Overcoming condensation problems in a closed cavity double skin façade.

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SUMMARY

For highrise office buildings, double skin façades offer a attractive alternative in building envelope conception. A recurrent problem in concepts with single outdoor and double indoor glazing ("passive façade") is condensation on the cavity side of the single glass pane.
Permasteelisa Group developed a innovative concept, employing a fully sealed cavity and a very modest dry air flow ("closed cavity façade"), that prevents condensation at all times, thus preventing dirt offset on the window panes and eliminating the need for cleaning inside the cavity over the lifetime of the façade.
This paper presents a coupled multizone airflow / thermal model developed to assess condensation risk inside the cavity under different climate conditions and the initial validation. Additional validation experiments are held in the 2008-2009 winter season.
This model is now implemented as a R&D tool and to size the system components in actual projects.

KEYWORDS

Double skin façade, Condensation, Closed cavity, Model, Risk assessment

INTRODUCTION

In office building architecture, glass envelopes have gained popularity since the rise of modernism, even in arctic climates. Traditional glass facades however, have a number of implicit disadvantages. The most relevant in this context include poor thermal insulation properties for winter conditions and high overheating risks, even in extremely cold climates, in sunny conditions. In noisy environments, poor acoustic insulation can also be an important drawback.

Today, Double skin facades combine the aesthetic value of a fully glazed envelope with good thermal and acoustic performance. Moreover, they protect shading devices, mounted in the cavity between exterior and interior glazing, from wind gusts. This allows to operate the shading even in windy conditions and thus protect the building better against overheating.
The title 'double' or even 'multiple skin facades' covers a broad variety of setups. In this paper, one specific type of exterior curtain-wall is discussed. In this setup, a single exterior glass pane is mounted in front of an interior double glazing unit, with a completely sealed cavity. The Permasteelisa Group developed this so-called "closed cavity façade".

A problem with all single glazing exterior pane arrangements is the occurrence of condensation on the cavity side of this exterior glazing. This causes aesthetic discomfort and necessitate the accessibility of the cavity for cleaning purposes.

Experiments, conducted by Gartner in Germany[1], demonstrate that slightly pressurizing a fully sealed cavity with dry air can be an effective countermeasure for this problem, thus reducing the need for cleaning in the cavity, the associated operational costs and the accessibility it requires. Since operable window parts are far more complex and expensive, avoiding these can be economically interesting. Moreover, operable parts are far less airtight, thus increasing energy losses trough the envelope, with obvious economical benefits.

This paper proposes a TRNSYS-COMIS[2] model, developed to assess the condensation risk in the cavity of such a setup, for different façade configurations and under any cold or moderate climate condition. This model is implemented in a tool, used in the design of the pressurized curtain wall units for the quantification of the required element air tightness and optimal sizing of the compressed air system.

METHODS

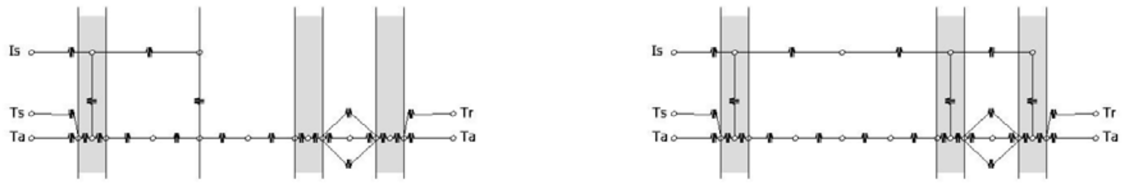
Model

Two models are coupled to describe the double skin façade. The thermal model simplifies the actual situation by ignoring the impact of the frames. This simplification is acceptable since for condensation risk assessment, only the coldest point in the cavity is important. The frames, having a lesser thermal resistance than the glazing ensemble, heat up the sides of the glass panes. Ignoring them thus only leaves out less critical areas of the setup.

In Figures 1. and 2., the complete thermal resistance scheme of both the simplified 'actual' situation and the resistance scheme of the model are depicted as a cross-section through the façade element. Note that especially in the situation where the shading device ("blind") is not activated, the model deviates considerably from 'reality'.

a) b)

Figure 1. 'Actual' resistance scheme. a) blind down, b) blind up.



a) b)

Figure 2. Modelled resistance scheme. a) blind down, b) blind up.

