ABSTRACT

Many Architects and their clients prefer to have buildings with glass façade. Most of these buildings have a single skin façade that are consisting of single windows which form the outer surface of the building. Since the most energy loss in the mid/high rise buildings happens through exterior envelope (skin dominated), it is essential to highly optimize that part of the building. This will allow for significant energy savings at the same time providing natural light and comforting atmosphere. The aim of this study is to find out whether the DSF (double skin façade) has an important role in energy saving for the buildings or not.

BACKGROUND

The Double Skin Façade is a system consisting of two glass skins placed in such a Way that air flows in the intermediate cavity. The ventilation of the cavity can be natural, Fan supported or mechanical. Apart from the type of the ventilation inside the cavity, The origin and destination of the air can differ depending mostly on climatic conditions, The use. The location, the occupational hours of the building and the HVAC (heating, ventilation and air conditioning) strategy. The glass skins can be single or double glazing Units with a distance from 20cm up to 2 meters. Often, for protection and heat extraction reasons during the cooling period, solar shading devices are placed inside the cavity. Poirazis (2004)
INTRODUCTION

This is the project in which I want to use the Revit technology and BPA to analyze the specific building which I am currently designing in Chicago to figure out what kind of material I need to use, what kind of windows do I need (in terms of specifications and properties), what size of windows have to be used in terms of designing a building with higher level of energy use efficiency. Then I want to design the second skin for the building and use the program to find out how much of an effect does it have on building’s energy usage. The results of my analysis will provide measurable values of energy loss and based on different variants of either insulation or glazing percentage I will be able to make informed design decisions.

RESEARCH QUESTION

One of the fundamental questions which are associated with double skin façade is how much heating and cooling energy is required for the building with DSF.

Could we increase the performance of a building envelope by using a double skin façade?

OVERVIEW

I will begin the project in three steps; first of all I am going to design the building then analyze it based on standard materials and single pane glazed windows. This will allow me to see how much energy will be used. Then I will change the materials to the ones that are more thermally efficient, change the windows material and use the Revit to calculate the energy usage. The final step will involve adding double skin façade and perform the energy analysis again. I want to compare the results and decide which one variant works best for my building based on costs. At the end this will allow me to see if double skin façade is a good option for the building.
Amsterdam, the Netherlands
This new housing project on the edge of Amsterdam uses a double skin façade to improve energy performance and comfort, and also to create flexible semi-enclosed outdoor spaces for each dwelling unit. Solar heat gain is managed through shading with in the cavity. Natural ventilation is provided via operable inner and outer windows. The double skin also provides an acoustic buffer from an adjacent rail yard. The inner wall serves as a final weather barrier, allowing the faceted crystalline character of the outer wall. The overall building form includes a courtyard and tower, with connecting wood walkways and landscaping.

<table>
<thead>
<tr>
<th>Project name:</th>
<th>Het Kasteel housing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td>Amsterdam, the Netherlands</td>
</tr>
<tr>
<td>Latitude:</td>
<td>52, 21° N</td>
</tr>
<tr>
<td>Date of completion:</td>
<td>2008</td>
</tr>
<tr>
<td>Architect:</td>
<td>HVDN Architecten</td>
</tr>
<tr>
<td>Floor area:</td>
<td>108 apartments</td>
</tr>
<tr>
<td>Floor levels:</td>
<td>15</td>
</tr>
<tr>
<td>Façade system:</td>
<td>C.Vorsselmans Aluminum and Glaswerken</td>
</tr>
</tbody>
</table>

www.hvdn.nl
2- Deutsche post tower

With a completely transparent double skin, this building relies on dynamic shading within the cavity, as well as natural ventilation, thermal mass, and a geothermal system to help moderate the interior without air conditioning. The space and costs of the complex façade systems are offset by the savings gained by avoiding the space and costs that would have been required by an air distribution system. Individual building occupants can control the day lighting, air quality, and temperature of their office environment.

- Project name: Deutsche post tower
- Location: Bonn, Germany
- Latitude: 50, 42’ N
- Date of completion: 2002
- Architect: Murphy, John
- Floor area: 65300 m2
- Floor levels: 40+ 3 for mechanical
- Façade engineer: DS plan
- Energy concept: Trans solar
- Façade system: Permasteelisa in collaboration with Gartner

www.murphyjahn.com

These case studies are selected as evidence for the validity of double skins.
Conserving More Energy

A central and attractive feature of the tower’s design is its transparent skin, which creates ventilated atriums that naturally conserve energy by moderating the atrium’s air temperature. “Green building and sustainable design were a common goal for the designers, as well as the property owner,” says Xia. “Model-based design was essential, as many aspects of our performance-based design were realized through simulations and analyses,” adds Peng. For example, during the design phase the project team used the Revit Architecture model for whole-building energy analysis, giving the designers quantitative feedback on building energy performance. “We shared this information with our owners and consultants to better inform our design decisions and trade-offs,” says Peng.
4- Commerz Bank

Description

At fifty-three storeys, the Commerzbank is the world’s first ecological office tower and the tallest building in Europe. The project explores the nature of the office environment, developing new ideas for its ecology and working patterns. Central to this concept is a reliance on natural systems of lighting and ventilation. Every office is daylit and has openable windows, allowing the occupants to control their own environment. The result is energy consumption levels equivalent to half those of conventional office towers.

