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Perforated Facades Design Approach to Sustainable Building for Visual and Thermal Comfort

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Abstract—*Perforated walls, panels, and screens are often related to the architecture of hot climatic regions, including North Africa, Middle-East, and Asia. The screens in addition to filter the light and air - while allowing the selective privacy - can contribute for the distinctive customization of a building. Screens with complex patterns can now be created quickly and easily in various types of material due to the development of computer-controlled technologies.*
Sustainable architecture design helps to improve the construction process or restraint in the use of materials, energy and minimize the negative environment impacts in the economical ecosystem. Design and sustainable construction processes that justify these perforated screens as technological and decorative element simultaneously. Thus, special attention is given to the need to support designers to design better buildings - using the constructive solution perforated facades - with relevance to the understanding of how the environmental comfort (thermal, acoustic and luminous) influences the design of perforated facades screens.

Keywords*: Perforated panels, optimization, thermal comfort*

1. INTRODUCTION

Understanding the factors, which have their genesis in issues such as Sustainability; The Quality of Life and Energy, identified by the need to optimize the relationship between visual comfort and thermal comfort in buildings, is the central theme of this reflection on perforated facade panels. In the buildings particularly their lighting and air-conditioning, which are mostly supply with the electricity or fossil fuels (such as coal, oil, and natural gas) are responsible, directly or indirectly, carbon dioxide (CO2) and Methane (CH4) are main Greenhouse gases (GHG) emission and these gases to contributes in global warming [1]. The International agreements at the Paris Summit (2015) related to the reduction of CO2 emissions are expected to respond the trend of non-compliance with those established at previous conferences, such as the Earth Summit (Rio de Janeiro, 1992), and the Kyoto Protocol (1997). This solution, among the several that aim to reduce environmental aggression, is the object of study of this work and presents bio-climatic characteristics that refer to the field of Sustainable Architecture. The objective of this work, related to the theoretical criteria of the perforated façade panels, is to find processes of design and sustainable building construction that adequately enable these elements of external shading.

2. LITERATURE REVIEW

The perforated panels aim to respond to about essential issues through structures, materials and equipment, with physical qualities that adequately react to the large amount of solar radiation, which acts directly on the facades of buildings.

Fig. 1: Amit Gupta and Britta Knobel Gupta, Punjab Kesari Headquarters Project.

Within these exterior shading architectural solutions is the Punjab Kesari Headquarters project, by architects Amit Gupta and Britta Knobel Gupta (see Fig. 1.), whose concept is not only the guarantee that no artificial lighting is needed on a normal day, optimizing the ratio of as well as the reduction of heat gains. It is a responsive structure created through digital simulations in iterative processes, which results from the inspiration in translating a traditional Indian facade pattern.

Among the several characteristics that define this building, the following stand out:

Illuminance level - 500 lux (at workstation height);

Daylight factor - 2 (on more than 80% of the floor slab);

Ratio of drilling - 46% to the East; 73% to the South; 38% to the West; 19% to the North;

Material - reinforced concrete with glass.

The air box between the perforated panels and the glazing provides a natural reduction of the internal air temperature because the air, already cooled by the panels, is drawn into the atrium through the chimney effect which, due to its morphology, Provides. Thus, the cooling load for the air conditioner is reduced (see Fig. 2.).

Optimized natural lighting and reduced heat gains are like concerns centred on this sustainability project.

Another example is the *Tagusgás* Headquarters building, designed by the *Saraiva + Associados* atelier, which consists of the realization of the first BREEAM (Building Research Establishment Environmental Assessment Method) certified office building in Portugal (see Fig. 3.).

