VENTILATED OPAQUE WALLS - A PERFORMANCE SIMULATION METHOD AND ASSESSMENT OF SIMULATED PERFORMANCE

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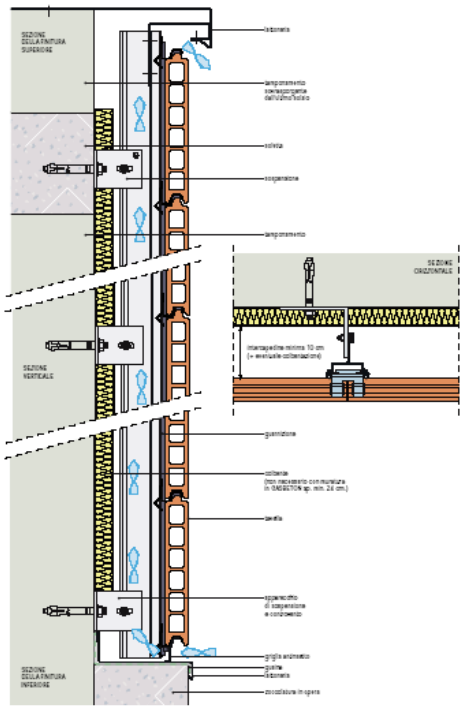
What is an Opaque Ventilated Façade

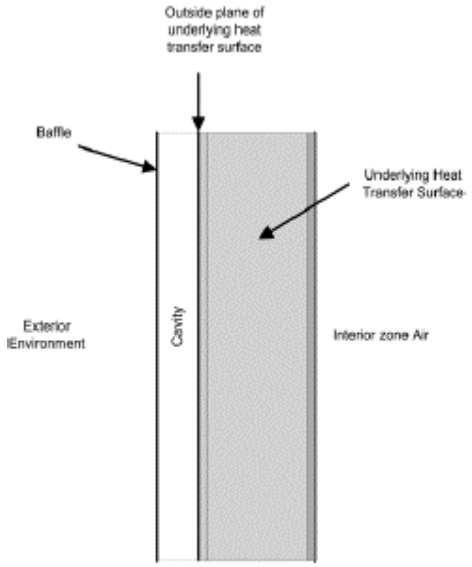


Typical ventilated opaque façade section.

An opaque ventilated façade is a special façade case where the outer face consists of a detached layer that forms a naturally ventilated cavity.

- A solution with potential for improving thermal performance in Europe and particularly Italy.
- Opaque ventilated façade building envelopes are affected by the 2002/91/EC European Directive on the Energy Performance of Buildings and by the Italian DL192/2005.
- European Directive refers to whole building consumption. The performance of every component has to be calculated and integrated in the design Ventilated façade is traditionally implemented without first evaluating its performance and its effects on energy consumption.

How To Evaluate And Certify The Performance Of A Ventilated Façade



Typical configuration of a ventilated façade.[1]

Evaluation of the ventilated façade performance is difficult because of:

- The absence of software tools capable of fully evaluating ventilated opaque façade thermal performance.
- General lack of data related to the ventilated façade's thermal behavior and energy performance.
- More specifically, the lack of data on envelope's thermal performance in Italian climates.

A ventilated façade is designed and implemented in a new building without evaluation and proper certification of [its effect on] building performance (2002/91/EC European Directive on the Energy Performance of Buildings and DL192/2005)

(For existing buildings ventilated façade performance can be assessed through on-site measurements).

