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SCALE-MODEL BASED COMPARATIVE ANALYSIS OF SOME ALTERNATIVES FOR THE DESIGN OF A LUMIDUCT

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ABSTRACT

The redesign of a school building of Almedina in the centre of Coimbra, an ancient town in the centre region of Portugal, has had, among other concerns, the objective of improving the visual comfort of the school's occupants. Several measures involving the use of conventional windows, open spaces and adequate artificial lighting options, have been considered.

In particular, a lumiduct has been included in the design, that has been considered as a means of providing a presence of natural light at the west end of a corridor, to be sensed by the occupants in two of the floors of the building, and some daylight to the dressing room next to the existent gymnasium.

Hence, daylight availability was to be evaluated in order to assess energy performance complementary aspects of the architectural design, this one primarily intending to use natural light as a means of improving esthethics and occupants satisfaction thereof.

The test in a scale model, for several situations created by differents material and arrangements of the building elements, have been used as a support to the final solutions of the lumiduct design.

THE SCALE MODEL

A scale model (1/20) has been used, that allowed the testing of three different configurations for the non vertical external aperture of the lumiduct. It also allowed the use of different materials of lumiduct walls and different kinds of glazing for the internal apertures existent at the two upper floors along the lumiduct way.

In Fig. 1 a very schematic representation is made of the layout of the measurements. The dotted lines above and aside the lumiduct represent the possible surfaces for light penetration, both transparent. In some of the tests the horizontal surface has been obstructed to simulate the possibility of a lateral light penetration only (West facade).

In Fig. 2 an alternative design of the top of the lumiduct is depicted, in a simplified perspective. This particular design is an architectural option aiming redirecting light by means of a white painted wall at the north side of the top aperture.

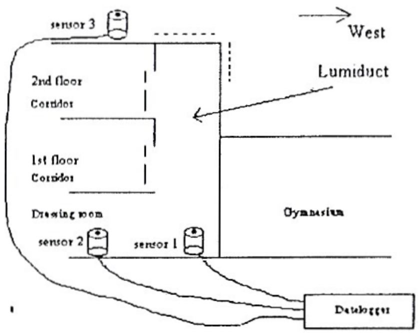


Fig. 1. Scale model whit external apertures

Back to Fig. 1, the hatched vertical lines between the lumiduct and the corridors represent apertures that have been either obstructed, or provided with transparent glazing, or provided with translucid glazing. The total obstruction case intended to assess the light "losses" as viewed from the dressing room, by comparison to the unobstructed cases.

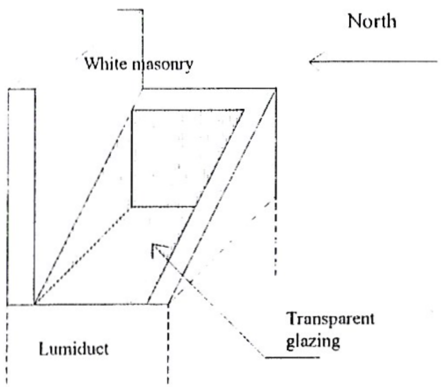


Fig. 2. Top aperture alternative design

The tests have been conducted whit two different surface conditions of the lumiduct internal walls: white painted or covered whit aluminium foil for high reflectance.

DATA COLLECTION

Data have been collected by means of three sensors and a datalogger, as depicted in Fig. 1. Sensor 1 was placed right below the lumiduct aperture, sensor 2 inside the dressing room, approximately at the centre, and sensor 3 at the rooftop of the model, to measure global illuminance.

ORGANIZATION OF THE TESTS

The tests have been carried out for several situations created by different arrangements of the building elements and also for clean and overcast sky. Table 1 summarizes the set of situations where data have been collected.

The interval between measurements has been set to 1 minute. The values obtained have been averaged to fit to five minute intervals between contiguous points in the graphical representations below.

