

## Double facades a more sustainable solution than a optimal single facade

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# DOUBLE FACADES A MORE SUSTAINABLE SOLUTION THAN A OPTIMAL SINGLE FACADE

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## ABSTRACT

Facade parameters influence the energy flows coming through the facade, in order to optimize the indoor environment for the comfort of the individual building occupant with minimal energy use. How can the facade make optimal use of the free incoming energy flows to maximize the comfort level of the individual building occupant at minimal energy use? The type of facade described as a second skin facade is characterised by a single glass layer on the outside and an isolated facade layer on the inside, which often includes an insulated glass layer. The application of the single glass layer as a second skin around the insulated layer results in an air cavity between these two layers. The property that distinguishes a second skin facade from other DSF is that it relies on natural ventilation of the cavity, in comparison to other facades which use mechanical systems to induce the airflow. The advantage of merely using natural ventilation in the facade cavity is the lower energy consumption. However, it also results in some unresolved issues which require further attention. This project is concerned with the behaviour of a highly complex shaped second skin facade on a Dutch office building, and the thermal comfort impact on the building user. During 3 weeks different measurements were done to determine the main characteristics of the glass and the facade. These measurements were related to earlier measurements done by other buildings with a second skin facade. A key difference between a second skin facade, as well as other climate facades, and more traditional opaque facades is its dynamic behaviour.

*Keywords : double skin facade, thermal comfort*

## INTRODUCTION

The facade of a building is one of its most distinct features, defining not only a buildings aesthetics, but also separating the indoor environment for the outdoor climate as a large part of the building shell. As a result of this, a facade strongly affects the comfort level and energy use of a building. Improving the performance of the facade is therefore aspired in order to further improve the quality of a buildings indoor environment while also reducing its energy consumption. In modern buildings the facade is often considered as part of the climate system, since its performance greatly affects the indoor climate and thus comfort and energy use. The second skin principle offers excellent possibilities to improve the comfort level and energy use of existing buildings, by applying the second skin to its current facade. Despite all these positive effects associated with the application of the second skin facade to buildings, sometimes realized applications are linked with comfort problems [1-4]. The inducement for this study originates from a building in the Netherlands, displayed in figure 1. Occupants of this building complained about the quality of the indoor environment, especially the thermal environment. It was discovered that the behavior of the applied second skin was not in accordance with its design, and the presumption is made that this could be the cause of a part of the comfort complains. Considering all the positive and negative implications associated with a second skin facade made it a very interesting subject for further study.



Figure 1: Outside of the façade, the cavity of the DSF and the atrium behind the DSF

## METHODOLOGY

The aspect of thermal comfort is one of the key facets of the indoor climate, which has an essential part in the quality of the indoor climate of a building. And it is also strongly related to the energy household of a building. The objective is to determine the interactions of a transparent facade with the comfort perception of a occupant. In order to do this it must first be determined how the thermal comfort of the indoor environment should be assessed, and how the façade impacts this. The comfort aspect can be subdivided into four aspects according to the European standard EN-15251: Thermal environment; Lighting; Air quality and Acoustics. From these four aspects the thermal environment (Constant and Warmth) is discussed because of their relationship to the dynamic changing conditions of the façade and their higher contribution to the overall comfort perception of a building user according to [5], which is displayed in table 1.

Table 1. The relative importance of six indoor comfort aspects in European offices

	Coefficients	SE	t	p
(Constant)	1.24	0.062	20.0	<0.001
Warmth	0.39	0.023	17.0	<0.001
Air movement	0.16	0.024	6.6	<0.001
Humidity	0.12	0.024	4.8	<0.001
Light	0.05	0.023	2.3	0.020
Noise	0.13	0.019	6.6	<0.001
Air quality	0.36	0.021	17.2	<0.001

Currently, the most common method to determine the quality of the indoor thermal environment is based on the predicted mean vote (PMV) and percentage people dissatisfied (PPD), which expresses the mean thermal sensation vote of the building user, and the number of building users that is expected to be dissatisfied with the thermal environment in the building based on the PMV, respectively. The PMV is determined according to four thermal environmental factors and two personal factors: Air temperature, mean radiant temperature, air velocity, relative humidity, activity level and clothing.

