Ventilated facade design in hot and humid climate

Matthias Haase
Dr. Alex Amato

Department of Architecture
Faculty of Architecture
The Hong Kong University
Pokfulam Road, HK, China

September 2006

Ventilated facade design in hot and humid climate

• Background
  ➤ Principles
  ➤ Case studies
• Simulation
  ➤ Analysis
  ➤ Results
• Conclusions
Background

• Need for sustainable development
• Key role of Building industry

Energy consumption (world-wide)

Energy consumption (Hong Kong)


Edited by Mat Haase, Image credit: http://www.emsd.gov.hk
Background

• Energy in buildings in HK

Energy consumption (Hong Kong)

- Commercial 34%
- Transport 36%
- Residential 18%
- Industry 12%

27% of energy in HK is consumed by Air-con and Lighting in commercial buildings
Background

- Possible integrated functions

- Daylight
- Ventilation
- Sun protection/shadowing
- Acoustic protection
- Photo-voltaics
- Insulation
- Heating/cooling
- Passive solar

Façade technology

Background

- New concepts for sustainable buildings
- Double-skin facades for office buildings

Left: Multimedia Center, Hamburg, Germany by Foster and Partners
Right: Uni, Erlangen, Germany by UBA Erlangen
Image credit: http://www.fosterandpartners.com
Why double-skin façades?

- Reduction of peak wind pressure
- Improvement of energy efficiency of façade by
  - passive solar heat gain in winter
  - reducing thermal losses in winter
  - reducing overall solar heat gain (in summer)
  - support of natural ventilation (with the stack effect)

Background

Why double-skin façades?

• Improving comfort
  - **Thermal:**
    - predicted mean vote (PMV)
    - percentage people dissatisfied (PPD)
    - draft temperature
  - **Visual:**
    - daylight factor
    - glare
    - view
  - **Acoustic:**
    - intrusive noise

Classification of double-skin façades (DSF)

Main Type
- Box window façade
- Corridor façade
- Shaft-box window façade
- Multi-storey façade

Cavity ventilation
- natural
- hybrid
- mechanical

Airflow concept
- Supply air
- Exhaust air
- Static air buffer
- External air curtain
- Internal air curtain

Image credits: Thermal comfort, INNOVA AV Tec instruments and Haase.

Haase, M., Amato, A., (2005), Double-skin façades for Hong Kong, proceedings of the Fifth International Postgraduate Research Conference in the Built and Human Environment, The University of Salford, UK.
Principles of DSF

Principles of airflow in cavity

- **Open**
  - Exhaust air
  - Supply air

- **Not open**
  - Static air buffer
  - External air curtain
  - Internal air curtain

**Background**

**Heat transfer**

- **Radiation**
  \[ Q_{12} = \frac{A_1}{A_2} \left( T_1^4 - T_2^4 \right) \]

- **Conduction**
  \[ Q = \frac{A}{t} \left( T_1 - T_2 \right) \]

- **Convection**
  \[ Q = h_c \ A \ \Delta T \]

- **Traditional performance criteria**
  - U-value, SHGC, meaningless

Haase, M., Amato, A. (2005), Double-skin facades for Hong Kong, proceedings of the Fifth International Postgraduate Research Conference in the Built and Human Environment, The University of Salford, UK.
Background

Building design concept

Energy conservation

Utilization of renewable energy resources

Increasing efficiency

Energy conservation

Building energy consumption

Haase, M. and Amato, A., (2005), Development of a double-skin facade system that combines airflow windows with solar chimneys.
Climate analysis

Psychrometric Chart
Location: Hong Kong, China
Frequency: 1st January to 31st December
Weekday Times: 00:00-24:00 Hrs
Weekend Times: 00:00-24:00 Hrs
Barometric Pressure: 101.36 kPa
© A.J. Marsh '00

Selected design techniques:
1. exposed mass + night-purge ventilation
2. natural ventilation
3. direct evaporative cooling
4. indirect evaporative cooling

Selected energy conservation design strategies:
1. exposed mass + night-purge ventilation
2. natural ventilation
3. direct evaporative cooling
4. indirect evaporative cooling
Climate analysis

