performing their tasks. Slightly above the third of the interviewed occupants (35%) said that it was not fatiguing at all, 20,5% not fatiguing, 10,3% neutral, 20,5% somewhat fatiguing and 12,8% too fatiguing. The luminous environment at the macro-visual field is qualified by 74,4% of the interviewed occupants as suitable, 23,1% as too clear and only 2,6% as too dark. The zone where are located the desks is described as a clear one by most of the occupants (94,4%) whilst solely a few of them perceived it as gloomy (5,1%). The statistical data analysis does not reveal any significant relationships between the measured values and the occupants' answers as it is usual in experimental research work settings. This may be due to the fact that a field studies emphasizes more variables than the experimental ones and a linear relationship should not be easy to carry out.

The pilot study shows that the office workers adjust the heavy curtains in function of the time of the day. Thus, a survey of this action has been done at the same time of the photometric measuring (Fig. 4).

Fig. 4 A view of an office showing the effect of the use (above) or not (down) of the curtains on the luminous environment

The results of the survey are presented in the form of two values: i) the occultation percentage and ii) the WRR after occultation of the window. The first value represents the area of the occulted area of the window as a percentage of the whole (initial) window area. Slightly above the quart (28,2%) of the occupants occult less than 20% of their window whilst 23,1 %, 20,5%, 15,4% and 12,8% occult respectively 20% to 40%, 40% to 60%, 60% to 80% and above to 80%. The WRR for an important number of the office workers (74,6%) became not exceeding 25% (Fig. 5) whilst this ratio value (from 20% to 30%) exists for the offices where work only 38,4% occupants.

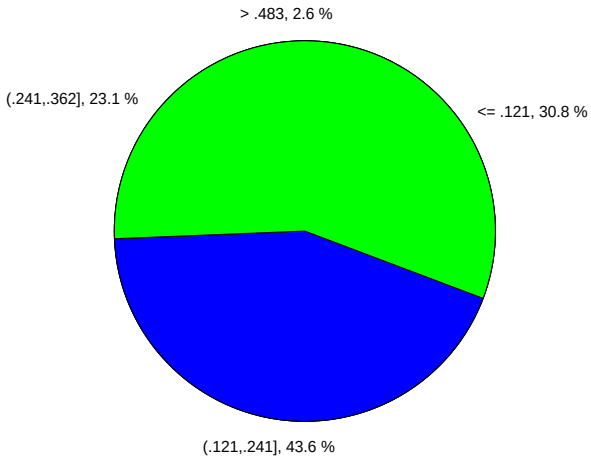

Fig. 5 The various categories (in percentage of the interviewed users) of the occulted window area to the room area ratio (WRR)

9. Conclusion

Whilst daylighting is more and more perceived and proved to be an efficient strategy for a sustainable design, the hot arid regions seems to not being ready to take advantage of the great benefit it posses that is daylight. This research work shows that Algeria as a country form this area of the world has not any building regulation or any recommendation related to daylight for public buildings. This study tries to look at this topic by means of a theory and an approach involving the users' perceptions and behaviors.

The results reveal that the building design was not respectful of the daylight related guidelines for building in the hot arid regions. This could inform about the knowledge of the architects about daylighting design which in turn invites to explore this area within the architectural practice and training. This became particularly more and more pressing at the time when sustainable design is one of the keys to preserve earth life.

The study outcomes show also that the users adapt their luminous to their needs and their comfort levels by simple means such as curtains. However they did not give precise relationships in order to fond performing and/or prescriptive daylighting design related building codes. For, it could be suggested undertaking more experimental research in this topic for the case of building under a clear sunny sky.

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He published several papers and his PhD thesis was published as a book twice to reach a wider audience.