SIMULATION-ASSISTED DOUBLE SKIN FAÇADE ANALYSIS OF AN OFFICE BUILDING IN TIRANA, ALBANIA

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ABSTRACT

Double-skin façades are becoming more required compared to conventional façade systems, due to the introduction of new materials, building technology and especially due to economic viability in a long-term expectation. DSF systems can be highly transparent and energy efficient if designed properly. On the other hand, still as a relatively new system, data and research about energy performance and occupant comfort of double skin facades is limited. A well-designed facade envelope of an office building is considered to reduce the energy consumption of the building and generate comfort, healthy and productive work environment for occupants. The present study analyses indoor environment quality of office buildings in Tirana and investigates the appliance of DSF in the existing buildings. Computer simulations with Rhino (Modeling Software) and DIVA 4 Rhino (Simulation software) were used to computationally simulate and analyse the daylight and thermal performance in existing and retrofitting scenario. Results showed that the use of DSF considerably reduces the glare and energy consumption in the office buildings.

KEYWORDS: Double-skin facades, Daylight, Energy Consumption, DIVA 4, Thermal Comfort

INTRODUCTION

The external building envelope is a critical parameter of energy design, determining the level of protection against outdoor conditions and also controlling the indoor environment. The trend of the DSF is mainly driven by the aesthetic result of a transparent and light envelope; the creation of a buffer zone for improving acoustics in noise polluted areas; the reduction of the occupational energy use of the building through reducing the heating and the cooling demand during winter and summer and through reducing the artificial light utilizing natural day lighting as much as possible, while avoiding glare problems. According Koinakis (2007), DFS systems could be implemented during the refurbishment without affecting significantly the operation of the building. Compagno (1999) classifies façade typologies according to the number of glazing layers and location of the shading devices. Boake and Harrison (2001) mentions several properties such as natural ventilation, daylighting, transparency and energy efficiency that should be optimized in the office façades design. Saelens (2001) defines the multiple skin facade as an envelope structure, which consists of two transparent vertical planar elements separated by a cavity. Salens (2002) distinguished three key elements: the envelope construction, the transparency and the cavity airflow. Arons (2000) summarizes the complexity of the system and extracted it under ten parameters. Whereas Li (2001) classifies the elements for the configuration of the DSF systems that affect the overall performance. The integration of façade systems implies a design that balances a wide range of performance parameters, which responds to energy concerns (Stec et al. 2005).

METHODOLOGY

Case study Description

European Trade Centre (ETC) office, a high-rise multifunctional or multipurpose building, is selected for study analysis. The western façade is oriented toward the main street, and totally exposed to the city view. Offices *(9000m^2)* are placed in the western part of the building. The façade is fully glazed and there are limited shading devices, positioned along the volume perimeter with a width of 80 cm. The 16-storey building (Figure 1) represents an effort to develop a new technology façade and the indoor layout. The façade skin offers visible separation of different volume, which hosts different occupancy uses commercial, residential and office space. The west wing consists of the volume *(N-S and W-E orientation)* containing mainly offices as shown in the plan in Figure 2, while downstairs in the first floors it is situated the shopping mall area. The shopping mall, *(8000m^2)* is placed on the ground till the third floor. The outside façade of the first storeys is designed in grey ceramic tiles. This volume is connected with the residential block, which compose the greater volume of the overall complex building. Based on their position, dimension and configuration, the shading system can be considered as a decoration element in terms of aesthetics rather than shading devices in terms of functionality to protecting against sun exposure. The building is equipped with heating ventilation and air-conditioning system.