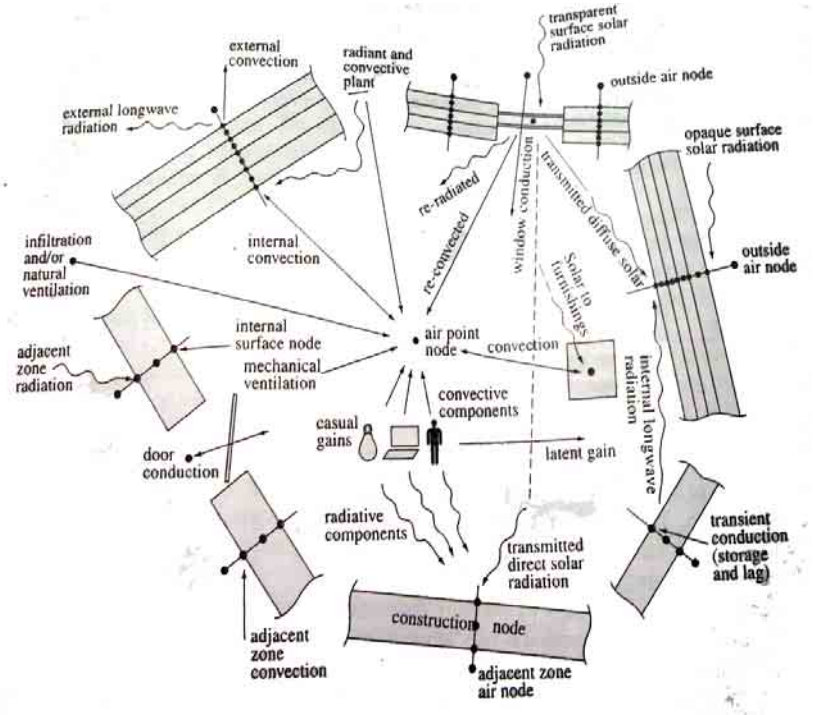
Dynamic Simulation

Envelopes performance and consequently building energy consumption depend on several factors that interact and determining energy flows:

- Climate and weather factors
- Surrounding environment
- Building shape
- Building materials
- HVAC system and mechanical equipment
- Internal loads
- Operating strategies

Because of the dynamic nature of the physical phenomenon time dependency is a relevant factor The performance analysis in this research was carried out with EnergyPlus[2] (time dependent simulation)

Energy Flow Paths[3] ➔



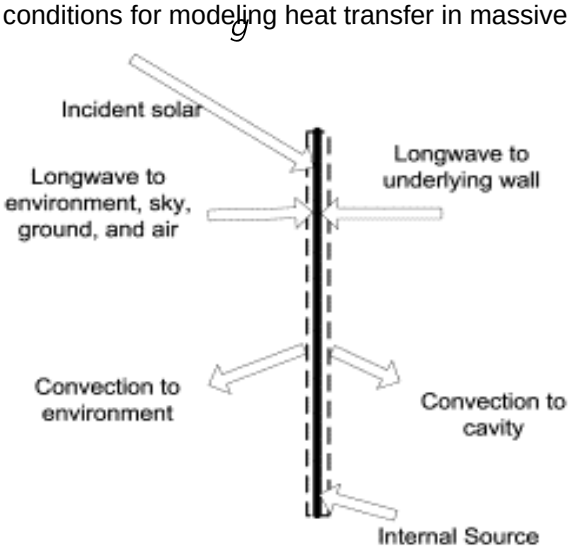
1 *EnergyPlus Engineering Documentation, p. 107*
2 *http://www.energyplus.gov*
3 *J. A. Clark, Energy Simulation in Building Design, p. 11*

Methods for evaluating ventilated façade performance

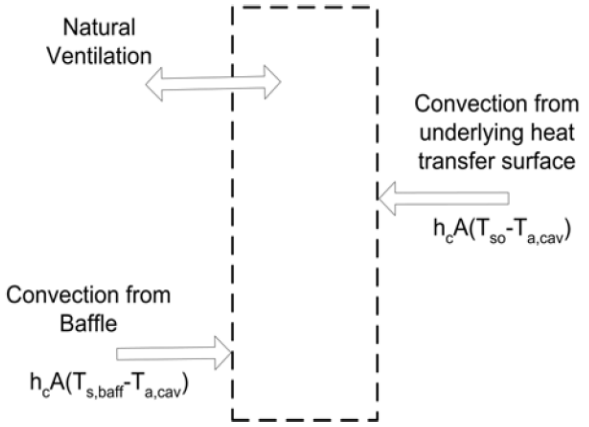
Current quantitative methods cannot fully evaluate ventilated opaque façades

However, the ExteriorNaturalVentedCavity[4] feature of EnergyPlus can be used to some extent to calculate the performance of opaque ventilate façades.

The model forms separate heat balances for baffle and cavity – these are used to determine boundary conditions for modeling heat transfer in massive underlying surface.