## CALCULATIONS

When considering the influence of the surface temperature of the façade on the MRT only the long wave radiation is taken into account. The range of this effect can be determined by finding the maximal range in view factors and surface temperatures in order to calculate the resulting effect on the MRT. The range in view factors is derived from previous work conducted by Rizzo [6]. The difference of the façade temperature compared to the rest of the indoor surface temperatures has been derived from manual calculation of the indoor surface temperature for various cases.

Table 2: Indoor surface temperatures ( $T_{si}$ ) of the glazed area as a result of various external temperatures ( $T_e$ ), which correspond to extreme outdoor conditions (30 and -10) or assumed cavity temperature (45, 60, 5) and indoor surface temperatures ( $T_{si}$ ) of the glass

$T_e$ (°C)	$T_i$ (°C)	$R_e$ (°C)	$R_c$ glass(°C)	$R_c$ frame(°C)	$R_i$ (°C)	$T_{si}$ glass(°C)
-10	22	0,04	0,75	0,42	0,13	17,5
5	22	0,04	0,75	0,42	0,13	19,6
30	24	0,04	0,75	0,42	0,13	24,8
45	24	0,04	0,75	0,42	0,13	27,0
60	24	0,04	0,75	0,42	0,13	29,1

The calculated surface temperatures above apply to the surface temperature of the glass surface on the inside of the building. In case a shading device is present and deployed on the inside a considerable difference can be present, because the temperature of this device can increase to temperatures much higher than the calculated indoor surface temperatures of the glass, and therefore affect the MRT to a greater extent. Although the temperature differences are greater, as can be seen in table 2, it must be kept in mind that the surface area, and therefore the view factor in regard to a building occupant is also considerably lower. Another part of the facade of which the temperature can differ of the glazed material is the frame in which the glazing is held. The thermal resistance of this part is often considerably lower than that of the glazing. As a result, the local surface temperature on the inside of the facade differs from the above calculated glass surface temperatures. For the effect of long wave (infrared) radiation on the MRT the indoor surface temperature and view factor are key parameters.

## MEASUREMENTS

During a period of nearly two weeks, from April 5th till April 17th 2013, the temperatures within the cavity were measured as well as the indoor solar radiation in the horizontal plans as well as parallel to the window. The surface temperatures ( $T_s$ ) of both sides of both panes are measured in one line and not too close to the window frame. The different sensors that are used for the measurements can be found in table 3. Since the measurements continue for one week, the data is stored with data loggers. Two different data loggers are used. One data logger is used for the parameters that are measured in the office space and one for the parameters that are measured in the cavity and outside the building. This data logger has a wireless connection with transmitters that are connected to the sensors, which makes it possible to station the data logger inside and the sensors and transmitters outside and in the cavity.

Table 3: Sensors used by measurements

Parameter	Sensor	Accuracy
Temperature	NTC thermistor Sensor data DC 95	calibrated sensitivity
Solar radiation	Pyranometer (CM5 and CM11)	1 %
Air velocity	Dantec 54R10	calibrated sensitivity

The air temperatures ( $T_a$ ) in the cavity are measured at three levels: 2<sup>nd</sup> floor, 3th floor and 4<sup>th</sup> floor. The pyranometer and air temperature sensor to measure the outside conditions are placed on appropriate positions on the roof, where there are no obstructions. The air temperatures inside are measured at 0.5 m from the façade at a height of 1.10 m. The air velocities are measured on the same positions as the air temperature at 0.5 m from the façade at a height of 1.10 m. The horizontal radiation asymmetry ( $T_{ra}$ ) is measured at 0.5 m from the façade at a height of about 1.1 m and the vertical radiation asymmetry is measured at the same distance from the façade at a height of about 1.1 m. The solar radiation inside is measured vertically at a minimum distance of the façade, see Fig. 2.