TABLE 1 Lumiduct tests

Test case n°	Non vertical external glazing	Internal lumiduct walls	Vertical internal glazing	Vertical internal glazing	Sky
1	Horizontal obstructed	White	Open	Transparent	Overcast
2	Horizontal obstructed	White	Open	Transparent	Clean
3	Horizontal obstructed	Aluminium	Open	Transparent	Clean
4	Horizontal obstructed	White	Open	Translucid	Clean
5	Horizontal obstructed	Aluminium	Open	Translucid	Clean
6	Horizontal obstructed	White	Obstructed	-----	Overcast
7	Horizontal obstructed	White	Obstructed	-----	Clean
8	Horizontal open	White	Open	Transparent	Overcast
9	Horizontal open	White	Open	Transparent	Clean
10	Horizontal open	Aluminium	Open	Transparent	Clean
11	Horizontal open	White	Open	Translucid	Clean
12	Horizontal open	Aluminium	Open	Translucid	Clean
13	Horizontal open	White	Obstructed	-----	Clean
14	Tilted open	White	Open	Transparent	Clean
15	Tilted open	Aluminium	Open	Transparent	Clean
16	Tilted open	White	Open	Translucid	Clean
17	Tilted open	Aluminium	Open	Translucid	Clean
18	Tilted open	White	Obstructed	-----	Clean

Measurements have lasted for several days in June, 1994 and 1995, when variable sky conditions have been observed. Most of the cases refer to clean sky, as this is the condition that prevails for most of the days of the year in the city of Coimbra.

RESULTS

Results of measurements for the different tests conducted have been organized in the following charts. for the sake of legibility, where illuminance values are plotted. In each on, the left axis represents global illuminance and the right axis represents internal illuminance, in lux.

The lines in every chart are to be interpreted in the following way:

- Thick solid black: external illuminance
- Thin solid black: internal illuminance, right below the lumiduct
- Gray: internal illuminance approximately at the centre of the dressing room