Baffle Heat balance[5]



Cavity Heat balance[6]

[4] *Module developed by Brent Griffith, National Renewable Energy Laboratory, Golden, CO*
[5] *EnergyPlus Engineering Documentation, p. 109*
[6] *EnergyPlus Engineering Documentation, p. 110*

A Partial Method For Evaluating Ventilated Façade Performance – Exterior Naturally-Vented Cavity Coefficients Need To Be Verified

"The model developed is based on engineering first principles and has not been experimentally validated. There are currently very few appropriate input data to use with the model." (Brent Griffith" (http://gundog.lbl.gov/dirpubs/eplpub05-10.html)

Factors that the module takes into account: • Diffuse and direct radiation • Wind intensity • Ventilated façade geometry and height • Tilted surfaces • Open or sealed geometry • Cavity thickness and obstructions • Baffle absorptivity and emissivity Given Output:Exterior cavity dry bulb temp. [C] • Exterior baffle Temp. [C] • Exterior cavity air changes per hour Passive [ACH] • Exterior cavity total natural vent mass Flow[kg/s] Indirect output: • Energy consumption summaries	➔ ➔ ➔	Experimental and field research are needed to **characterize appropriate input values** for the ventilation opening areas and discharge coefficients for various types of systems **Cavity convection coefficients** could be modeled with accepted correlations for window glazing – ISO Standard 15099 (2003) – even though these correlations may not perform well for some configurations **Natural ventilation rates** are calculated using simplistic correlations based on user-provided **discharge coefficients**

Verify The Method For Evaluating Ventiled Façade Performance Vented PV Cavity Module Experimentation And Characterization

We have conducted an experiment to characterize appropriate input values for the Vented PV Cavity module for ventilated façade applications.

We have designed a ventilated façade that has been built for the Aderma S.r.l. manufacturing building located in Turate (Como), Italy.

South and North ventilated façades are vertical.

West and East ventilated façades are partially tilted.

Installed façades include instrumentation to record envelope thermal behavior – a weather station is installed on top of the building.

The manufacturing building is reproduced virtually to enable the simulation of ventilated façade performance.

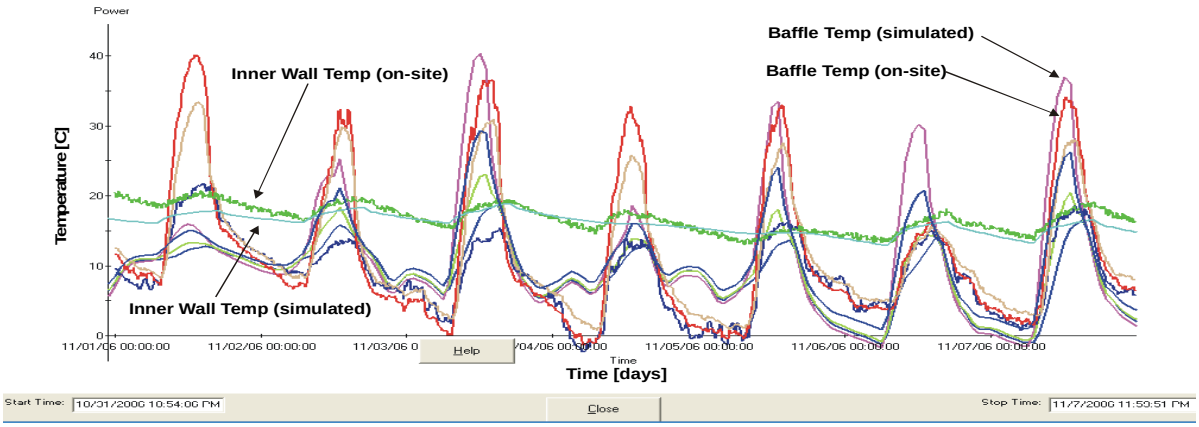
South façade – planar surface

East façade – partially tilted

Verify The Method For Evaluating Ventilated Façade Performance

South Ventilated Façade – A typical week in November
Comparison of simulation with on-side measurements