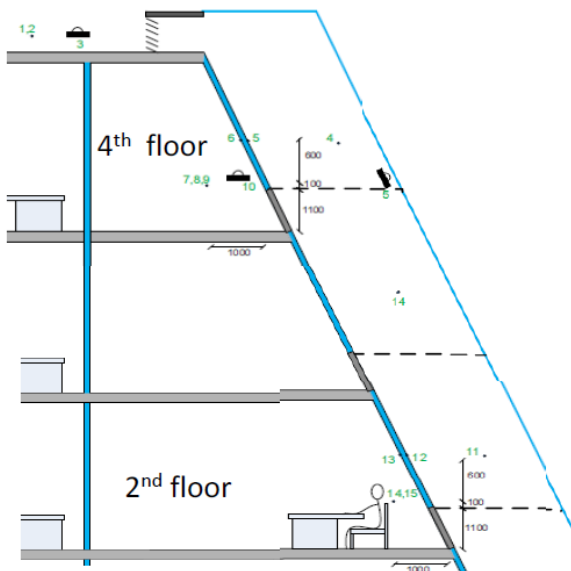
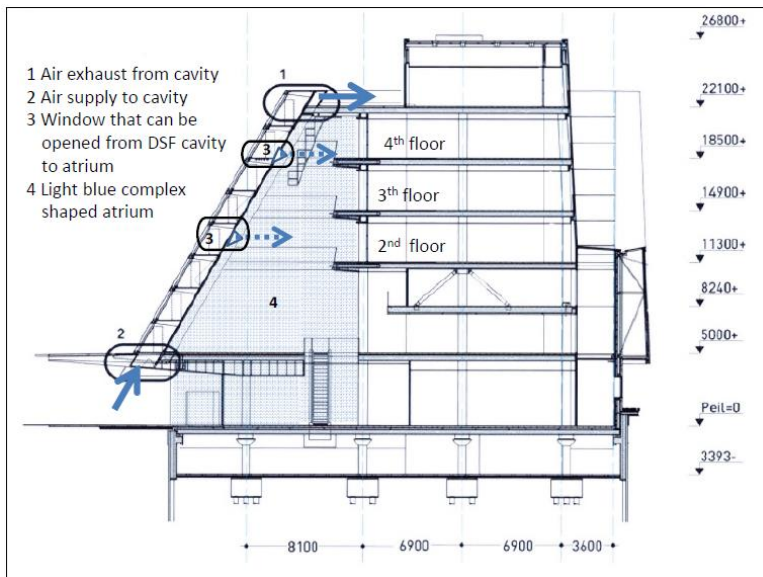


Figure 2: The schematic representation of the ventilation supply from the cavity to the atrium and the schematic measurements setting on the 2nd and 4th floor

## RESULTS

Here the focus is the cavity temperature increase and the inner glass temperature due to the solar radiation and the fast changes to the thermal indoor conditions for the occupants. Beside the MRT the radiation asymmetry is also a comfort indicator related to the facade. The Fig. 5 and 6 provided previously correlated dissatisfaction between radiant temperature and air temperature. This corresponds to the difference between the indoor MRT and the surface temperature on the inside of the facade. In the Fig. 5 & 6 the comfort lines are drawn related to the approach by Lusden and Freymark [7] to indicate the range of perceived thermal comfort.