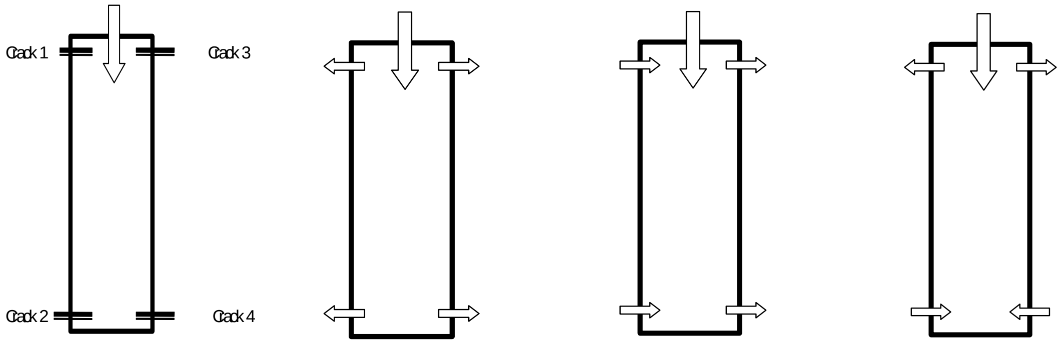
The cavity has been modelled with two separate zones in TRNsys in order to simulate the radiation exchange between the shading device and both glass panes more accurately. As is demonstrated below, this will have an important on the behaviour of the model under sunny conditions when the blind is up. Since the blinds are usually automated and radiation controlled, this situation is not relevant.

Because of the modelling technique (multi-zone model), no thermal gradient effects are taken into account. The model therefore corresponds to the lower central part of the glass pane. Measurements have indicated that this is indeed the most critical point of the façade element.

The airflow problem is also modelled according to the multi-zone principle, with the assumption that all air in the cavity is well mixed. For the calculation of the humidity balance, only the capacitance of the air inside the cavity was considered, given that no buffer materials are found inside the cavity.

Airflow from the environment and the building interior to the cavity is represented trough the introduction of 4 links. One of these is located at the bottom of each glazing pane, and one at the top. The value for the airtightness of each of the panes of is calculated based a pressurization test and a wind pressure test.
The partition of the airtighness of a pane is then assumed to be equal for the upper and the lower link. Both this hypothesis and the one of concentration of the leakage at the top and the bottom maximize the airflow generated by thermal buoyancy.

Figure 3. illustrates graphically the three main flow effects that occur in the façade element under this generalization.



a) b) c) d)

Figure 3. Flow phenomena. a) setup, b) pressurization, c) wind pressure, d) buoyancy.

Test Setup

To validate the dynamic behaviour of the model, measurements from Gartner were used. The testbox was constructed as a stand-alone building. Two elements were mounted next to each other. In the elements, all surface temperatures were measured, together with air temperatures, relative humidities, pressure differences etc. The indoor environment was continuously monitored and controlled by a HVAC system. The outdoor temperature, humidity, wind speed, wind direction and solar irradiation were logged. The Thermocouples for glass surface temperature measurements were shielded with reflective tape to avoid absorption of incoming solar radiation.

The airtightness and flow coefficient of the façade elements was determined with a pressurization and wind pressure test. The properties of the supplied dry air (pressure, flowrate, humidity ratio) were also continuously monitored.

Analysis of the measurement values indicated that there was a problem with the humidity measurements in under sunny conditions. In the temperature peaks caused by the solar radiation, physically incompatible relative humidity levels were reported. Therefore, this set of information could not be used.

Figure 4. Shows the testbox as it was during the tests.

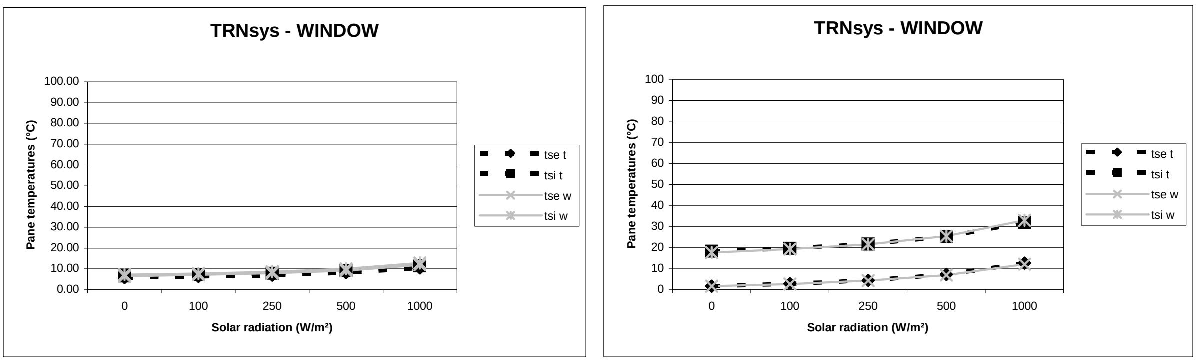
a) b)

Figure 4. Gartner Testbox. a) outside, b) inside.

