Experimental testing of the Closed Cavity Façade for a hot desert climate

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October 2010
MSc Thesis:

Experimental testing of the Closed Cavity Façade for a hot desert climate

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Acknowledgment

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For this reason almost all of this thesis is deleted out of this report.
Preface

I started with this thesis in December 2009 in collaboration with the Permasteelisa Group and Somfy. First of all I want to thank Arie Bergsma to pointing me to thesis assignment and all the help during the thesis. Although the work wasn’t always easy, I never enjoyed studying at the Tu Delft this much before. I think this thesis was tailor made for me. I want to thank Regina for all the help during this thesis.

First I will tell something about the company who gave me the opportunity to do this research. The Permasteelisa Group is a company based worldwide. The company is specialized in design and construction of architectural building envelopes. They specialize in element based systems for high rise buildings. Some examples are shown in Fig. 1

![Fig. 1 Aldar HQ by MZ and Partners, Abu Dhabi; BMW Welt by Coop Himmelb(l)au Munchen; Yas Hotel by Asymptote architecture, Abu Dhabi; Hearst HQ by Foster + Partners, New York](image)

The research for this thesis has been done at the Research and Development department of the Permasteelisa Group at Scheldebouw, Middelburg. I want to thank the colleagues at Scheldebouw, Henk, Maaike, Peter, Paul en Danielle in the Netherlands for all the help and the hospitality of taking me in.

The first experimental test for this thesis has been done at the factory of Permasteelisa/Gartner in Dubai in the United Arab Emirates. I want to thank all the guys at the factory of Gartner in Dubai, who made me feel at home in the middle of desert. I also worked with the Somfy group.

Somfy is a company specialized in the automatic control of openings and closures in buildings. They make systems to control the blinds in a smart way. They focus on developing new control systems for specific markets needs. I want to thank Edwin who helped me with controlling the blinds and troubleshooting for the control systems.

My greatest gratitude goes to Sanneke who helped me believing in this master thesis, who gave me the opportunity to go the Middelburg and who was never fed up with helping me.
Abstract

This research is about the experimental testing of a new type of façade. The façade is a variant on a Double Skin Façade. This new type of façade is called the Closed Cavity Façade. The Closed Cavity Façade is a Double Skin Façade which is not ventilated. The Closed Cavity Façade is currently used in Western Europe, but it is expected to be a Double Skin Façade which is suitable for a hot desert climate. To find out if this façade is suitable for this kind of climate this research is done.

A dynamic energy performance calculation for a whole building is made to compare the energy performance of the Closed Cavity Façade to other types of façades used. The Closed Cavity Façade is a viable option in comparison to other Double Skin Façades for a hot desert climate.

An experimental test is done in Dubai, whereby prototypes of this façade are tested in a hot desert climate. Another test, which is an accelerated ageing test for solar blinds, is done in the Netherlands. In the end is looked at the prospect for a year of the Closed Cavity Façade.

The conclusions on this thesis are deleted because of confidentiality.
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2 Climate of Dubai

Before starting with this research it is important to know about the boundary conditions of the climate in Dubai. In this chapter an analysis is given about the hot desert climate of Dubai in the United Arab Emirates.

2.1 Classification of the climate in Dubai

There are different classification methods for climates. Two different classifications are given here for the climate in the United Arab Emirates. Rivas-Martínez & Rivas-Saenz (1996) classify the United Arab Emirates as a ‘tropical desertic anphitropical, arid climate’. By the widely used Köppen–Geiger climate classification system, the United Arab Emirates has a BWh classification (Peel et al. 2007). The first two letters (BW) stands for a desert climate. These climates are characterized by the fact that the mean annual precipitation is less than five times the precipitation threshold. The third letter ‘h’ of this classification means that the mean average temperature is above 18 °C.

Both classify the climate in Dubai as an arid desertic climate with high mean temperature.

2.2 Comparison of the climate in Dubai to the climate of Amsterdam

The climate in the United Arab Emirates is different from the climate in the Netherlands. To have an idea of the differences and to find the best orientation for the test setup in Dubai some comparisons are made between the climate in Dubai and in Amsterdam. The source of the climate data of Dubai is Meteonorm version 4, with a standardized year. The source of the climate data for Amsterdam is from the Royal Netherlands Meteorological Institute for the year 2004 from the weather station at Schiphol Airport, near Amsterdam. Amsterdam is located at 52°22’N, 4°54’E, and Dubai is located at 25°15’N 55°18’E. Fig. 2 shows the location of Amsterdam and Dubai on a large map.
2.2.1 Temperature

There is a difference between the Dutch temperature and the temperature in Dubai. The temperatures are higher in Dubai than the temperatures in Amsterdam. The climate of Dubai has a mean day temperature between 17 °C and 37 °C, with mean hour temperatures as high as 43.6 °C for this reference year. In comparison, the climate of Amsterdam has a mean temperature course between -5 °C and 27 °C, with mean hour temperatures of 27.5 °C for the year 2004, see Fig. 3.

