The Relationship Between Inner Space Features and Daylighting Internally Reflected Component

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ABSTRACT: Daylighting presents a series of attributes that proves its usefulness in the architectural design. The addition of daylight in a space may bring benefits related to aesthetics, health, and energy saving. The purpose of this article is to study how the inner space geometry, the openings percentage, positions and distribution in buildings façades affect the values and distribution attributed to the Internally Reflected Component (IRC). Such knowledge should allow establishing parameters and relations among the mentioned variables so as to fill the gap in the existing bibliography. The simplified methods foreseen and used by the present Brazilian legislation to assess the daylit environment do not take into account the light basic components, which affect the internal spaces. Therefore, this fact influences negatively in the prediction of light behavior. Daylighting contribution in an environment depends straight on the sky component, on the light reflected on external surfaces and also on the light reflected on internal surfaces, among others, being this knowledge crucial for a good comprehension of the daylit environment.

Keywords: daylighting reflected component, comfort, space geometry.

INTRODUCTION

Contemplating daylight as a project component might bring countless benefits to the building. Schools, offices and commercial premises that make use of suitable daylight contribute to a better performance of its users [1,3]. Heschong et. al (2003), in his studies regarding daylight in schools, demonstrate the positive relationship between daylight and the students` performance, enhancing the visibility due to the increase of daylight, promoting a better quality of the luminous environment, mental stimulation, boosting humour, behaviour and wellbeing. Not to mention its importance in energetic terms, consolidating its capacity to reduce the building energy consumption apart from declining the peak demand [7].

It is the architect`s responsibility to work daylight captured and chiefly, to intervene in the indirect illumination (fig 1). The internally reflected light correct manipulation might decrease the contrast in the environment, and therefore assure a better distribution of the light [2]. The internally reflected light will rely not only on the walls reflected factors, but also on the environment shape [8]. A satisfactory result will be achieved if daylight and the consideration of the environmental principle are regarded as the main principles [9].

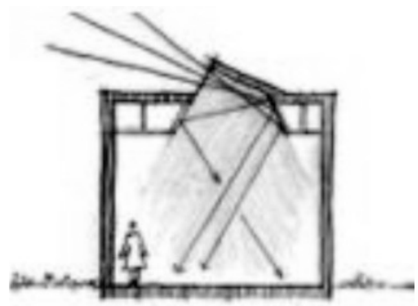

Fig 1. Direct and indirect solar illumination..

METHODOLOGY

The present work aims at tackling the IRC contribution inside the buildings through theoretical models using computer simulation, manipulating variables values and parameters, which affect the reflected light in order to ensure both the quantity and mainly the quality of the daylit environment. The software chosen was Apolux which uses the radiosity algorithm, developed by the Laboratory of Environmental Comfort, Federal University of Santa Catarina [4]. The results obtained in these models were compared with measurements in the scale model of a real building performed under a mirror-box type artificial sky. This comparison has enabled to address daylighting design through geometric drawings and openings features manipulation. Through such considerations it was possible to relate theoretical models to the design reality faced in architect`s daily routine. With the intention of observing daylight behavior concerning the environment configuration, four standard models were developed from which all the other models are derived. They have the same area, but the length, width and the ceiling height present variations.

The first model consists of a square base with three metres ceiling height, being the other models originated from the former. The second and third are parallelograms, one long in length and the other in size, both keeping the same ceiling height. The fourth keeps the first's same base, however, its ceiling height is increased by 25%, see table 1. Through these geometries, it is possible to highlight the reflected light correlation in four possible environmental conditions: intermediary (A), deep (B), wide (C) and high (D).

Table 1: Models characteristics.

MODEL	A	B	C	D

The floor area common to all the models allowed the comparison between the results. From these geometries, models that alternate features of the apertures and surfaces properties were developed.

