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Evaluation of the thermal performance in a Double Skin Facade

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Abstract
A Double Skin Facade is an envelope system, which has an external and internal layer, that contains an empty space in the middle used to control ventilation and solar protection.
Previous research analyzed how the use of ventilated facades contributes towards the energy reduction of indoor thermal gains. The use of the cavity as a ventilated channel reduces temperatures in the facade trough this system it is possible to create a sort of protection from outdoor heat.
However, little has been researched in the field of thermal performance, control and monitoring of full-scale buildings with double skin facade in the UK, and the majority of previous studies are mainly concentrated on the performance of this system during the summer period.
This paper is based on an existent load of knowledge and data in the field with the addition of a monitoring study using a full-scale Double Skin Facade type building in the UK and a comparative modelled assessment of the thermal behaviour.

1. Introduction

1.1 Double skin facade introduction
Glazed facades are becoming a frequent component in the design of office buildings a possible reason for the use of the glass material in this kind of building is the transparency with which a fully glazed envelope can improve the natural lighting potentiality of the indoor space.

A Double skin facade can also add significant heat gains and heat losses sensibly modifying the total quantity of energy for the heating and cooling system.

This is a type of envelope system, which has an external and internal layer that contains an empty space used to control ventilation and solar protection.

These facades can contribute to the reduction of winter heating loads, on the other hand, during the summer period this system can cause overheating if shading is not used, especially when the building is located in moderate or hot climates where heat gains are predominant and the cost of cooling becomes a major issue.

The use of a ventilated cavity can reduce temperatures in the facade and the indoor thermal conditions can be assessed in relation to the facade configuration as part of the compliance of the system to the building requirements.

Nowadays, double Skin Facades are used as a method to reduce the thermal fluctuations of inner spaces due to the growing use of large glazed areas in buildings.

This facade concept has also provided the possibility of improved sound insulation and the creation of pre-heating air for ventilation.

Although that the concept of Double Skin Facades is not new, there is an increasing trend by architects and engineers to use this kind of system ; however the function of this kind of façade is not yet totally investigated.

The general concept of Double Skin Facades is complex and its use can affect different parameters of the building that can sometimes interact with each other or work in complete opposite directions.

This particular facade system has influence on daylight, natural ventilation, acoustics, thermal and visual comfort, energy use, environmental profile, and often the improvements in one of this parameters may origin losses in another one.

The literature studied is from different fields and it is also important to mention that in this first examination it has been considered essential to present the function and the impacts of the mentioned system from different point of views.

1.2 Aims

The aim of this thesis is to research and assess if a double skin facade can be considered as a powerful device in controlling the thermal performance of a building and will answer to the following different points:

- Which is the state of the art of Double skin facade design?
- Is the DSF system a potential thermal benefit for office buildings in London during the summer period?

The results of the monitoring study has been used to identify the key elements in controlling the thermal performance of a Double Skin Facade, and if this particular system successfully improve the performance of the building acting as a protection against heat gains during the summer period.

2. DSF system background

2.1 DSF definitions

Different definitions have been given and it is interesting to underline some of them in order to introduce some of the most important authors in this field and to briefly introduce how they defined the Double Skin Façade System.

Harrison and Boake, (2003) in the book *Tectonics of the Environmental Skin*, described the Double Skin Facade system as *"essentially a pair of glass "skins" separated by an air corridor. The main layer of glass is usually insulating. The air space between the layers of glass acts as insulation against temperature extremes, winds, and sound. Sun-shading devices are often located between the two skins. All elements can be arranged differently into numbers of permutations and combinations of both solid and diaphanous membranes".*

Arons, (2001) defines the Double Skin Façade as *"a façade that consists of two distinct planar elements that allows interior or exterior air to move through the system. This is sometimes referred to as a twin skin."*

2.2 The DSF concept

The correct function of a DSF device is based on the physical interaction of each of the components of the cavity. The explanation of these functions has to include complex mathematical models and simulations, for this reason most of the theory assessing the physics of DSF is based on thermal performance models, airflow and daylight simulations. The main physical aspects relative to the physical basis of DSFs are: *1 .Physics of Light. 2. Thermal characteristics. 3. Airflow.*

In this paper are described the second of these parameters as more relevant to the research subject of this paper.