The plan of the building is triangular, comprising three ‘petals’ – the office floors – and a ‘stem’ formed by a full-height central atrium. Winter gardens spiral up around the atrium to become the visual and social focus for four-storey office clusters.

From the outside these gardens in the sky give the building a sense of transparency and lightness. Socially, they form focal points for village-like clusters of offices, providing places to meet colleagues or relax during breaks. Environmentally, they bring light and fresh air into the central atrium, which acts as a natural ventilation chimney for the inward-facing offices. Depending on each garden’s orientation, planting is from one of three regions: North America, Asia or the Mediterranean.

The tower has a distinctive presence on the Frankfurt skyline but is also anchored into the lower-scale city fabric, through the restoration and sensitive rebuilding of the perimeter structures to reinforce the original scale of the block.

These buildings provide shops, car parking, apartments and a banking hall, and help to forge links between the Commerzbank and the broader community. At the heart of the scheme is a public gallery. With its restaurants, cafes and spaces for social and cultural events, it has become a popular pedestrian thoroughfare. Interestingly, on the day the Commerzbank opened, the Financial Times adopted it as the symbol of Frankfurt, just as it features the Houses of Parliament and the Eiffel Tower as symbols of London and Paris.
ANALYSIS TOOL

The method used in this study is to model the residential building in Chicago with and without a double skin façade and then compare the energy demand and thermal environment for these alternatives. For this purpose, Green building studio project is selected to be used for this project. In order to take advantage of this powerful software, the Revit model must be prepared for analysis. Green Building Studio energy-analysis software enables architects and designers to perform whole-building analysis, optimize energy consumption, and work toward carbon-neutral building designs earlier in the process.

1-Green building studio project


2-Revit Architecture


Energy Analysis for Autodesk Revit

There are two ways to make the model in Revit for Energy simulation:

1-Use Conceptual Masses for Energy Simulation

Create conceptual masses, enable mass floors, define energy settings (especially location and building type) and submit an energy simulation to the Autodesk Green Building Studio web service. When an alert appears the simulation is complete and ready for viewing. You can also display multiple simulation results for side-by-side comparisons. Use simulation results to understand building energy use to move your project towards sustainable design.

Energy Analysis for Autodesk® Revit® using conceptual masses is intended to provide insight into the role of building form (size, shape, orientation, glazing percentages, shading) and materials on potential building energy use from the earliest stages of the design process.
2-Use Building Elements for Energy Simulation

The energy analytical model created from conceptual masses can also be exported to 3rd party applications for further analysis in a variety of common formats; gbXML, DOE2 and EnergyPlus. Create building elements i.e. walls, roofs, floors, windows etc. (room/space elements are optional), define energy settings (especially location and building type) and submit a whole building energy simulation to the Autodesk Green Building Studio web service. When an alert appears the simulation is complete and ready for viewing. You can also display multiple simulation results for side-by-side comparisons. Use simulation results to understand building energy use to move your project towards a more sustainable design simulation.

Energy Analysis for Autodesk® Revit® using building elements is intended to provide insight into potential building energy use given more detailed information typically available at later stages in the design process. The energy analytical model created from building elements can also be exported to 3rd party applications for further analysis in a variety of common formats; gbXML, DOE2 and EnergyPlus.

In this study building elements for energy simulation is used. By using conceptual mass for energy simulation I was not be able to use energy simulation for the double skin mass. Revit could not calculate both skins and make a correct energy model.

In first step the 3D model is made on Revit based on the imported floor plan from AutoCAD. Then the model is sent to green building studio project for energy analysis. In second step the properties of walls are changed from standard materials to materials with thermal properties, insulation and air space, and the windows are changed to double pane glazing. The model is sent to green building studio project for energy analysis. In third step the walls are changed to double skin façade.

Outside: double glazing curtain wall with air space- 90cm cavity- masonry wall-insulation-air space- structural wall- inside.

The results of the energy analysis and the materials that are used in this study are shown below.