A graphic method was adopted with the purpose of understanding the distribution directions taken by light through respective drawings. The graphic method describes the use of a set of concepts, taking into account the different types of daylit environments as a general party design tool. This method assumed that the reflected light can be directed to a certain internal area according to the following categories: spacial geometry, apertures and surfaces features. As far as daylighting is concerned, the apertures are regarded as the main sources; therefore, they are crucial elements to classify the internal reflected light direction. With the purpose of enabling the reading of such directions, a classification was developed, presenting a lighting distribution tendency with lateral and zenital apertures, and identified as: central, edges, opposed, lateral and parallel to the apertures (fig.2). Since this classification considers every aperture, the space is divided into 9 quadrants of the same area. The ones which reveal the highest percentage of daylight factor, concerning internally reflected light (DFr), will be responsible for the light directioning in the environment [6].

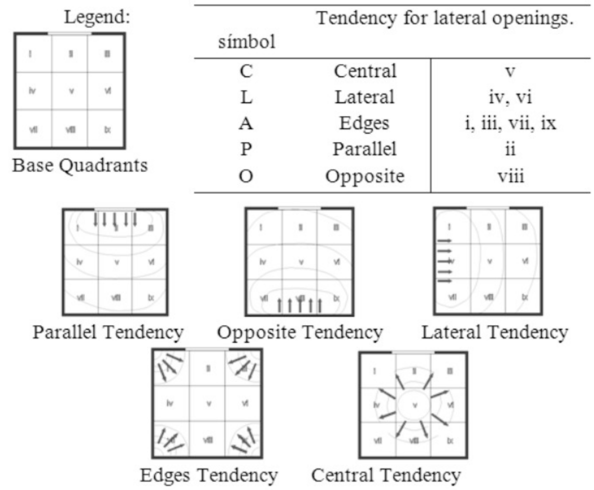

Fig 2. Light distribution tendencies classification..

RESULTS

The results obtained in all the theoretical models evaluation will be described, with regard to every category. A single model of the respective analysis group was selected to be compared to the real building ligthing sample. Firstly, a contrast between the theoretical model and a real building will be introduced considering the environment geometry influence in the internally reflected lighting performance. Then, the light behaviour will be stressed as the apertures features are altered. The selected architectural samples were the Slice House, the Cascais House and the Light Chapel.

Room Geometry X Internally Reflected Light As far as the geometry is concerned, it might be concluded that the environmental floor plan is the crucial element in the light directioning. Modifications in the length and width might alter the luminous environment configuration, whereas variations in height just change the reflected light intensity.

Intermediary classified environments and those with higher ceiling, with a centralized aperture, reflect the light from the surrounding edges and from the window opposite surface; whereas in deep environments the light is reflected in the edges and in the wide ones on the opposite surface.

The ratio between the envelope and the aperture areas might be taken as an assessment parameter of the reflected light performance. Considering that it presented a relevant correlation for quantitative characteristics (DFrm- **D**aylight **F**actor **M**edium **R**eflected), and for qualitative ones (IRC contribution- **I**nternally **R**eflected **C**omponent). Contemplating the results obtained, it might be suggested that the correlation between the environment shape with the aperture strongly influence the reflected light behaviour. In order to obtain a better performance of such reflections in deep environments, the architect must focus on the surfaces closer to the edges adjacent to the aperture. However, in the wide ones the focus would be on the surface opposite to the window.

A piece of work that tackles such type of architectural solution is the "Slice House" – architect's Fernando Rihl (fig. 3). A study accomplished in a laboratory at the Federal University of Santa Catarina, evaluated daylight conditions through physical scale model under an artificial mirror-box sky, where the main room is assessed. The room presents a superior aperture (swimming pool bottom) on a narrow face and opposite it there is a large access opening. Perpendicular to the previous faces there is an upper opening on one of the wider faces.

In a second moment the environment with the wider face opening closed was assessed. Despite the measures have been developed considering the total illumination, the maps comparison resulted from such measures with the maps produced with reflected light simulations (I_C models -fig 4.), exemplify how the reading of theoretical models can be applied to the architecture. The green spot indicating the light level reduction, when the opening is closed, coincides with the form of light distribution in the theoretical model, spreading from the wall opposite to the opening, Fig. 3. Through the opening closure it is possible to demonstrate that the reflected light loss was extremely significant to the context, proving its contribution to the environment illumination.