2.2.1 Thermal characteristics

The concept of a Double Skin Façade has been developed in order to create a monitored greenhouse effect between the two parallel surfaces of glass that in poor words produce a thermal barrier to improve thermal insulation.

The process used is the thermal buoyancy and depend upon the difference of temperature inside the cavity, indeed the heat trapped between these layers increases the density of air inside the cavity and develops a difference of pressures and temperatures along the height of the façade.

This pressure difference is given by: Δp = 0.043 $h\Delta t$, where p is the air pressure in Pascals, h is the height of the column at mean temperature difference Δt from the surrounding air.

The resulting air flow is approximately given by: $V = 0.121A(h\ \Delta t)^{0,5}$, where V is the volume flow rate (m^3/s) and A is the area of each opening.

3. Case of study

3.1 Building description

The monitoring study has been conducted on the Wellcome Trust Building, located at 215 Euston road London.

Is the central main office building of the Wellcome Trust, the second charitable association based on medical research in the world.

The building has been designed by the group Hopkins Architect and was completed in 2004, it consists of an 8 storey office edifice facing Euston road (north facade) and a 4 storey block facing Gower Street (south facade). These two volumes of different height are connected by a curve transparent roof that lights the central atrium at the level of the ground floor.

The double skin facade system is designed creating a frame of 3m wide by 4,3 meters high modules covering a surface of 1800 m^2 at the north west elevation and 1000 m^2 at the south east one.

The company that has produced the modules is the German Metalbrau, based on the following design:

Outer layer: 12 mm laminated clear glass panel with aluminium frames and with the 10% of the surface used for inlet/outlet openigs.

Cavity: the intermediate air space is 70cm wide accessible from the office space trough sliding glazed doors for maintenance and operation of the facade, a 20% perforated venetian blind system is placed at 5 cm from the inner pane and is automatically controlled by the building service management or manually by a button on the inner sliding window frame.

Inner skin: Double glazed sliding panel with low-e coating on one pane and clear glass on the other one.

The operation of the natural ventilation within the cavity consist on a manual control of the inlet/outlet openings that can be easily opened or closed by the maintenance two times per year during the seasonal changes between winter and summer.

3.2 Monitoring study

The purpose of the monitoring study was to assess the thermal behaviour of the double skin facade of the Wellcome Trust building, in order to obtain this 6 data loggers have been placed in the building to register temperature and humidity for a one week period in between the 9th and the 16th of August.

Figure 1 Wellcome Trust building Euston road view

These devices have been programmed to record temperatures and humidity values at an interval of 15 minutes and have been positioned 3 per facade at the 4th floor, the two in the cavity have been placed at the same height just above the grille, one near the outer pane and the other one below the shading device, another data logger has been positioned into the room 3 meter away from the glass.

After the readings have been realised graphs with the data collected that are presented and observed in the followings paragraphs.