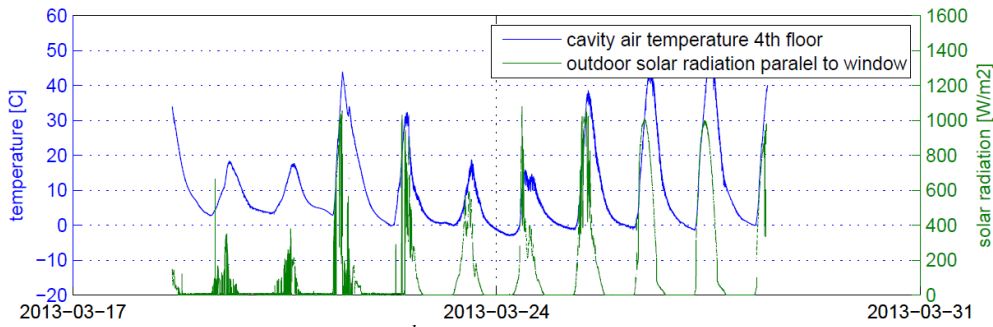


Figure 3: Cavity temperature 4<sup>th</sup> floor versus outdoor solar radiation

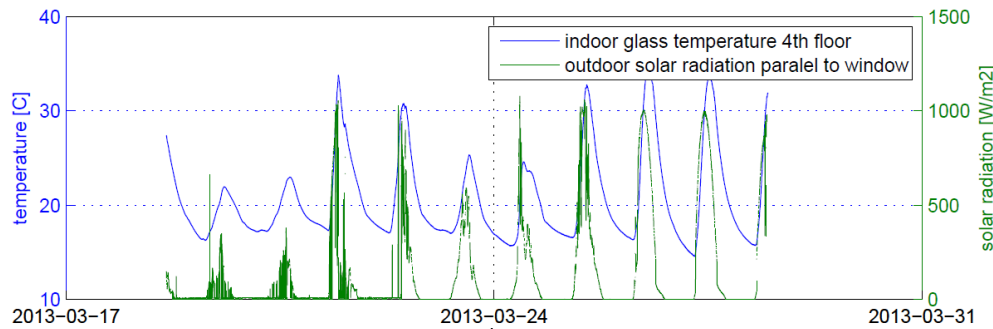


Figure 4: Indoor glass temperature 4<sup>th</sup> floor versus outdoor solar radiation

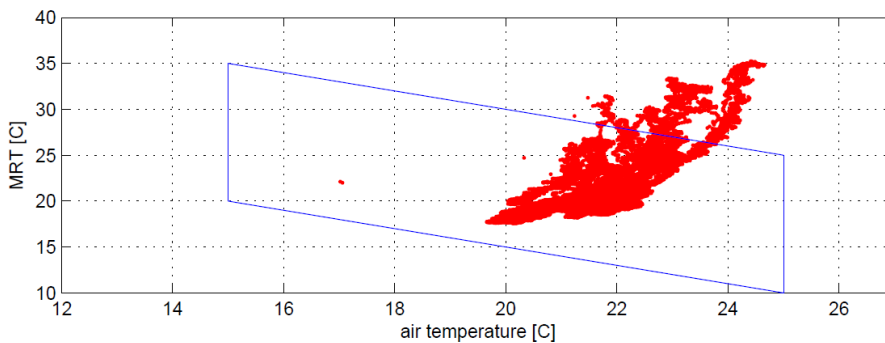


Figure 5: Ration between radiant temperature and air temperature of 2<sup>nd</sup> floor

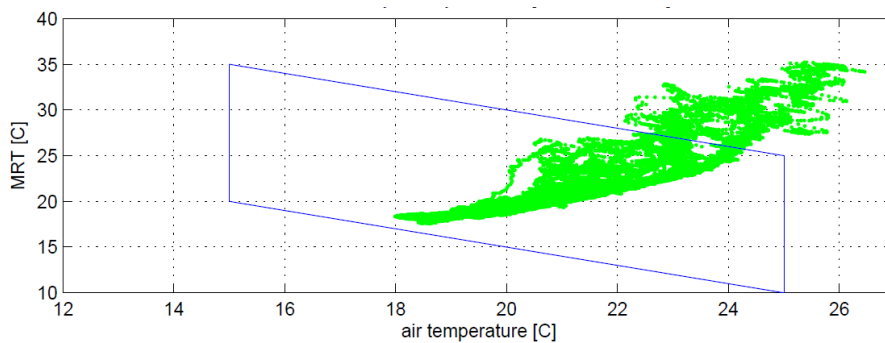


Figure 6: Ration between radiant temperature and air temperature of 4<sup>th</sup> floor