Typical Floor Plan
PROJECT

First model: the model in Revit is made based on the design. The materials used in this model are listed below:
Exterior walls: light weight construction- no insulation
Interior walls: light weight construction- no insulation
Roof: typical insulation- cool roof
Floor: light weight construction- no insulation
Glazing: Single pane clear- no coating

Second model: the model in Revit is made based on design. The materials used in this model are listed below:
Exterior walls: High mass construction- typical cold climate insulation
Interior walls: light weight construction- no insulation
Roof: High insulation- cool roof
Floor: light weight construction- High insulation
Glazing: Triple pane clear- LowE Hot or Cold Climate
Include thermal properties

Third model: the model in Revit is made based on design. The materials used in this model are the same as the second model (thermal model), besides a double skin façade is defined for the building with the cavity of 90 centimeter.

The model is analyzed in green building studio project software based on given information. The result is shown below:

<table>
<thead>
<tr>
<th>Building Performance Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
</tr>
<tr>
<td>Weather Station:</td>
</tr>
<tr>
<td>Outdoor Temperature:</td>
</tr>
<tr>
<td>Floor Area:</td>
</tr>
<tr>
<td>Exterior Wall Area:</td>
</tr>
<tr>
<td>Average Lighting Power:</td>
</tr>
<tr>
<td>People:</td>
</tr>
<tr>
<td>Exterior Window Ratio:</td>
</tr>
<tr>
<td>Electrical Cost:</td>
</tr>
<tr>
<td>Fuel Cost:</td>
</tr>
</tbody>
</table>
# ENERGY ANALYSIS RESULTS COMPARISON

## First model

### Energy Use Intensity

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity EU1</td>
<td>173 kWh / sm / yr</td>
</tr>
<tr>
<td>Fuel EU1</td>
<td>971 MJ / sm / yr</td>
</tr>
<tr>
<td>Total EU1</td>
<td>1,592 MJ / sm / yr</td>
</tr>
</tbody>
</table>

### Life Cycle Energy Use/Cost

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Cycle Electricity Use:</td>
<td>38,540,750 kWh</td>
</tr>
<tr>
<td>Life Cycle Fuel Use:</td>
<td>216,620,618 MJ</td>
</tr>
<tr>
<td>Life Cycle Energy Cost:</td>
<td>$3,592,945</td>
</tr>
</tbody>
</table>

*30-year life and 6.1% discount rate for costs

### Renewable Energy Potential

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Mounted PV System (Low efficiency):</td>
<td>82,851 kWh / yr</td>
</tr>
<tr>
<td>Roof Mounted PV System (Medium efficiency):</td>
<td>185,301 kWh / yr</td>
</tr>
<tr>
<td>Roof Mounted PV System (High efficiency):</td>
<td>247,952 kWh / yr</td>
</tr>
<tr>
<td>Single 15' Wind Turbine Potential:</td>
<td>989 kWh / yr</td>
</tr>
</tbody>
</table>

## Second model

### Energy Use Intensity

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity EU1</td>
<td>163 kWh / sm / yr</td>
</tr>
<tr>
<td>Fuel EU1</td>
<td>491 MJ / sm / yr</td>
</tr>
<tr>
<td>Total EU1</td>
<td>1,043 MJ / sm / yr</td>
</tr>
</tbody>
</table>

### Life Cycle Energy Use/Cost

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Cycle Electricity Use:</td>
<td>33,049,500 kWh</td>
</tr>
<tr>
<td>Life Cycle Fuel Use:</td>
<td>105,739,984 MJ</td>
</tr>
<tr>
<td>Life Cycle Energy Cost:</td>
<td>$2,682,621</td>
</tr>
</tbody>
</table>

*30-year life and 6.1% discount rate for costs

### Renewable Energy Potential

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Mounted PV System (Low efficiency):</td>
<td>88,700 kWh / yr</td>
</tr>
<tr>
<td>Roof Mounted PV System (Medium efficiency):</td>
<td>177,400 kWh / yr</td>
</tr>
<tr>
<td>Roof Mounted PV System (High efficiency):</td>
<td>286,100 kWh / yr</td>
</tr>
<tr>
<td>Single 15' Wind Turbine Potential:</td>
<td>989 kWh / yr</td>
</tr>
</tbody>
</table>

## Third model

### Energy Use Intensity

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity EU1</td>
<td>162 kWh / sm / yr</td>
</tr>
<tr>
<td>Fuel EU1</td>
<td>521 MJ / sm / yr</td>
</tr>
<tr>
<td>Total EU1</td>
<td>1,102 MJ / sm / yr</td>
</tr>
</tbody>
</table>

### Life Cycle Energy Use/Cost

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Cycle Electricity Use:</td>
<td>24,500,664 kWh</td>
</tr>
<tr>
<td>Life Cycle Fuel Use:</td>
<td>76,950,253 MJ</td>
</tr>
<tr>
<td>Life Cycle Energy Cost:</td>
<td>$1,991,511</td>
</tr>
</tbody>
</table>