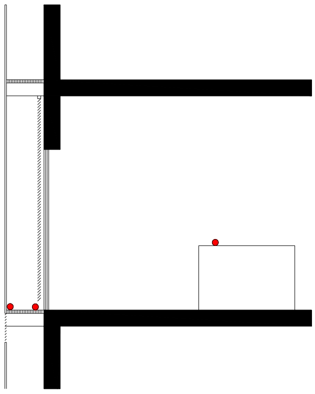

Figure 2 Wellcome Trust Building Double skin facade section

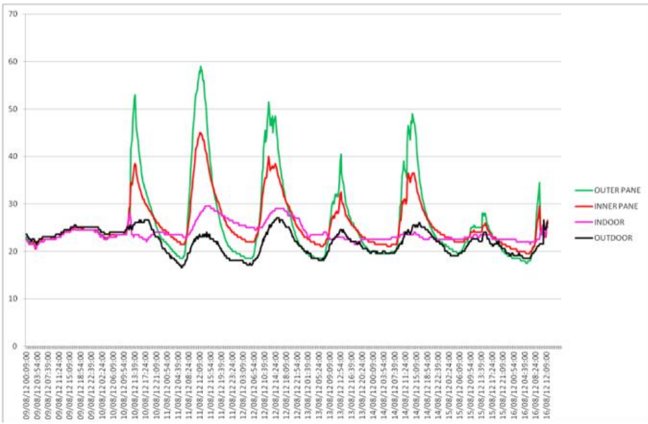

Figure 3 Temperatures graph south facade

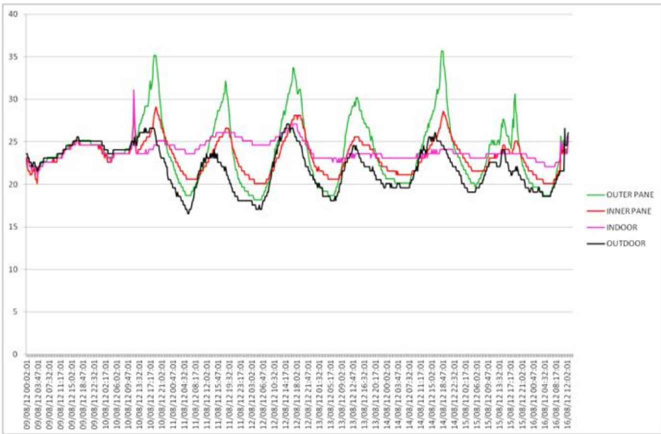

Figure 4 Temperatures graph north facade

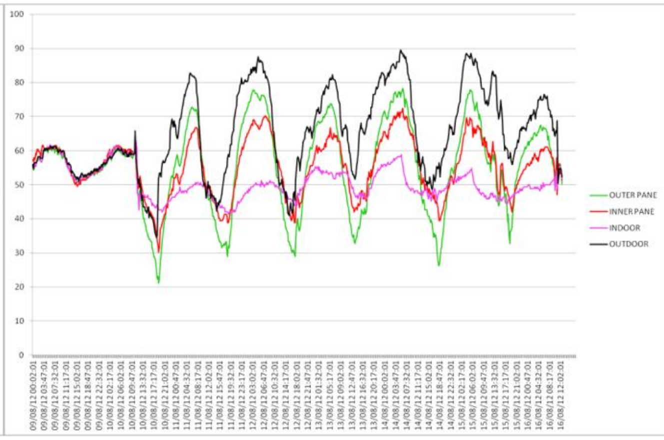

Figure 5 Humidity graph north facade

3.2.1 South Elevation

The south facade presents a difference of temperatures between the inner pane and the outer one, there are picks between 50° and 60° degrees in which the temperature of the outer side of the cavity is more than 10° higher than the inner pane area, this can be due to the fact that the data logger placed just by the external layer may have been reached by direct solar radiation.

However the 45° peak temperature of the air near the inner pane is too high warming up the indoor air near the facade. This effect may be due to the shading system which radiate heat throughout the aluminium venetian blinds during peak solar irradiation periods that have substantially raised the temperature condition.

The temperature inside the building is always between 20° and 30° due to the air conditioning system.

The level of temperature inside the cavity is higher of the outdoor temperature, a possible explanation to this can be that the natural ventilation system inside the cavity is not working, indeed the inlet and outlet openings of the outer pane were closed during the site inspection.

This scenario points out a critical point in the operation of the double skin facade that in this case could generate overheating problem and certainly an overuse of the air HVAC conditioning system.

3.2.2 North Elevation

In this case the average outer pane temperature is almost 1° higher than the inner pane one. Even in critical points for example around the pick of 35.6 °, the outer pane result to have temperature 6 degrees higher than the inner 29° one.

The indoor temperature is between 24 and 27 degrees and the cavity average temperature seems to be much more close to the values of the indoor one if compared with the south facade scenario.

Nevertheless also in this case the cavity air is sensibly warmer than the outdoor one resulting in an excessive use of the HVAC system.

Also in this case the natural ventilation system seems to be not working and it would result interesting analyze if these inlet and outlet openings could successfully reduce this amount of heat gain of the air between the cavity.

However analyzing the graph of the humidity, it is possible to point out that in this case the DSF system is effectively working as a barrier against the outdoor condition, indeed the humidity rate decrease going from outside to the inner pane, creating better conditions for the subsistence of the indoor range between 40% and 60%.

3.3 Airflow Analysis

During the monitoring of the building has been taken measurements of the wind speed velocity in the cavity and outdoor.

The average wind speed in the cavity is 0,22 m/s with a peak of 0,35, these cannot be considered as a value enough high to remove the heat loads of the air between the two glazed panes.

On the other hand the outdoor wind speed measured in the same morning has an average value of 1,13 m/s with peak of 1,48, these variable is almost 5 times higher than the level inside the cavity.