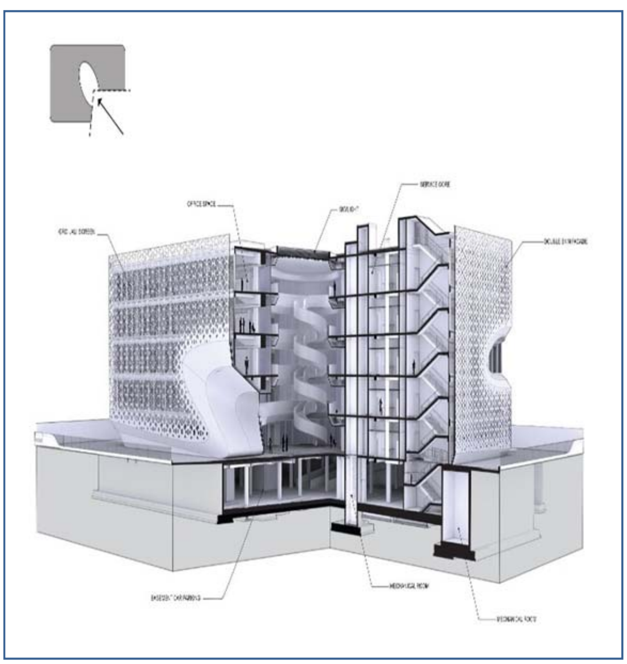

Fig. 2: Amit Gupta and Britta Knobel Gupta, Punjab Kesari Headquarters Project.

Fig. 3: Saraiva+Associados, *Tagusgás* Headquarters.

The certification was achieved by guaranteeing not only the visual and thermal comfort of its users, but also the environmental management of the building and the reduction of operating costs.

3. PRINCIPLES OF SUSTAINABILITY

The first step in achieving sustainable architecture, that is, the harmony between the final work, its construction process and the environment consists of raising awareness among all those involved in the project, that the search for their well-being causes changes in All quadrants of sustainable development. This basic notion of understanding, interpreting and / or imitating the natural cycles of planet earth is fundamental in the realization of the sustainable model that conceptualizes the building as a living being with head, trunk and limbs. An organism that breathes, feeds (energy) and is inhabited by human beings who need it to shelter, reproduce and grow.

It means, therefore, that buildings will never reach ecological and sustainable fullness, because their impact on the environment is impossible to eliminate. Despite this inevitability, it is Man's responsibility to minimize his ecological footprint, walking, and thus evolving, in search of new themes, concepts and philosophies. Aiming at reducing the aggression to the environment, one can briefly outline the main features of sustainable architecture in three criteria [2].

The use of light, versatile, collapsible, expandable and recyclable structures;

The efficiency of the insulation, lighting, ventilation and energy production functions by means of secondary elements of the enclosure (curtains, blades, frames, etc.);

The design of mass elements that guarantee optimum climatic conditions with the use of passive technologies and restoring traditional constructive methods, according to the climatic requirements.

4. TYPOLOGIES OF SHADING

The improvement of environmental comfort results not only from the prediction of the set of specific situations to which the shading systems must respond - technically and functionally - but also from the importance of classifying the systems themselves [3]. Despite its breadth and complexity, it is possible to classify the different shading systems per location (exterior, intermediate or interior). Although they are more expensive and subject to maintenance, outdoor shading systems have advantages not only economical but also architectural advantages over indoor shading systems. The outer shields are more effective, intercepting the incident solar radiation before the glazing and thus preventing the greenhouse effect. The performance of these systems also depends on the type of material that compose them. Exterior solar protections can be considered the systems installed on the outside of the glazing, forming an autonomous body on the facade. Due to the likelihood of damage, wind resistance, and climatic conditions in general, must be considered when selecting the components of the external protection. There are three main categories in which the various solutions for exterior façade protection can be classified: fixed; mobile

4.1Fixed Shading Systems

Brise-soleil: in these systems, the most widely adopted solution is the *brise-soleil* (sun-breaker), which intercepts solar radiation through a "grid" composed of linear panels or slats assembled in parallel (horizontally or vertically) in a fixed frame or adjustable.

Overhangs: incorporated in the structure of the construction, either by the projection of the slabs or by the aggregation to the facade, the blades are elements of fixed external shading.

Fig. 4: Fixed Shading Systems

4.2 Moveable Shading Systems.

Moveable shading systems consist in modifying the blinds or blades angle, allowing the optimization of the natural light quantity.