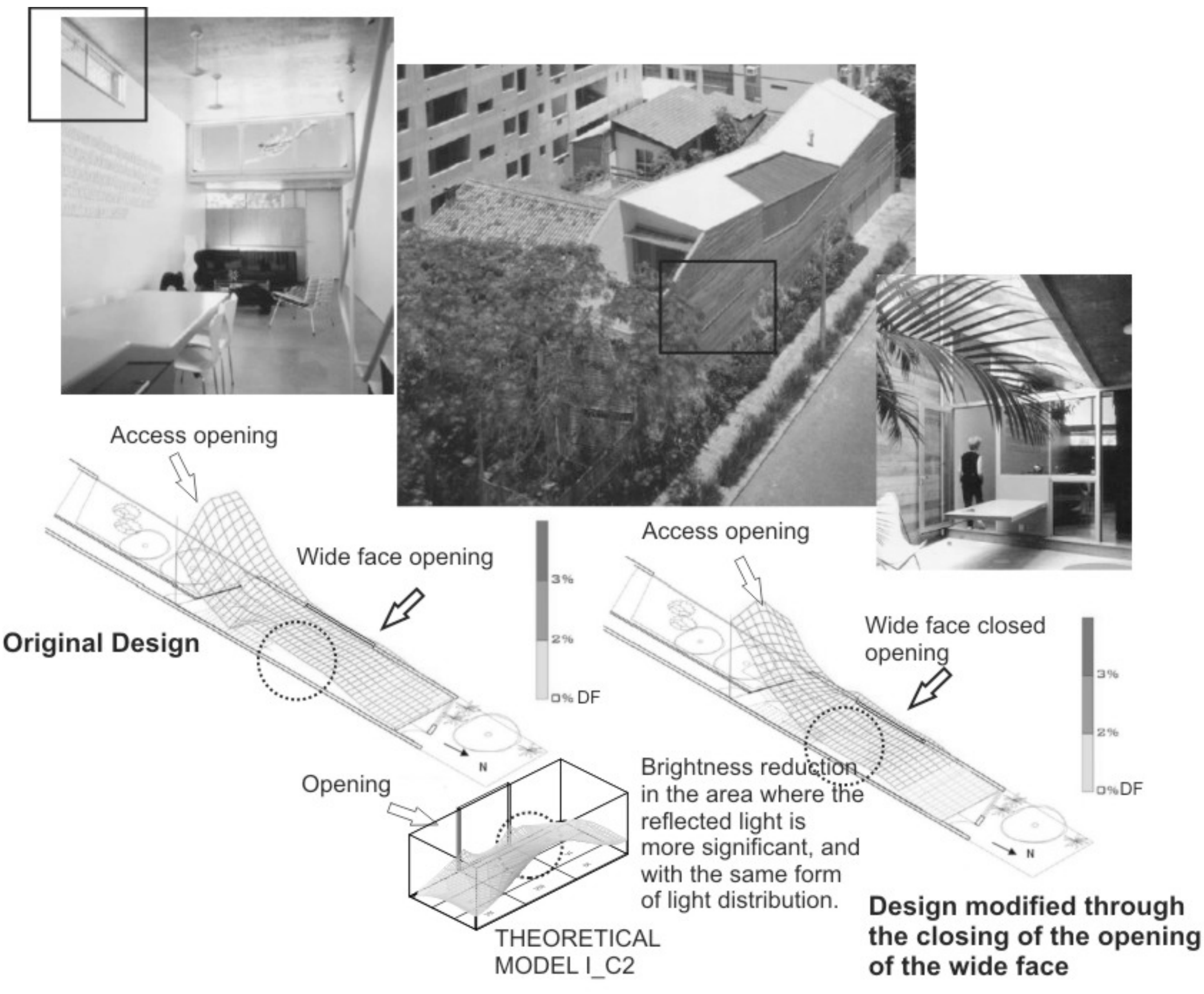

Figure 3: Relationship between theoretical models and architectural example. Slice House -Brazil.