Figure 1: ETC exterior

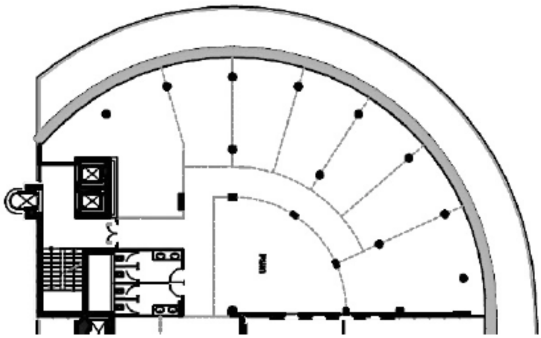

Figure 2: Office plan ETC

Questionnaires

In order to have a real impact of indoor workplace environment, despite physical measurements and field observation, the study involves direct questionnaires. The participants were asked to evaluate their working environment using the perceptual evaluation and preferential judgment. Each employee had to estimate the interior air, thermal comfort, lighting and the overall comfort in the indoor environment. Another section includes question about the influence of the physical environment *(daylighting, comfort level, temperature)* on the employee's productivity to find out if their efficiency is connected to the surrounding workplace. The last section asks for information about any use from occupants of thermal environment control means such as fans, devices used, daily working hours and some demographic data.

Simulations

DIVA simulation tool is used to evaluate the current and proposed IQE. DIVA is an environmental analysis plugin for Rhinoceros 3D modelling program and Grasshopper plug-in. DIVA-for-Rhino is a highly optimized daylighting and energy modelling plug-in for the Rhinoceros modeller. DIVA performs a daylight analysis integrating Radiance and DAYSIM (Reinhart et. al. 2011). Radiance and Daysim engine can do both dynamic and static daylight analysis. For glare study, DIVA with the use of Evalglare can generate point in time and annual glare study. DIVA-for-Rhino allows users to carry out a several building performance evaluations and urban landscapes including Radiation Maps, Photorealistic Renderings, Climate-Based Daylighting Metrics, Annual and Individual Time Step Glare Analysis, LEED and CHPS Daylighting Compliance, and Single Thermal Zone Energy and Load Calculations (diva4rhino.com, 2016). DIVA-for-Rhino operating system is shown in Figure 3. ETC was chosen for simulation in the existing conditions with one curtain wall layer and no shadings and after the refurbishment suggestion with DSF. Daylight analysis and Thermal Analysis are carried with DIVA 4 Rhino. The façade proposal for the refurbishment of the existing building includes: the existing inside layer, an additional curtain wall layer in at least 80 cm distance, ventilation flops louvers at the top of the building which are adjustable (Figure 4), movable aluminium sheets at the bottom of the building (Figure 5) to let fresh air in, and sunscreen shutters as shading devices

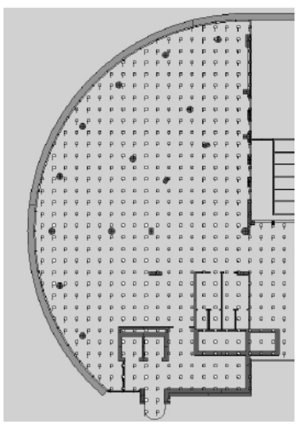

Figure 3: ETC plan showing DIVA-Created Nodes

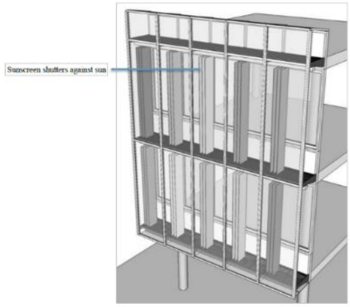

Figure 4: DSF refurbishment model - Air exhaust DS

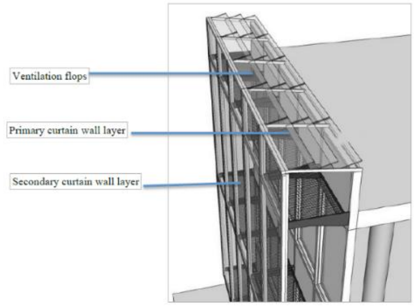

Figure 5: SF refurbishment model (envelope layers), top part of the façade

RESULTS

Questionnaires

According to the questionnaires (Figure 6) employees are satisfied with the lighting system. Most of them admit that lighting affects their concentration during the work time. They have plenty of natural lighting, and this is understandable given the fact that the building has a fully glazed façade. On the other hand, they are not protected from sunlight exposure or glare occurrence. This result explains the non-effectiveness of the 'buildings' shading devices. Meanwhile overheat in summer season is not avoided, despite the use of air conditioning and ventilation system.