RESULTS

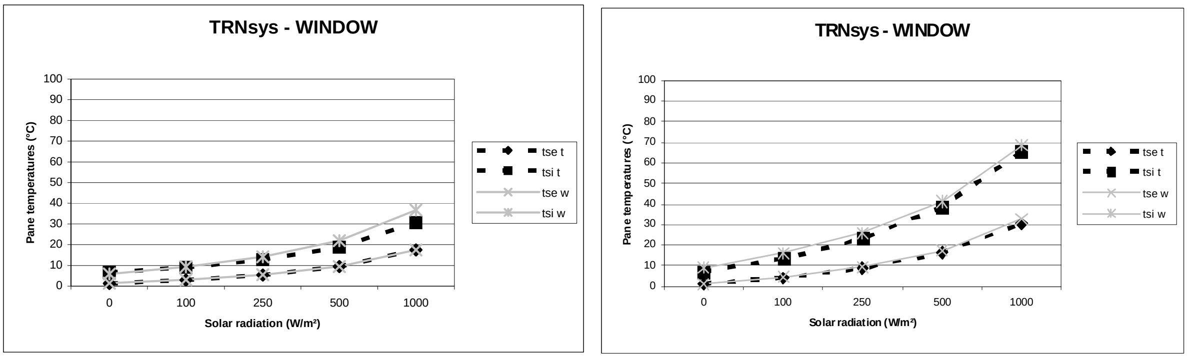
Validation of thermal model in steady state.

The thermal model was validated in steady state conditions by comparing the temperature predictions with those generated by both European and American standard software WIS[3] and WINDOW[4]. The results of this comparison with window are depicted in the graphs below. Table 1. Demonstrates the good agreement of both standard programs with regard to this type of façade element.



a) b)

Figure 5. Glazing surface temperature. a) single, b) double.



a) b)

Figure 6. Element outdoor / indoor surface temperature. a) blind up, b) blind down.

Table 1. Surface temperatures in WIS and WINDOW.

	Te	Tse	Tsi	Tshe	Tshi	Td1e	Td1i	Td2e	Td2i	Ti
WINDOW	35	52.9	54.2	75.8	75.8	65.5	65	34.8	34.4	25
WIS	35	53	54.3	77.7	77.7	67.6	67.2	34.6	34.4	25

Validation of thermal model in dynamic conditions

For the validation of the model in dynamic conditions, the predicted temperatures were compared to those measured in the Gartner testbox. The agreement between measurements and model is demonstrated in the graph below.