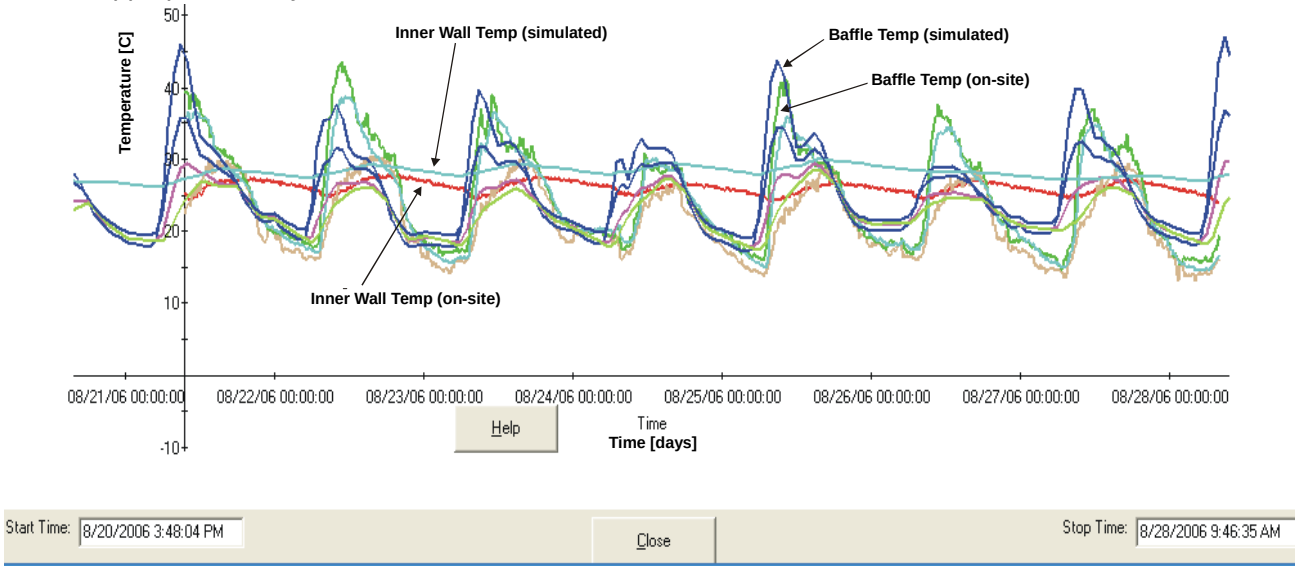
- Field: Cv, Effectiveness for Perforations with respect to Wind-driven Flow=0.25
- Field: Cd, Discharge Coefficient for Openings with respect to Buoyancy-driven Flow=0.65
- Baffle, cavity and inside temperatures have similar shapes



Verify The Method For Evaluating Ventilated Façade Performance

East Ventilated Façade (partially tilted) – A typical week in August
Comparison of simulation with on-side measurements

- Baffle, cavity and inside temperatures have similar shapes
- Calibration to obtain discharge coefficients could not be done at this time because of missing albedometer information – this information will enable the generation of a custom weather file and appropriate analysis



Comparison and Module Characterization Results

- Default discharge coefficients seem to realistically predict the opaque ventilated façade thermal behavior
- Still, an appropriate custom weather file needs to be developed for the exact definition of these coefficients
- Gaps in results seem to be due to the fact that calculated wind effects depend on wind velocity magnitude (coefficients were used to account for wind direction)

Recommendations for future module exstensions

- The module should be sensitive to wind directions as well, rather than just wind velocity
- The module should be modified for use with thick and/or composite baffle types with large heat capacity
- The module should be linked to the EnergyPlus Airflow module (that would allow natural ventilation and infiltration to be calculated based on window openings, cracks, crack dimensions, buoyancy and wind driven pressure differences, etc., rather than be just scheduled)
- Further development of cavity discharge coefficients is needed for a variety of special cases

Assess the Ventilated Façade Performance in Italian Climates

Now that the module for opaque ventilated façade has been tested, one can continue to examine the façade performance itself.

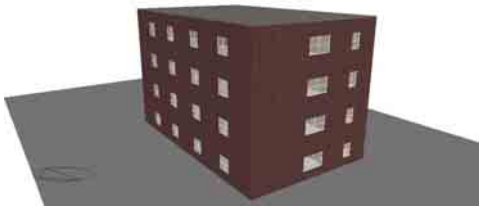
1. What is the ventilated façade energy performance/efficiency compared to a non-ventilated wall?
2. How is the ventilated façade performing in different Italian climates (Rome, Milan, Palermo)?
3. Could a seasonal cavity closure valve improve winter performance?