*30-year life and 6.1% discount rate for costs

### Renewable Energy Potential

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Mounted PV System (Low efficiency):</td>
<td>70,602 kWh / yr</td>
</tr>
<tr>
<td>Roof Mounted PV System (Medium efficiency):</td>
<td>141,203 kWh / yr</td>
</tr>
<tr>
<td>Roof Mounted PV System (High efficiency):</td>
<td>211,805 kWh / yr</td>
</tr>
<tr>
<td>Single 15' Wind Turbine Potential:</td>
<td>989 kWh / yr</td>
</tr>
</tbody>
</table>
First model

Energy Use: Fuel

- HVAC: 83% (M): $66,234 (Btu): 6,039,482
- Domestic Hot Water: 17% (M): $12,954 (Btu): 1,181,205

Total: $79,188 (Btu): 7,220,687

Energy Use: Electricity

- HVAC: 35% (kWh): $109,681 (kWh): 763,270
- Lighting: 25% (Btu): $28,711 (kWh): 199,798
- Misc Equipment: 25% (Btu): $45,335 (kWh): 315,490

Total: $183,727 (kWh): 1,278,558

Second model

Energy Use: Fuel

- HVAC: 67% (M): $26,198 (Btu): 2,388,832
- Domestic Hot Water: 33% (M): $12,456 (Btu): 1,135,933

Total: $38,654 (Btu): 3,524,765

Energy Use: Electricity

- HVAC: 18% (kWh): $85,776 (kWh): 596,908
- Lighting: 19% (Btu): $27,726 (kWh): 192,943
- Misc Equipment: 28% (Btu): $43,924 (kWh): 305,556

Total: $157,424 (kWh): 1,096,517

Third model

Energy Use: Fuel

- HVAC: 69% (M): $20,053 (Btu): 1,828,557
- Domestic Hot Water: 31% (M): $8,807 (Btu): 803,117

Total: $28,860 (Btu): 2,631,674

Energy Use: Electricity

- HVAC: 17% (kWh): $66,525 (kWh): 462,946
- Lighting: 17% (Btu): $19,508 (kWh): 135,755
- Misc Equipment: 26% (Btu): $30,884 (kWh): 214,920

Total: $116,917 (kWh): 813,621
First model

Second model

Third model
First model

Monthly Electricity Consumption

Second model

Monthly Electricity Consumption

Third model

Monthly Electricity Consumption
First model

Monthly Peak Demand

![Graph showing the simulated electricity peak for the first model over the months of the year.]

Second model

Monthly Peak Demand

![Graph showing the simulated electricity peak for the second model over the months of the year.]

Third model

Monthly Peak Demand

![Graph showing the simulated electricity peak for the third model over the months of the year.]
As it is shown in results the energy use for model one is: Electricity 1284693 KWh, Fuel 7220687 MU, energy use for model two is: Electricity 1101650 KWh, Fuel 3524666, and energy use for model three is: Electricity 816688 KWh, Fuel 2631675. The cost of energy for model one is 263.799 $, for model two the energy cost is 196.962 $ and for model three is 146.220 $.

Based on the charts above: the monthly cooling load and heating load are higher in model one rather than model two which means more energy is needed to make the building one (without thermal properties and double pane windows) cool in summer and warm in winter. The monthly cooling load and heating load in model two are higher than in model three.

The electricity consumption and the fuel consumption in model one (building with standard materials and single pane glazed windows) are the highest, and in model three (double skin façade) are the lowest.

The monthly peak demand range in model one (standard materials) during the year is between 210 to 300 KW. In model two (thermal properties) this range is between 197 to 244 KW and in model three (double skin façade) it is between 150 to 185 KW

**CONCLUSION**

As it is clearly broken down above, the numbers for the double skin analysis come out to be much more efficient. Basically, all the factors: electricity consumption, fuel consumption and therefore their costs are significantly lower in the third model (double skin). The initial higher cost of installing double skin façade is going to be minimized every year by the annual savings due to the improved thermal properties of the building (annual savings of approximately 117.579 $ that is 45%).

The broad analysis mentioned above highlights the efficiency of the double skin façade. Its importance is not limited not only to the building’s environmental impact but also greatly improves the economics of the development.
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MODELING OF THE DOUBLE-SKIN FACADES FOR BUILDING ENERGY SIMULATIONS: RADIATIVE AND CONVECTIVE HEAT TRANSFER
Nassim Safer*, Monika Woloszyn, Jean-Jacques Roux, Gilles Rusaouën and Frederic Kuznik
Ninth International IBPSA Conference
Montréal, Canada
August 15-18, 2005

HEATING ENERGY IN DOUBLE SKIN FAÇADE BUILDINGS
Marlon Leão, Érika Borges Leão, Panyu Zhu, Aymen Aklan, Volker Huckemann
（IGS - Institut für Gebäude- und Solartechnik, Univ.-Prof. Dr.-Ing. M. Norbert Fisch, School of Architecture at the Technical University of Braunschweig, Germany）

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