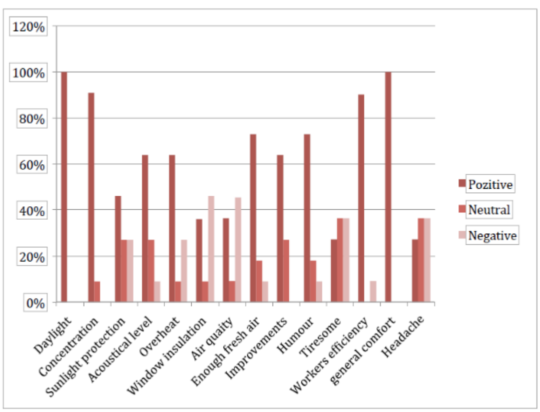

Figure 6: Results of indoor workplace performance based on questionnaires of ETC

Daylight Simulations

Based on the simulation held in the building without shading devices (Figure 7) in the working place, the graph shows the presence of glare occurrence. The case of fully glazed façade of single skin without shadings allows sun to penetrate through the windows and create visual discomforts to the occupants. Most of the glare occurrence is the working panes close to the façade.

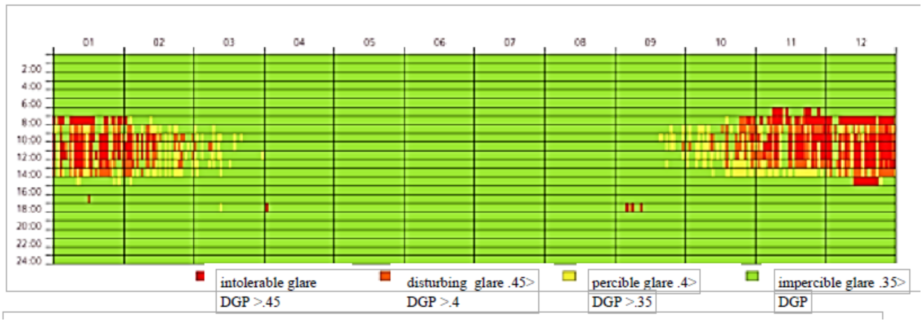

Figure 7: Output from an annual glare calculation with no dynamic shading devices.

After the daylighting simulation with static shading devices (Figure 8), the proposed model reduces glare occurrence by 80% during the sunny hours by adjusting its sunscreen shutters. During the winter, the sunscreen angle is 90° to the façade to let the radiation enter through the daylight and heat. While with the more detailed façade (Figure 9) it is possible to almost disappear the glare occurrence and improves the visual comfort of the users.