![Mean day temperature for Dubai and Amsterdam](image)

The difference between day and night temperatures in Dubai is larger than the difference between the day and night temperatures in Amsterdam (Fig. 4), because in the desert there is a possibility of clear skies at night whereby the temperature will decrease a lot because the energy radiated in during the day is not held in the atmosphere. Surfaces become even colder than the air temperature because there is night sky radiation occurring. The surface radiates to the clear sky so that surface can even have a lower temperature than the air temperature. When these conditions occur there is chance of condensation on the surface of the glass and profiles of façades.

![Day night cycle of temperature in summer for Dubai and Amsterdam](image)
2.2.2 The relative humidity and dew point temperature

The relative humidity in Dubai is not as high as in Amsterdam but is high for a desert climate (see Fig. 5). Because of the high temperatures in Dubai in comparison to the temperatures in Amsterdam, there is more moisture in the air in Dubai with a lower relative humidity. Fig. 6 shows that the dew point temperature is higher in Dubai than in Amsterdam. For example this means that in summer condensation starts to occur in Dubai at surfaces with temperatures of 25 °C and lower.

Fig. 5 Relative humidity for Dubai and Amsterdam

Fig. 6 Temperature of dew point for Dubai and Amsterdam
2.2.3 Sun path

An important difference between Dubai and Amsterdam is the path of the sun in the sky. Because Dubai is near the equator the sun has a ‘higher’ path in the sky. See Fig. 7 for the sun path diagram of Dubai and Amsterdam.

![Fig. 7 Sun path diagram for Dubai (left), Sun path diagram for Amsterdam (right)](image)

The difference between the sun path is visualized for Dubai and Amsterdam in Fig. 8. The higher path is for Dubai, the lower path is for Amsterdam.

![Fig. 8 Sun path in 3D for Dubai and Amsterdam](image)
2.2.4 Sunrise and sunset

Because Dubai is near the equator, the difference between daylight time in summer and winter is smaller than the difference in daylight time in summer and winter in Amsterdam. That is why Daylight Saving Time is applied in Amsterdam. Daylight Saving Time is the practice of temporarily advancing clocks so that afternoons have more daylight and mornings have less. Because the difference between daylight time in summer and winter is small in Dubai, there is no reason for Daylight Saving Time in the United Arab Emirates.

Fig. 9 Sunset and sunrise in Dubai (top) and sunset and sunrise Amsterdam (bottom)

This is important to note because by day fully glazed buildings have a lot of reflections, which will give a less transparent look. When it is dark the high transparency buildings have a more powerful appearance because the building becomes transparent by night, because of inside lightning.

Because most offices in Dubai are being used till 7 o'clock, the high transparency is even more appreciated. This could be a reason for building more transparent buildings in Dubai. This is even more important in Dubai than in Western Europe where the sun sets later in summer. As is clear from Fig. 9 the opening times of buildings are even more in daylight in summer in Amsterdam than in Dubai.
2.2.5 The maximum sun load on a façade for different façade orientations

There is a significant difference in the sun path in Dubai in comparison with the sun path of Amsterdam as we saw in the previous paragraph. This means that there is a significant difference between the external sun load in Dubai and the external sun load in Amsterdam on a façade. There is also the fact that Dubai has less sky coverage by clouds. This means that there is often a clear sky in Dubai in comparison to Amsterdam. The highest sun load on a vertical surface is in winter in Dubai. In summer the sun is too “high” in the sky to give a high sun load on vertical surfaces (see Fig. 10). In the Netherlands the sun load maximum on a vertical surface occurs in spring and autumn, see Fig. 11. These graphs show the maximum sun load on different orientated vertical planes during a year. These graphs were made with the program Capsol with the specified climate data from paragraph 2.2. Capsol has a sun model, which is used to calculate the different sun loads for a square meter façade in a given orientation.

![Fig. 10 Maximum total sun load on different orientated vertical planes in Dubai](image)

![Fig. 11 Maximum total sun load on different orientated vertical planes in Amsterdam](image)
2.2.6 The total energy on a façade for different façade orientations

The next figures (Fig. 12, Fig. 13) show that the total energy reaching the façades is higher in Dubai than the total energy reaching the façades in Amsterdam, especially in winter. The total amount of cooling needed for a glass façade is in direct relationship with the total sun loads, but depends also on other parameters, for example: internal loads, insulation value and shading devices.
2.2.7 Total amount of energy in a year on the façade with different orientation

Fig. 14 shows the total amount of sun radiation over a year on façades with different orientations. As is clear in this figure, the façades facing south, south-west and south-east have the most sun radiation through the year.