Persian shutters: consist in sliding or folding doors that can block completely the solar rays or, sometimes, with operable slats, that can be either adjustable to the comfort of the occupant, or composed by small slots that allow the entrance of a dim light, allowing simultaneously the air circulation. Produced in different dimensions and materials, such as aluminum, wood, and PVC, they are widely used in residential buildings.

Roller blinds: consist in winding a vertically moveable set of horizontal slats. Besides functioning as a protection to the sun’s rays and allowing air circulation through small openings between the slats, this common and economical shading system can also be controlled manually or automatically, and applied easily to the existent structure. When performing the shading function, they block too much the entrance of the light and the visual contact with the outside, being this its main disadvantage.

Venetian blinds: Like the previous one, this system is also quite common, economical, and easily applicable to the existing structures. It consists in orienting the blades to protect the interior from the direct exposure of the sun rays, and controlling the entrance of natural light and brightness, or even obtain the complete obscuration of the space. Produced in slightly variable dimensions according to the intended function, which allows an effective sun protection, and uniformly collectable by stacking successively the blades, it is typically used, not just in spans where the height is bigger than its width, but also in residential building renovations, where there is not much available space and the option for façade inclusions does not meet the aesthetic expectations or the regulatory requirements. From residential to professional ambiences, this manually or motorized protection system, can be designed for a wide range of applications.

Fig. 5: Moveable Shading Systems

4.3 Perforated panels

Large glazed spans find a sunscreen solution on the perforated panels to simultaneously create a more diffused luminosity, and filter and reduce direct sunlight. The control of the level of shading and the creation of different patterns, modules and different façades, result from the possibility of choosing the frame and the type of panel, this being one of the great advantages of these panels. In the facades of these buildings a dynamic is created by the perforated panels, whose aesthetic presence (light/shadow and translucent/opaque effects and geometry) varies per the games of natural light and the viewing angle. The application of this solution allows a new perception in existing buildings, thus representing an increase of value in the redesign of the façades.

Although wood and metal are also used, the most widely used material in the composition of perforated panels is stainless steel, as it is highly resistant to detonation and corrosion. Whatever material is used in its manufacture, this shading device must ensure adequate operability and an aesthetic value over time, avoiding the degradation of the material caused by the deposition of particles. To ensure user comfort, the designer is asked about the combination of the evolution of environmental control techniques and the detailed computational software support, to carefully choose the shading elements during the design phase.

5. PERFORATION RATIO

Influencing significantly the direct gains of solar energy and the consumption of energy, the proportion between the glazed and opaque areas of the facade. That is, the window-to-wall ratio is an important metric in the composition of facades [4].

In general, the improvement of the performance of façades in any type of climate can be achieved through strategies that can reduce the drilling area, since even if the glazing is well insulated, the thermal resistance of an opaque element is, Typically greater than a translucent one. It is also advisable to vary the drilling ratio per the solar orientation of each facade that makes up the building.

To predict, and improve, interior thermal and visual comfort requirements - such as energy consumption (based on HVAC systems and lighting); Useful natural lighting, the likelihood of glare; As well as visual contact for the exterior - in office space, Cristian Lavin and Professor Francesco Fiorito have proposed an optimized perforated panel for the protection of glazed facades [5]. This solution was tested in a virtual model, based on a multifunction room in the Faculty of Architecture, Design. And Planning at the University of Sydney, NSW, Australia, whose standards of occupancy and visual comfort closely resemble those of an office space. The model has undergone some changes, to obtain not only useful and replicable information, but also equal window-wall ratios, and a better understanding of the influence of the shading elements, thus defining the base case scenario for the study in question. The final model is a square-shaped room, located in a west-facing and north-facing drawer, and both walls have a 0.45 wall-to-wall ratio.

Per the Australian National Building Code, several premises were considered, among which:

. Occupancy rate = 0.1 person / m2;

. Luminous density ≤ 9 W / m2;

. Energy density ≤ 15W / m2.