Taking into account that the 10% of the surface of the facade is composed of inlet/outlet openings in order to create natural ventilation it is possible to understand that the mechanism is not used properly indeed during the visit to the building has been observed that the openings where most of the time shut.

In order to better assess the potentiality of the natural ventilation devices installed in the facade it is interesting to insert the measured data in the formulas that *Oesterle* (2001) designed for DSF systems.

First of all it is important to calculate pressure difference of the uplift with the formula: $\Delta pth = \Delta_{\varrho}' \times g \times \Delta h \times \Delta t_m$

Δh = *distance between inlet and outlet* 4 m for this device

Δt_m = *temperature difference between outdoor (27) and cavity (45)= 18*

$\Delta pth = 0{,}004 \times 9{,}81 \times 4 \times 18 = 2{,}82\ Pa$

The average scenario is around a temperature difference of 4,5° between outdoor and the cavity :

$\Delta pth = 0{,}004 \times 9{,}81 \times 4 \times 4{,}5 = 0{,}71\ Pa$

Using than the formula of the stagnation pressure: $q = \frac{p}{2} v\ \ [Pa]$ and the formula of the pressure loss : $\Delta p_{loss} = \xi\, q\ [Pa]$ $\xi = 4$ *for airflow without relevant obstructions*

it is possible to calculate the wind velocity achievable in this configuration inside the cavity:

$v = \frac{\Delta ploss}{\frac{p}{2} x\, \xi} = \frac{2{,}82}{0{,}59x4} = 1{,}19\ m/s$ $v = \frac{\Delta ploss}{\frac{p}{2} x\, \xi} = \frac{0{,}71}{0{,}59x4} = 0{,}3\ m/s$

Taking into account the worst scenario in which a temperature inside the cavity of 59° represent a risk of overheating, and calculating an existent opening area of 0,9 m2 per module of double glazed layer, the possible airflow inside the cavity is 1,071 m^3/s or 3855,6 m^3/h an air volume more than sufficient to remove all the heat loads inside the cavity.

The above calculations highlight that a correct use of the natural ventilation grids can guarantee a better performance of the entire system under summer conditions.

Conclusions

The results from the thermal monitoring study of the Wellcome Trust building conducted in August 2012, revealed a negative performance in the use of DSF system during the summer period in London.

As analyzed in the temperature readings graphs the cavity was constantly warming up the air keeping the indoor scenario in contact with much more higher temperature than the outdoor. In the analysed case of study the cavity around the building can be seen as a collector of heat gain that radiate this amount of heat to the inside.

In the case of study the monitored temperatures have revealed a possible risk of overheating especially for the south block of the building more exposed to direct solar radiation.

The DSF system of this building is underperforming even in the presence of a well designed natural ventilation scheme. Indeed after further calculation using the *Osterle* formulas has been assessed the potential airflow benefit of the designed inlet/outlet openings on the exterior pane.

Interpolating the results from the theoretical calculations with previous considerations, coming from the thermal monitoring study, about the probable use of natural ventilation only during the night period, is possible to state that in this building the management of the DSF devices is not correctly using the ventilation into the cavity resulting in underperforming the system and over consuming energy for the indoor air conditioning.

The statement after these considerations is that a DSF system in order to perform the best under summer conditions needs to be equipped with a powerful ventilation technique inside the cavity and even more important have to be managed taking into account any possible overheating risk using the airflow strategy to cool down the facade during the periods of maximum heating loads.

The research of *Arons* (2000), that considers the influence of blind materials on the heat transfer coefficient inside the facade, have been reflected in high temperatures measured in the interior side of the cavity where the blind venetian system radiates heat rising the average temperature of the air close to the internal glazed pane.

Therefore these findings highlight the importance of the shading device always placed in the cavity of DSFs and specially how the material and the position of the blind can influence the overall performance of the system.

Based on these observations the question if is the DSF system a potential thermal benefit for office buildings in London during the summer period can now be answered. The response is that a DSF can be cause of overheating problems when the average outdoor temperatures exceeds 25 -27 degrees for this reason should be paid great attention to the correct use of the ventilation throughout the cavity in order to cool down the internal heat loads, and more attention should be paid to the shading device during the design stage because correct choices about the blind system can improve the performance of the entire device.

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