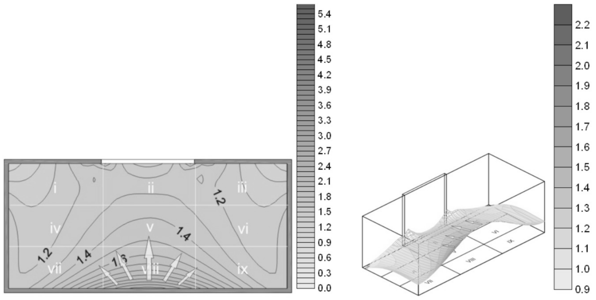

Figure 4: 2D ands 3D Daylight Factor Reflected maps of Theoretical model I_C2 - Opposite Tendency (scale DFr)

Opening Features X Internally Reflected Light – Aperture Percentage As for the opening analysis, it was concluded that the increase in the percentage of the opening does not affect the light direction tendency and it only increases the reflected light intensity. Figure 5 shows a luminous study, regarding the percentage of the opening about a room at Cascais House of architect Eduardo Souto de Moura. The study was accomplished in laboratory, in the same way than the former one. After comparing this study with the simulations developed in a theoretical model with an opening percentage of 25%, a similar light behaviour could be noticed in the architecture.

The house presents a frontal chief opening characterized by a great glass panel and by a narrow vertical opening on the left corner in the opposite façade. An experiment was developed creating an elevated opening, with dimensions close to 25% of the back façade area. Even considering that the experiment simulations take into account the total light, the light answer can be considered similar to the model II_B1(fig. 6), where the reflected light main contribution takes place next to the opening, coming into the environment, fig. 5. Although in this case, there is already a main opening, this type cooperates to create a balanced luminous environment, mainly in deep environments.