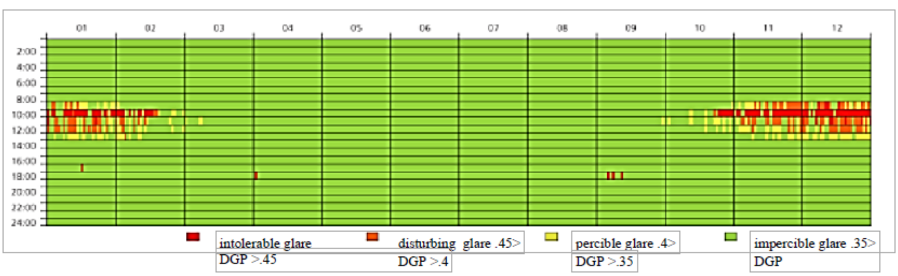

Figure 8: Annual Glare simulation of DSF with static shadings

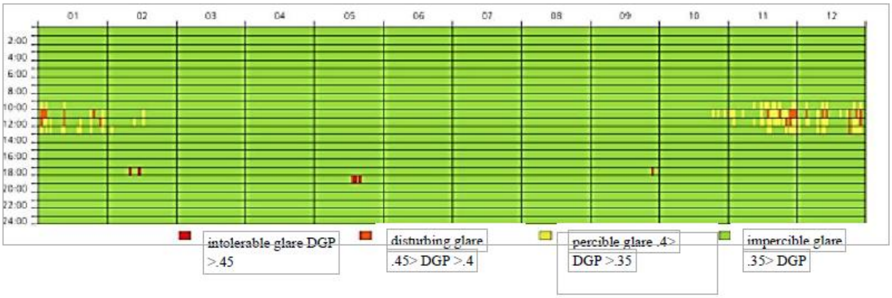

Figure 9: Annual Glare simulation of DSF with dynamic shadings

Thermal Simulation

In the case of the scenario of Single Skin Façade (Figure 10), the building consumes in total 39100 kWh (115 KWh/m^2). Heating problems are reflected also in the energy consumption. More cooling loads are needed to ventilate the working place during midday hours. The lack of shading devices increases the energy consumption higher and overheat during the working hours.

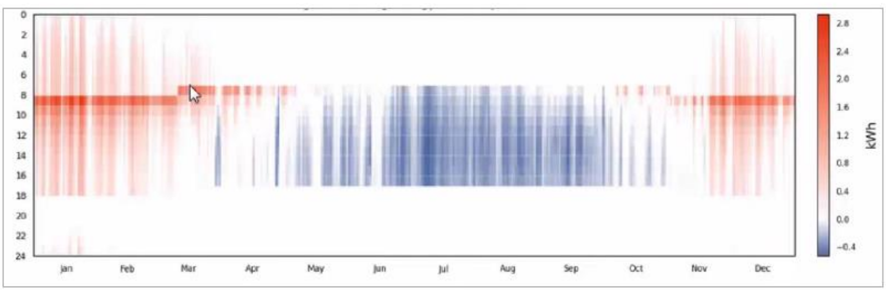

Figure 10: Hourly heating and cooling energy consumption (KWh/m^2) of exiting façade system

The thermal simulation on Double-Skin Façade (Figure 12) resulted positive as well due to the successful natural ventilation it presents: the fresh that air enters from the bottom serves to cool the space and the hot air exhausts from the top louvers.

Meanwhile during summer, the air circulates inside the building and heats the space. This façade saves 30% of the energy. This is also due to the second layer of glazing and the cavity between two curtain walls who decreases the energy loss between outdoor and indoor environment. Comparing the graphs, it results that the double skin façade creates a better insulation against the heating exposure during the afternoon working hours, not allowing transmitting it solar radiation. This means that the cooling energy consumption is diminished. The overall energy consumption including heating and cooling, interior lighting and heat transfer is 27370 KWh.

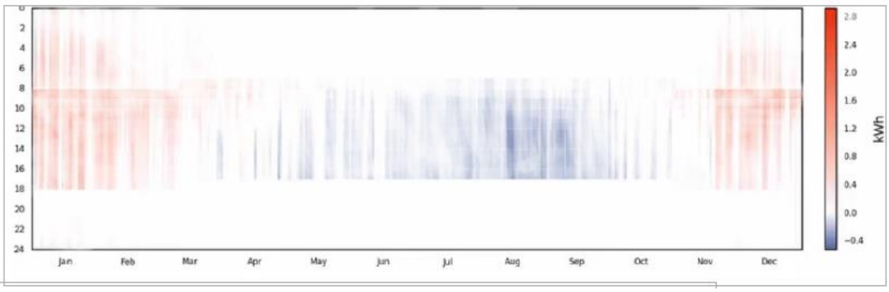

Figure 11: Hourly heating and cooling energy consumption (KWh/m^2) of Double Skin Facade

CONCLUSION

This study investigated the indoor environmental quality of an office buildings in Tirana. A combination of data collection tools, questionnaires, interviews and computational simulation was used to evaluate the existing façade of the office building and DSF system optimization. Based on the questionnaire results employees tend to prefer a fully glazed façade. On the other hand, the lack of shading devices occurs the glare. To improve the indoor environment quality, a refurbishment solution via DSF system is proposed. Results showed high improvement in terms of daylight control and energy consumption. The analysis showed that DSF is a quite promising solution when it is combined with the appropriate designed shading devices to prevent solar heat gain and provide natural ventilation while decreasing the overall energy consumption for heating and cooling throughout the year. Nevertheless, the design should be specific for the type of building its layout, orientation and envelope.

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