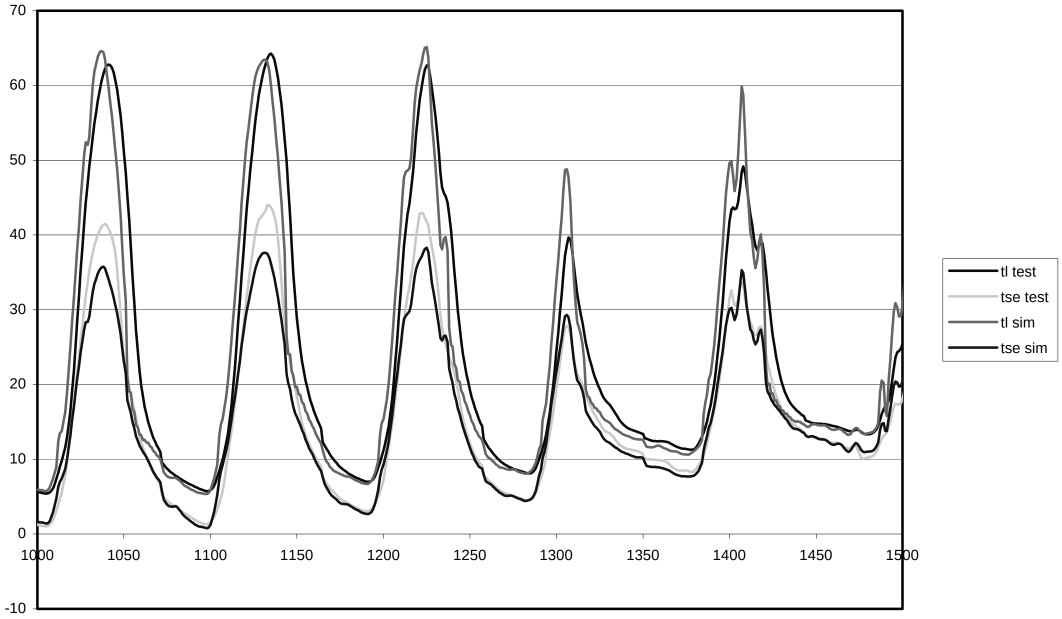


Figure 7. Temperatures of in- and outdoor glass pane of the cavity (°C), Simulation vs. test.

In the lower temperature ranges, with moderate solar radiation, the agreement is excellent. With high solar radiation however, somewhat more pronounced differences can be observed.

Validation of the airflow model

Because of the limited information available from the Gartner measurements, no validation data were at hand. Therefore the predicted dewpoint temperature in the cavity was evaluated with regard to the time constant τ, the time to reduce the difference dewpoint temperature between cavity air and supply air by factor e.

$$\tau = \frac{\rho V}{G} \tag{1}$$

With ρ the density of air (kg/m³), V the volume of the cavity (m³) and G the massflow of dry air (kg/s). Calculus of this trivial equation estimates the time constant to be about 20h with the following boundary conditions: no irradiation, flowcoefficient of the element for pressurization conditions 72 l/h*pa^n, dry air flow 25 l/h.

Figure 8. clearly demonstrates that the model renders similar results, keeping in mind that the dewpoint temperature of the dry air is about -20°C and that the x-axis is the number of timesteps (15 min).

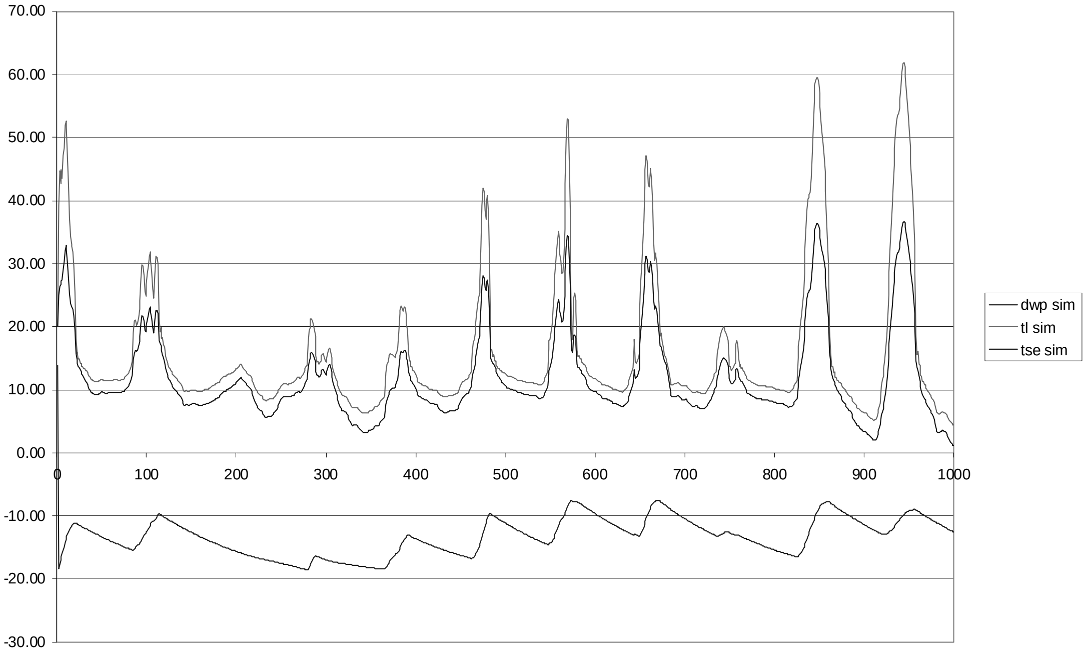


Figure 8. Dewpoint temperature of cavity air

DISCUSSION

The validation of the model in stationary conditions demonstrates that the assumptions that have been made do not compromise its validity. As was expected, the temperatures predicted tend to diverge for high solar gains with the blind up. With the blind down however, the model represents the real situation more accurately and good agreement is found. Since the application of the closed cavity façade element is combined with automated, irradiation controlled shading, the model is well suited for simulating this type of double skin façade.