A residential virtual building (with surface to volume ratio S/V=0.43) is simulated with different façades to answer this question:

- Single insulated wall with significant specific heat capacity
- Previous wall with ventilated façade applied to it
- Ventilated façade with seasonal closure valve

The building is located virtually in three cities – façade and each building envelope has a U value exactly as specified in DL192/2005 (these parameters change in relation to Italian climatic zones)

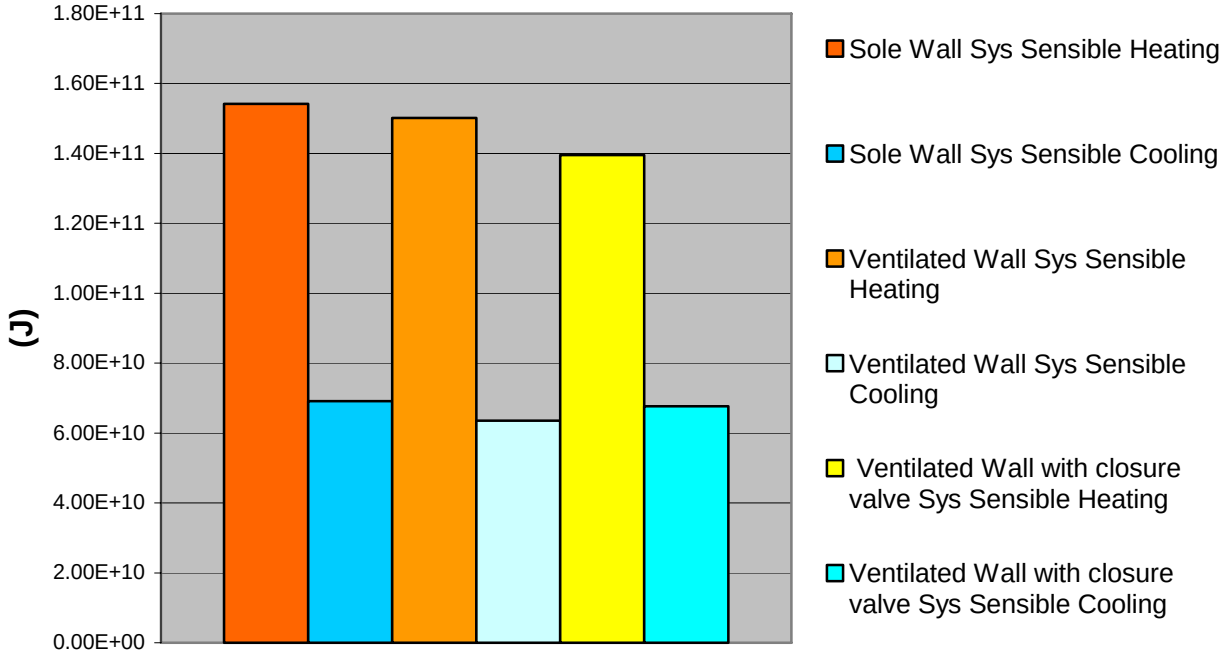
- Milan
- Rome
- Palermo



Main simulation parameters:

- Residential occupational schedule (working family)
- HVAC operating with winter and summer setback temperatures
- Natural ventilation and internal loads in compliance with EN ISO 13791:2005 (E)