CHART 1 - Test case n° 1

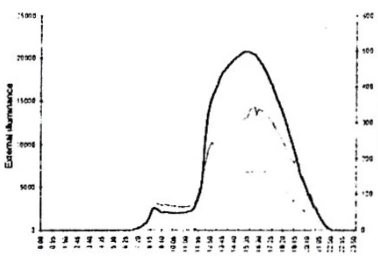


CHART 2 - Test case n° 2

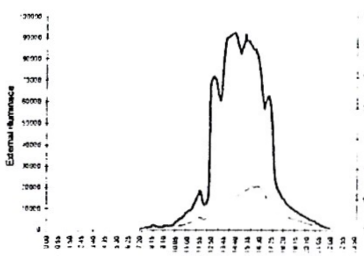


CHART 3 - Test case n° 6

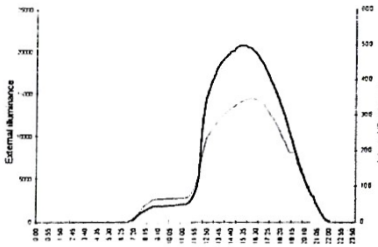


CHART 4 - Test case n° 7

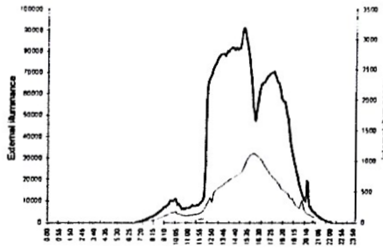


CHART 5 - Test case n° 8

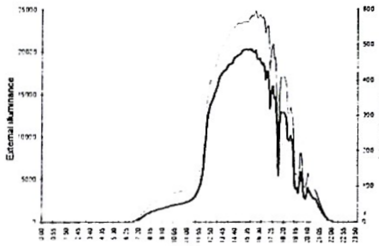


CHART 6 - Test case n° 9

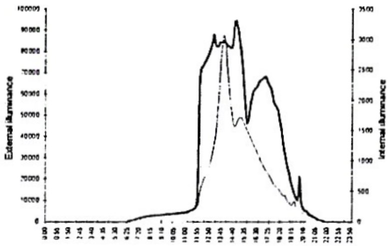


CHART 7 - Test case n° 11

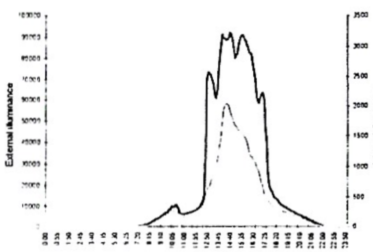


CHART 8 - Test case n° 12

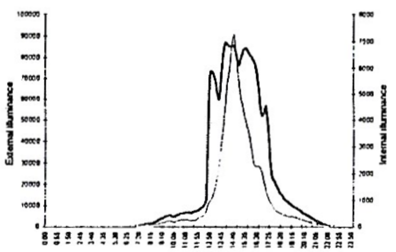


CHART 9 - Test case n° 13

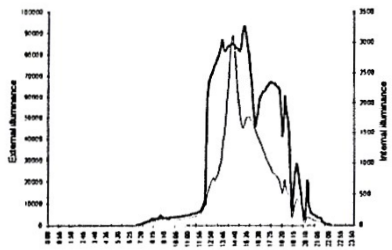
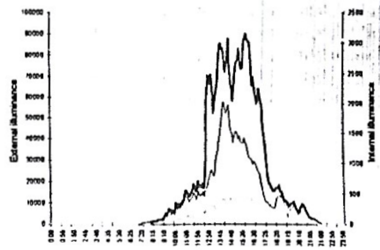


CHART 10 - Test case n° 16



COMMENTS AND CONCLUSIONS

When one considers the internal illuminances right below the lumiduct, there is a appreciable difference between the cases where the lumiduct has only a lateral aperture facing West and where it also has a top horizontal aperture, internal lumiduct walls being white painted. This is easily confirmed when one compares eg. test cases nos. 1 and 8 for overcast sky, or test cases nos. 2 and 9 for clean sky. With clean sky conditions, this difference is emphasized.

Moreover, the existence of a top aperture in the lumiduct anticipates the occurrence of the maximum internal illuminance value.

The results obtained clearly indicate that the final solution should consider the top aperture, so much the more that Coimbra has a high percentage of days per year with clean sky conditions. Also, the internal apertures of the lumiduct seem to have no significant influence on the illuminance registered inside the dressing rooom. On one hand, it seem feasible, by comparison to test cases nos. 9 and 11, to conclude that the maximum illuminance values measured inside the room do not differ when the internal apertures have transparent or translucent glazing. On the other hand, the existence of the apertures themselves seem to have no influence on the same variable. In fact, if one compares test cases nos. 1 and 8 for overcast sky, or test cases nos 2 and 9 for clean sky, it is possible to verify that when no apertures are considered (test cases nos. 6, 7 and 13) the internal illuminance values are very similar to the cases when apertures exist.

From the above comments it seems acceptable to consider that, for architectural reasons, internal apertures be provided whit translucid glazing to allow some natural light to be visible from the corridors of the both floors, but keeping in mind that the absence of internal apertures do not alter significantly the performance of the lumiduct.

Tests cases nos. 11 and 16 indicate that also the alternative design for the top aperture shown in Fig. 2 does not influence significantly the lumiduct's performance from the point of view of illuminance value inside the room.

Finally, comparison have been made between the two referred different finishing characteristics of the limiduct's internal walls. For this purpose, the situations of unobstructed horizontal top aperture and translucid apertures have been considered. Tests cases nos. 11 and 12 show the better performance of the case with high reflectance provided by the aluminium foil.

Illuminance measured in the centre of the dressing room is not only much lower than the one measured right below the lumiduct, but it also is rather insensitive to variations in those conditions that influence most the lumiduct performance. This is most probably due to the absence of some means of diffusing the light coming from the lumiduct to the room in order to guarantee a more uniform distribution of light. Hence, some solution to this problem should be considered in the final design.

In general, it may be concluded that one possible efficient configuration for the lumiduct consists of using the top aperture design shown in Fig. 2, internal apertures provided with translucid glazing and some diffusing device at the bottom of the lumiduct to provide higher illuminances at the back zone of the room.
Complementary, if cost is not seriously affected, the use of a highly reflective material, as aluminium, in the internal walls of the lumiduct should be considered.
The use of a scale model in the case study confirmed the virtues of previous simulation by this technique as a means of validation of architectural solution for efficient building design.

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