## DISCUSSION AND CONCLUSIONS

Concerning moderate environments the mean radiant temperature is a very significant factor even though the surrounding air may be at a comfortable level may lead to the asymmetry of the radiant heat flow around the person with the consequent onset of local thermal discomfort [8]. When comparing the results of this study with results of two other buildings with double facades [9], as shown the case study building is tending to a ration between radiant temperature and air temperature which is too warm already in some periods in winter.



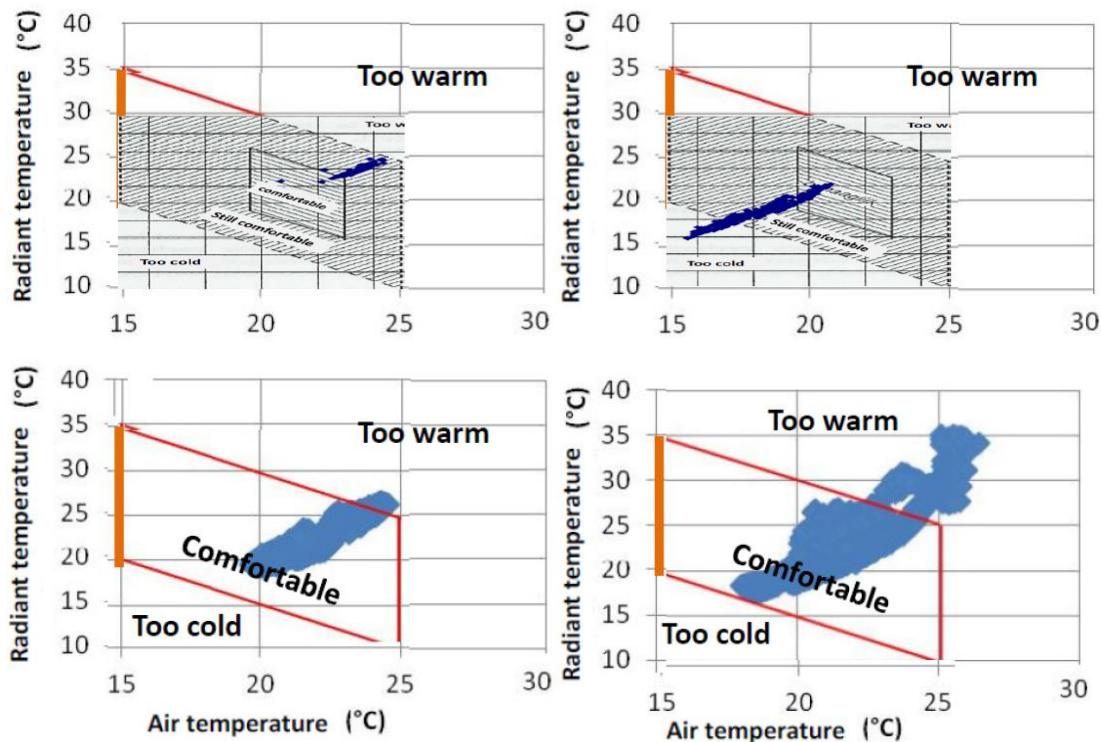


Figure 7: Comparison between radiant temperature and air temperature of projects[9].

The case study building with its double skin facade showed the strong effect of solar radiation with an average temperature increase of 20°C and peak increases reaching 40°C. The high increases of cavity temperature in the case study during the cold period indicate that the risk of the increased cooling load is very plausible during warm periods. Therefore, the effect of the additional air cavity to the façade by the application of the second skin is questionable for the optimization of thermal comfort and energy use. In this case more energy is needed to cool the occupants than will be saved by the reduced energy losses in winter.

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