![Figure 14: Total amount of sun energy in a year for different orientation](image)

2.3 Sand storms, dust storms

In Dubai sand and dust storms are a yearly returning phenomenon. The season for sand and dust storms is from January to April.

2.3.1 Definition sand and dust storms

A commonly used name for a dust storm seen in the Arabic world is *Haboob*. The word *Haboob* comes from an Arabic word which means ‘strong wind’ or ‘phenomenon’ (Qiu et al. 2008). Some other native name for a specific kind of sand storm around the Persian Gulf is *Shamal*. Shamal means “the northern winds” (El-Baz and Makharita 1994). In Dubai most of the power of the Shamal is diminished, but there is still a lot of dust and sand in the air. Nevertheless there is also a possibility for local storms in Dubai to occur.

![Figure 15: A sand storm in Camp Fallujah, Iraq, in 2006; Photo by Patrick Smith](image)
2.3.2. Sand, dust and fine dust

Squires (2001) describes “sand” of sand storms as soil particles in an approximate size range of 0.6-1 mm and describes “dust” in dust storms as particles <0.6 mm. In dust storms there is a possibility for the occurrence of natural fine dust. Fine dust is divided in different fraction, see Tab. 1.

Tab. 1 Fraction of fine dust

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Size Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM₁₀ (thoracic fraction)</td>
<td>&lt;=10 μm</td>
</tr>
<tr>
<td>PM₂.₅ (respirable fraction)</td>
<td>&lt;=2.5 μm</td>
</tr>
<tr>
<td>PM₁</td>
<td>&lt;=1 μm</td>
</tr>
<tr>
<td>Ultrafine (UFP or UP)</td>
<td>&lt;=0.1 μm</td>
</tr>
<tr>
<td>PM₁₀-PM₂.₅ (coarse fraction)</td>
<td>2.5 μm – 10 μm</td>
</tr>
</tbody>
</table>

Fine dust consists of fine particles. There are no reliable sources about the levels of fine dust and air pollution in Dubai.

The government of Dubai claims that the amount of PM₁₀ is mostly of natural origin, but this is probably not a reliable source. No current data is found about the air quality in Dubai.

Fig. 16 Dust storm in Dubai
2.4 Consequences of the climate

This conclusion is an abstract of the previous chapter and has some pointers for the further research. In this analysis of the desert climate in Dubai, a few important aspects become visible. What is clear from the temperature profile is that the highest temperature is reached outside in summer and that it is cooler in winter. The highest sun loads on a vertical surface occurs in winter; the south-west and south-east have the highest maximum sun loads in winter (see Fig. 10). In addition in Fig. 14 is shown that the south-west and south-east orientation get the most solar radiation in total on a yearly basis.

The cavity temperature of the Closed Cavity Façade is in close relation to the amount of the solar radiation on the surface. Because of this relation the most extreme temperature profile for the cavity is in south-west and south-east orientations. For this reason the orientation of the test façade in Dubai is south-west.

As is shown the absolute values of vapour (dew point) in the air in Dubai is more than the absolute vapour in the air in Amsterdam. This is something which has to be taken into account for the feasibility of the Closed Cavity Façade in Dubai. With the high dew point temperatures there is a possibility for condensation on the outside glass surface or on the profiles inside the cavity after a clear night.

As seen is Fig. 7 and Fig. 8, Dubai has a different sun path than Amsterdam. The sun in Dubai has a ‘higher’ path. The maximum angle of incidence of solar radiation is smaller in Dubai compared to Amsterdam. This means the angle of venetian blinds of the Closed Cavity Façade in Dubai can be lower (more open) than the angle of venetian blinds in Amsterdam. An elaboration on this topic can be found in chapter 3.5.

It is important to note that the time of sunset and sunrise in Dubai are more equal trough the year in comparison to Amsterdam. This means that the image of a building in Dubai is seen more at night compared to Amsterdam. This could be a reason for building more transparent buildings in Dubai.

Sand and dust storms are a yearly returning phenomenon in Dubai. This is a phenomenon we don’t know in the Netherlands. This has some consequences for the feasibility of the Closed Cavity Façade. The Closed Cavity Façade is designed for being low maintenance. An accumulation of dust and sand needs to be avoided, so that a low maintenance cycle can be applied to the Closed Cavity Façade. This is not as much a technical problem but it will decrease the visual quality of the Closed Cavity Façade.
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