Heat recovery with decentralized hybrid ventilation

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Table of contents

Problem statement
Research Question
Location
Driving Forces
Wind around the building
   Ansys Fluent
Design
Test setup
Design Possibilities
Advantages
Conclusion
Recommendations
Problem Statement

50% mechanically ventilated offices

HVAC systems use 55% of energy costs
- Ventilation 11% of total

One size fits all approach

Large centralized systems

Sources:
Natural/hybrid ventilation

- Higher temperature acceptance
- More perceived control and satisfaction

Sources:
Research Question

How can a decentralized mechanical ventilation system be redesigned to make use of natural ventilation principles?
Amsterdam

70's Dutch office building typology

10 stories high

Office depth of 6.5 m with corridor of 3 m

Main wind direction is SW

Single sided office
Driving forces

Total Pressure difference

\[ \Delta P_{\text{total}} = \Delta P_{\text{ath}} + \Delta P_{\text{cp}} + \Delta P_{\text{temp}} + \Delta P_{\text{in/out}} \]

No pressure difference due to Cp value

0.4 Pa pressure difference due to temperature difference

Correction factors for wind velocities

Correction factors in- and outlet vents

Open pipe

Venturi shape  (de Gids & den Ouden, 1986)
Wind around the building

Ansys Fluent

3D model

Box environment

Wind velocity of 6 m/s (4 Bft)

Denser mesh at the facade

Horizontal lines at facade

Angle of building 0, 30, 60 and 90 degrees
Wind around the building

Visualisation of the results

Wind 0 deg section. Vector (top), contour (bottom)

Wind 30 deg. h = 15 m Vector (top), contour (bottom)
Wind 60 deg. Vector $h = 15$ m (top), contour (bottom)

Wind 90 deg. Vector $h = 15$ m Vector (top), contour (bottom)
Wind around the building

Wind speeds at the facades

Leeward side

Wind 0 deg

Windward side

Wind 0 deg

Wind 30 deg
Wind around the building

Result analysis

Wind speed Leeward side not sufficient

Hybrid ventilation as a result of low wind speeds

Orientation to the W for optimal use of wind direction

Design boundary conditions

- Wind velocity facade 2.4 m/s
- Max velocity 0.2 m/s in office
- Different wind directions on the facade
Design

Double system
20 cm thick wall element
User control
Inlet interior at 1m height
Outlet interior near ceiling
Fiwihex heat exchanger
Inlet Temperature of 18 deg
Fiwihex

Air to air and air to liquid

Low pressure resistance

Compact, 480x240x100 mm

Small pressure drop: 4 Pa at 100 m³

Optimal at 100 m³/h

85-90 % Efficiency
Design Principle
Design

Elements

Rotating inlet cowl

Heat exchanger

Venturi outlet
Inlet: redirecting wind into the ventilation system

Outlet: Creating negative pressure at the outlet
- Venturi shapes
- Hill shaped

Wind velocity of 2.4 m/s
Inlet velocity 2.4 m/s

1.4 m/s air velocity for 50 m³/h

Low pressure drop due to heat exchanger
- Calibrated at 4Pa at 100 m³/h
Test setup

Wind tunnel test
- Extraction of the air by fan
- Heat exchanger

Measurements
- 4 locations in the system
- Pressure difference over heat exchanger
Test setup

Test vs simulation
- Wind velocity inside the system
  - 0.22 m/s tested - 0.28 m/s simulated
  - 0.87 m/s tested - 1.07 m/s simulated

Accuracy of the system

1.5 Pa pressure difference at 2.4 m/s
Facade design boundary conditions:
- Distance inlet-outlet min 1 m
- Center of opening at 0,15 m of the facade
- Dimensions internal box 0,3x0,2x1m

Design possibilities

- Exterior
- Vertical accent
- Standard option
- Floor/floor glass
- Double glass
Design possibilities

Floor layout
- Enclosed offices
  - Overpressure in hallway

- Open plan offices
  - Mechanical system at opposing facade
  - Additional rooms and toilets must be located at a facade

Enclosed office
Advantages

Small dimensions: 0,3x0,2x1m
- Simple to integrate in facade panel

More temperature acceptance due to natural principle
- 18 deg, during outside temperatures of -5 deg

Easy maintenance
- Few components
Advantages

Energy savings compared 6 mechanical ventilation systems
- Climarad
- Trox Schoolair-V
- Smartbox
- V4E - Smart ventilation (fiwihex)
- inVENTer
- Sonair A+

Energy saving up to 5% on total energy consumption
- Average annual energy consumption office building: 35.65 €/m²
- € 0.39 to € 1.87 per m²
- € 40,48 for a 21,6 m² office
- € 13763,- for the entire building
Conclusion

Natural ventilation with heat recovery is possible
- Wind induced ventilation
- High efficiency of the HE

Mechanical backup needed due to low winds on leeward side

Energy savings of 5% on total energy usage of the building

Increased user comfort
Recommendations

Study about wind velocities at the facade
   - Influence of facade elements on air flow

Environmental influences

Optimizing the Inlet and the Outlet of the ventilation system

Bypass of the heat exchanger during the summer

Relation between the simulation and the real-life tests
Heat recovery with decentralized hybrid ventilation