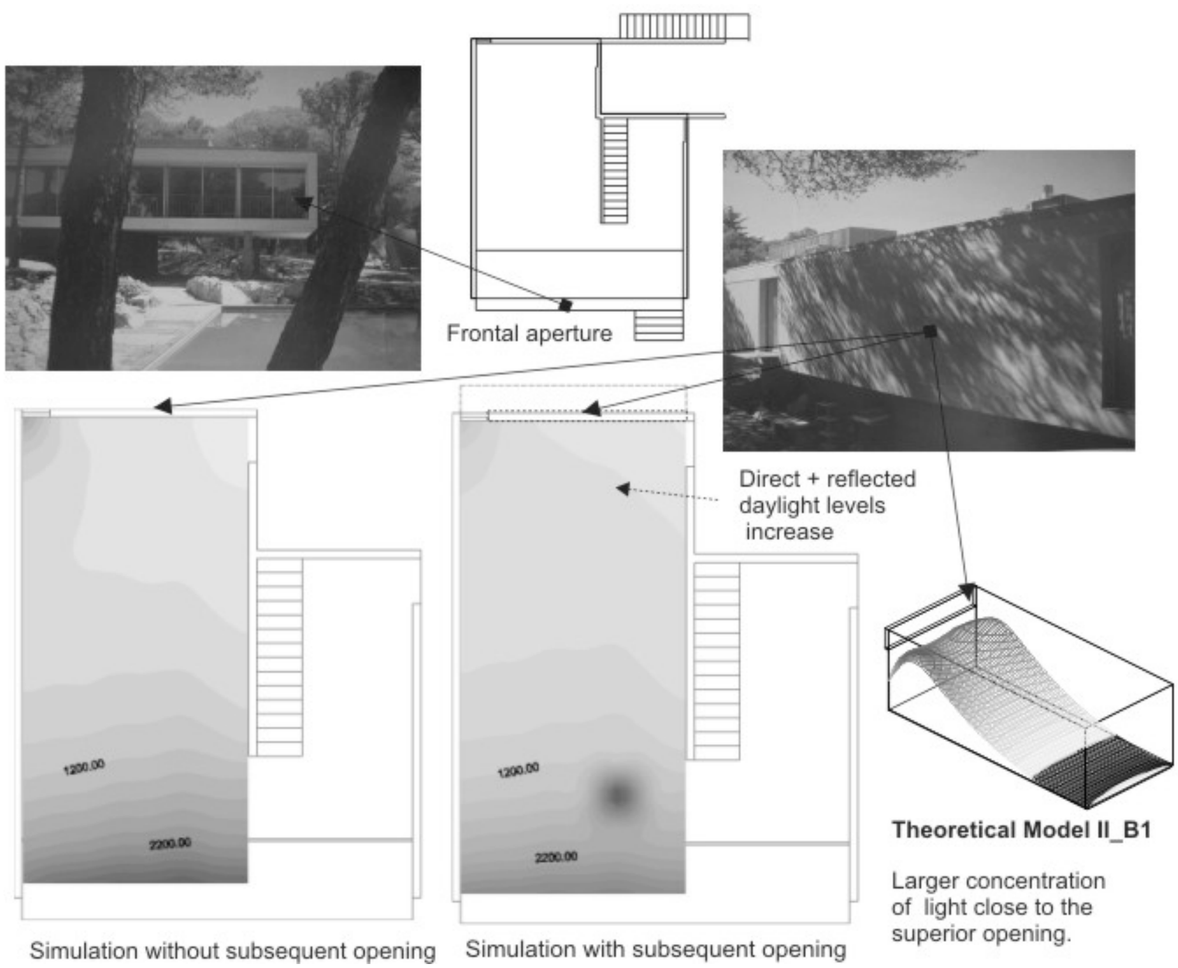

Figure 5: Relationship between theoretical models and architectural example. Cascais House- Brazil.

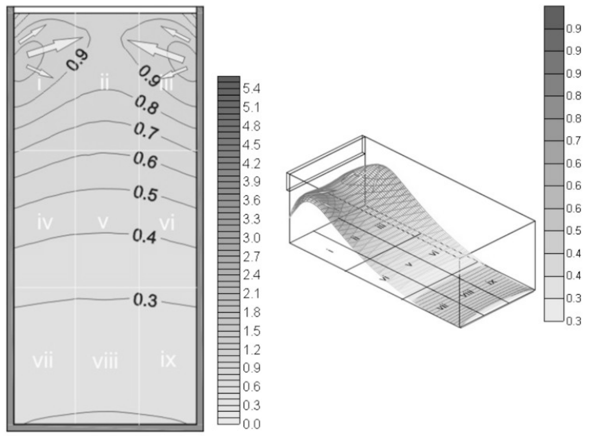

Figure 6: 2D ands 3D Daylight Factor Reflected maps of Theoretical Theoretical model II_B1 - Edges Tendency (scale DFr)

Opening Features X Internally Reflected Light – Aperture Position A change in the positioning of an opening can alter the tendency in the light directioning. The result of such change in the position modification occurs in a singular way to all spatial geometry. However, it is quite similar when the geometric difference is just in the height.

Centralized zenithal openings will always reflect the light on the closest vertical surfaces, promoting a tendency in the light directioning from the lateral surfaces regardless its geometry. The Light Chapel from the Japanese architect Tadao Ando, which is an emblematic building, was chosen to observe the reflected light influence according to the apertures positioning. The object in study is a slit in the shape of a cross, compared to the theoretical model III_B1 which presents a vertical aperture.