Comfort Percentages

Case studies of existing DSF in Hong Kong:

1. Dragon Air office building, Lantau
2. Kadoorie Biological Science Building, HKU
3. Science Park (Phase 1), Pak Shek Kok
4. Governmental offices, Shatin
5. No. 1 Peking Road, Kowloon
6. New emsd hq, Kai Tak
Case studies

- Double-skin façade (external air curtain) (as in Dragon Air office and in Science Park)
- Double-skin cavity acts as external shading device
- Sealed façade with cavity externally naturally vented

Image credit: Meinhardt Facade Technology

Example of DSF with EAC: Dragon Air office building by Wong Tung & Ptns.

Image credit: www.dragonair.com and Meinhardt Facade Technology
Case studies

- Example of DSF with EAC:
- Science Park (Phase 1) by Simon Kwan
- Building here: with PV integrated

- Kadoorie Biological Science building by Leigh & Orange
- Building here: with HVAC system components in cavity
Case studies

- Airflow window (internal air curtain)
- Shatin Governmental Offices
- No. 1 Peking Road
- New emsd hq
Case studies

• Example of AFW with IAC: Shatin Governmental Office by ASD
• Active window (developed by Meinhardt Façade Technology)

Image credits: HK Construction Ltd

Case studies

• Example of AFW with IAC: No. 1 Peking Road by Rocco Ltd
• Active façade system (developed by Permasteelisa Group)

Image credits: Permasteelisa and Mat Haase
Case studies

- Example of AFW with IAC: New emsd hq by ASD
- 2 upper storeys
- Refurbishment

Image credit: emsd and Mal Haase

Simulation

double-skin facades
base case DSF AFW
Simulation

• Thermal building simulation coupled with airflow simulation

• DSF

double-skin facades

basecase

DSF

ARW
Simulation

• Thermal building simulation coupled with airflow simulation

• ARW

Cp over height vs wind direction for different facades:
- Façade 1
- Façade 2
- Façade 3
- Façade 4

The graph shows the Cp (performance coefficient) over height and wind direction for DSF2-2, DSF2-3, and DSF2-4 facades.
Simulation

- Results

Control strategies

- Controlling solar radiation
- Controlling HVAC
- Controlling exhaust airflow using a climate sensitive regulator
Haase, M. and Amato, A. (2005), Double-skin facades and thermal comfort, proceedings of Healthy Buildings HK.

Haase, M. and Amato, A. (2005), Double-skin facades for Hong Kong, proceedings of the Fifth International Postgraduate Research Conference in the Built and Human Environment, The University of Salford, UK.
• Results

Monthly simulation results for DSF and AFW with and without climate control

• Results

Annual simulation results for DSF and AFW with and without climate control
## Simulation

### Results

<table>
<thead>
<tr>
<th>Simulation results for basecase, DSF and AFW</th>
</tr>
</thead>
<tbody>
<tr>
<td>basecase (internal shading)</td>
</tr>
<tr>
<td>DSF1-1</td>
</tr>
</tbody>
</table>

## Conclusions

- Possible to design an energy efficient DSF system
- Amount of energy through the building envelope resulting in cooling loads can be reduced by designing a ventilated airflow window that is optimised in respect to heat transfer
- Airflow through the DSF depends on the cp-values of the façade, estimated the cp-values for different building shapes and heights did not influence the performance of the model with DSF
- The EAC uses buoyancy to reject solar heat gain
- Possibility to reduce annual cooling loads as well as peak cooling loads
- EAC with a climatic control better in reduction of cooling loads in the hot summer period
- IAC does not reduce cooling load
- Best results depend on an enthalpy based control that extracts air in order to reduce the cooling load
Conclusions

Planned future work

- Validation with measured data
- Detailed daylight analysis
- Solar assisted extract air device
- LCA of different façade systems

Ventilated façade design in hot and humid climate

- Background
- Simulation
  - Analysis
  - Results
- Conclusions

http://thegreenroom.arch.hku.hk