The model that was presented has demonstrated that it predicts the progressive temperatures under dynamic conditions quite well. Some divergence occurred in the high temperature ranges. Several causes for these deviations can be distinguished. First of all, the deviation is the largest on the outer glazing. This could indicate that the thermocouples mounted on this pane were not adequately shielded. Secondly, most of the deviations are well within the measurement error of the thermocouples used. Moreover, testruns have shown that the moment of activation of the shading device has a considerable impact on the temperature. No data were available to determine the exact moment of activation of the blinds in the test. Finally, the model is heavily dependent on the glassproperties used in the simulation. Deviations from product specifications of the glazing can introduce inaccuracy.

Although first indications about the validity of the air flow model are positive, the absence of data did not permit to demonstrate this more elaborately. A new measurement campaign has been scheduled for the 2008-2009 winter season to collect these data.

The yearlong glass temperature and dewpoint temperature profiles generated with the model can easily be used for condensation risk assessment, as presented in figure 9. All points beneath the black line indicate condensation.

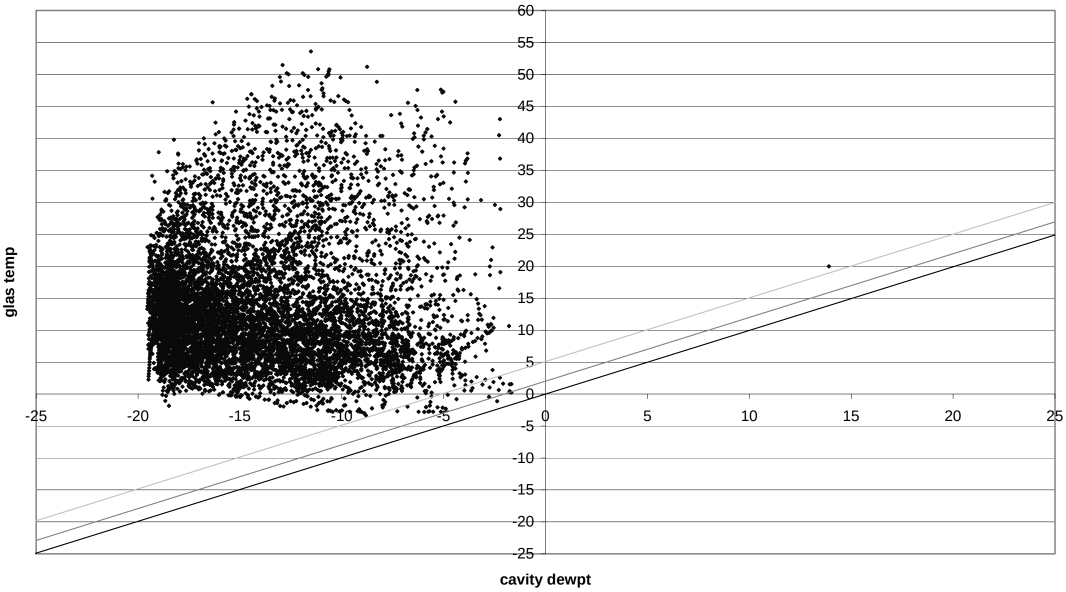


Figure 9. Condensation risk assessment in closed cavity facade (°C)

The relatively simple setup of this model allows to use it in conceptual design of highly 'build to demand' façades. It allows to asses both the risk of condensation in the cavity and the temperatures that can be expected. This in turn allows to engineer all components of the façade accordingly, prolonging the expected lifespan of the façade augmenting its thermal performance. The comfort inside the office building can consequently be predicted and guaranteed more accurately.

CONCLUSIONS

With the model that was presented in this paper, sizing of airflows to prevent condensation and subsequently required dry air supply systems and maximum leakage levels for closed cavity double skin façades is possible for all moderate and cold climates. For hot climates, with actively cooled buildings at temperatures below the outside temperature, the influence of the frames shifts from the heating to cooling. Moreover, the condensation risk is then located at the cavity side of the interior (double) glazing. This requires more attention of engineers when interpreting the results generated by this model, although the general assumptions and basic principles are still valid.

ACKNOWLEDGEMENT

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REFERENCES

To be continued