In addition, the influence of the panels, namely on energy consumption, was better understood when considering the office as fully air-conditioned:

. Setpoint temperature for heating = 20 °C;

. Setpoint temperature for cooling = 24 °C.

In this optimization, five different reference points, corresponding to positions of a potential user (P1, P2, P3, P4 and P5) were considered, since the room represents an "open-space". The sensor point is located at eye level of a seated user and points, orthogonally, to one of the facades, thus contemplating the glare calculations. As for the period of use of the room, it was stipulated a schedule from Monday to Friday, from 08:00 am to 06:00 p.m.

Once the methodology is defined, the optimization analysis itself is started. To avoid light oscillations in the perforations of the panels, placed 0.10 m from the glazing, these were molded without thickness. The best possible solution, through the optimization process, is allowed by the possibility of composing panels with different dimensions and drilling densities in each of the two orientations. In this way, a combination of the West and North panels was performed for each of the five measurement points, aiming the optimization analysis of natural light; Calculation of energy consumption; And finally, the reflex risk analysis.

Due to the double orientation of the room, there is an amplification of issues related to solar radiation and sunlight. The absence of shading elements, in the base case under analysis, causes several problems, namely increased energy demand, lighting and the likelihood of glare; As well as the variation of useful natural illumination values along the different reference points (the results worsen the closer the points are to the glazing).

These values show a significant improvement after the inclusion of the outer perforated panels. By effectively controlling direct sunlight, which causes discomfort due to high levels of illumination, all solutions have values between 80% and 86% of useful natural illumination.

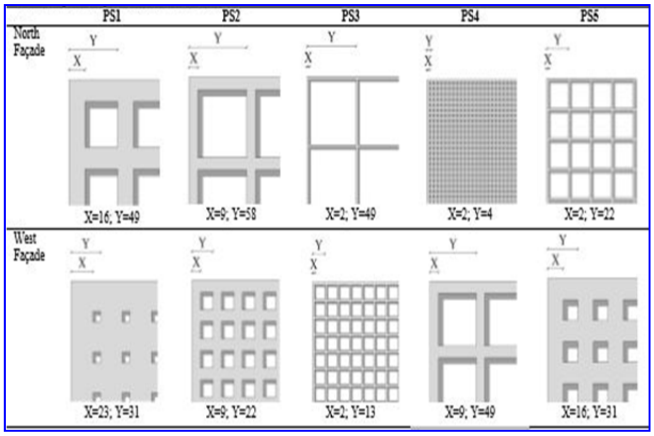

Fig. 4: Cristian Lavin and Francesco Fiorito, perforated panels optimized for each case.

The sunscreen of the west façade, because it is exposed to direct sunlight and solar radiation in the afternoon, is more opaque than that oriented to the north, except for the fourth solution where the inverse happens. The fact that P4 is situated far from the west façade may explain this exception. At this point of measurement, compared to the other points, the influence of the perforated panel oriented to the West is not so relevant. In general, there are similarities between the different cases in the dimensions and distribution of the perforations.

6. CONCLUSION

The perforated facades translate into the sun protection (shading) of the glazed areas through secondary elements (panels, screens, etc.) coupled to the surrounding building. This study on the optimization of perforated panels for facades can help to understand the importance of the distribution and the size of the respective perforations in the guarantee of visual and thermal comfort.

In the various systems covered in this work, the perforated panels are the most used for aesthetic reasons, even presenting perforations without any relation to the demands of interior comfort. The natural lighting and thermal properties of a building can be improved by these standard solutions, however, they may not be the best solution of all types of climates, since there could be losses of efficiency of the shading system in the aesthetic building. Might be perforated panels having higher coat due to material and deigns. The maximum efficiency of the perforated panels can be achieved more easily by the optimization process for each specific context to operational and maintenances.

Compared to solutions without any type of shading, the perforated panels present much better outcomes, namely in the distribution of useful natural light; In reducing the likelihood of natural light reflection; And reducing energy consumption and CO_2 emissions [6].

7. ACKNOWLEDGEMENTS

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