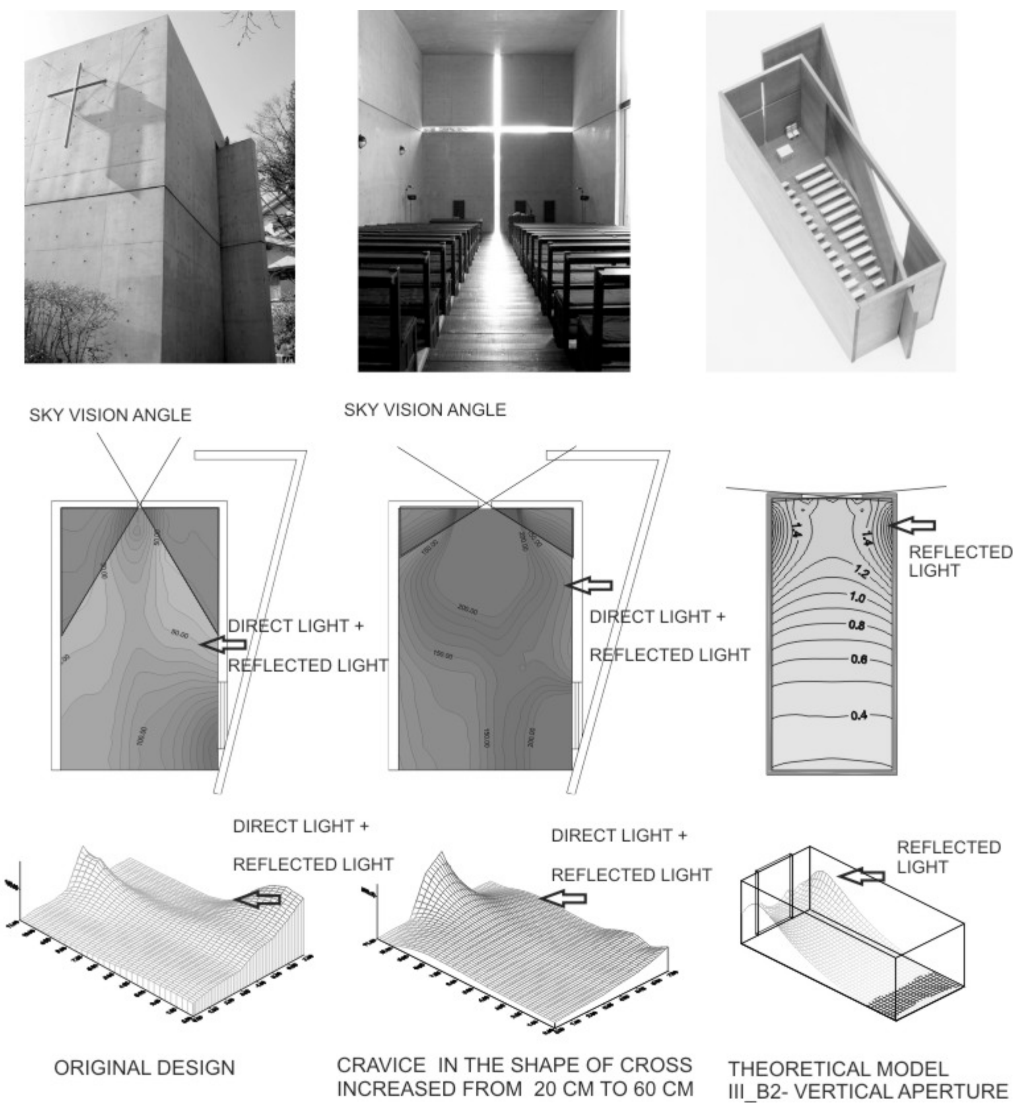

Figure 7: Relationship between theoretical models and architectural example. Light Chapel- Japan.

From the results obtained it could be inferred that the largest the opening becomes, the light reflection will take place closer to the adjacent edges of the respective aperture. This environment portion will consequently present higher light levels. Such phenomenon is explained by the visible sky angle through the aperture dimension (fig 7). Figure 7 shows the original floor plan, where only the church front portion was evaluated in a 1:20 scale model. In this model, the cross slit was enlarged from 20 cm to 60 cm, and compared to the theoretical model III_B2. The direct illumination is added to the reflected one in the models measured under artificial mirror-box sky, whereas in the theoretical model only the refleted illumination is taken into account. It is also known that in the models which depict the chapel, the cross horizontal element affects the lateral illumination. Nevertheless, a source of light distribution could be observed from the lateral walls for the three respective models keeping their various proportions.

CONCLUSION

The research enabled to devise the correlation of the IRC with the room and fenestration physical features. The comparison with the real buildings, like the Slice House - Fernando Rihl (related to inner space geometry), the Cascais House - Eduardo Souto de Moura (related to apertures percentages) and the Church of Light – Tadao Ando (related to apertures position), allowed to stress daylighting design through geometric drawings and apertures features. The obtained results permitted to analyze which environment features strongly influences the reflected daylight performance, and how to better explore this lighting component, in order to improve the daylit environment quality. In addition, the applied methodology can be used as a practical tool to investigate and design reflected light solutions in the initial architectural design stages.

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