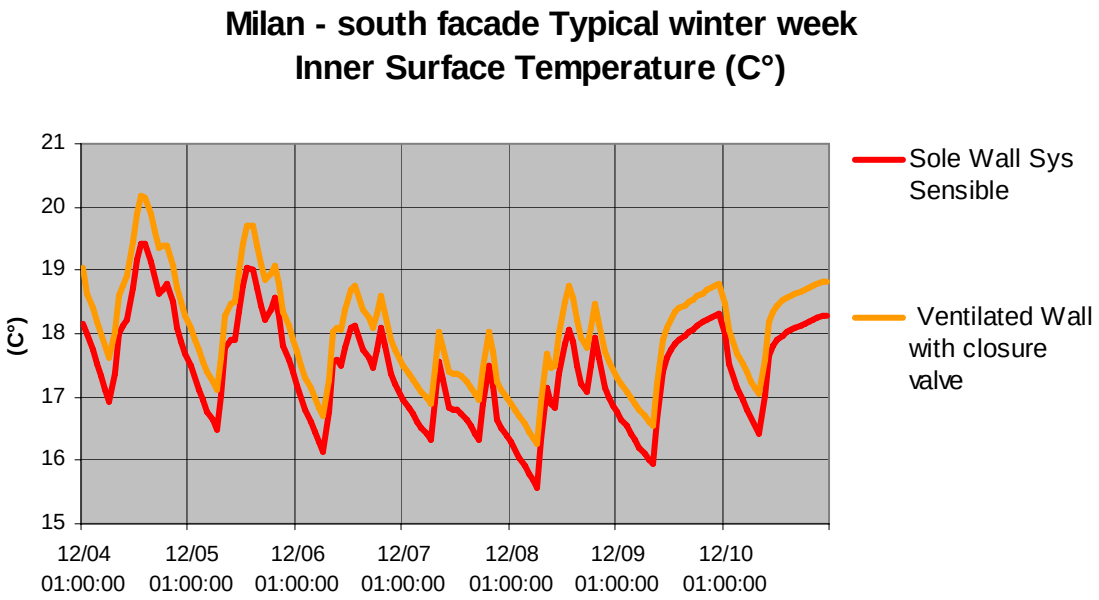
Milan - Delivered Energy (J) - Annual



ANNUAL HEATING, DELIVERED REDUCTION
Milan: 2.6%
Rome: 1.1%
Palermo: 2.2%

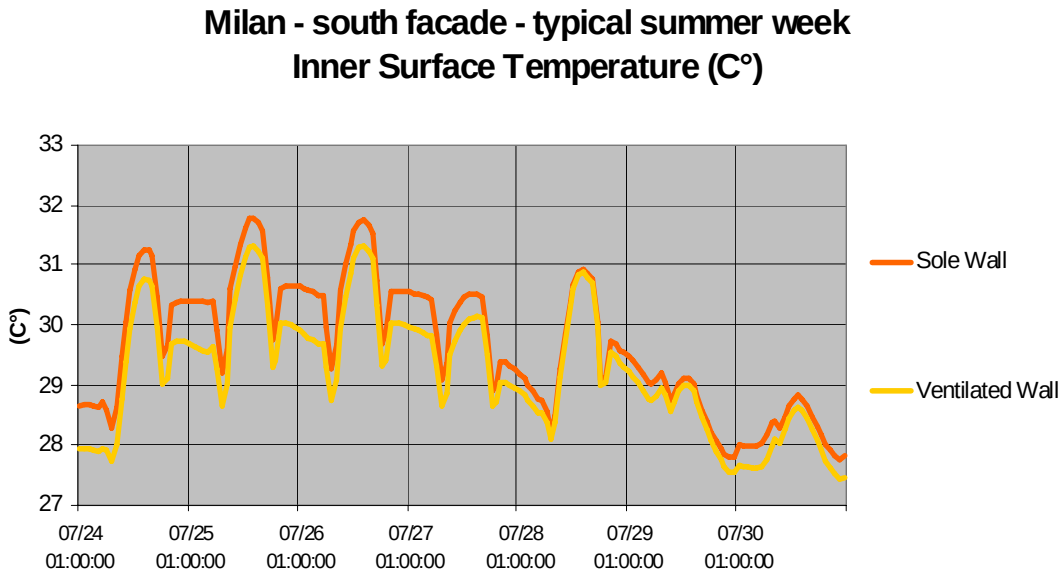
With closed cavity during winter season:
Milan: 9.5%
Rome: 2.1%
Palermo: 4.7%

ANNUAL COOLING, DELIVERED REDUCTION
Milan: 8.1%
Rome: 6.25%
Palermo: 7%



TYPICAL WINTER WEEK

- Ventilated façade with the cavity closed during winter gives higher inner wall temperatures



TYPICAL SUMMER WEEK

- Ventilated wall has lower inner surface temperatures
- That is accentuated during peak hours of the day

Assess The Ventilated Façade Thermal Behavior

The opaque ventilated façade acts as a thermal damper

Winter

- Wind barrier
- Reduction of infra-red heat loss to surroundings (specifically to the night sky)
- Reduction of positive contribution from incoming solar radiation

Summer

- Barrier to solar gain
- Buoyancy takes away heat trough convection during peak load hours of the day (when electricity costs more)

Opaque ventilated façade seems to increase the energy saving in the studied cases

- Main energy savings for studied cases during the cooling season (summer) are realized as a reduction in delivered cooling energy (Milan 8.1% - Palermo 7%)
- Ventilated façade does not show reduction of heating loads
- A seasonal cavity closure valve could decrease heating loads (9.5% Milan)

What have we learned

- The Exterior Natural Vented Cavity Module can be appropriately used to simulate some opaque façade
- Module's default discharge coefficients can be applied to other opaque ventilated façades similar to the one studied
- Models of different façade types need to be characterized trough measurements obtained in physical experiments
- The method can be used to design and certify European buildings with a ventilated façade (2002/91/EC European Directive on the Energy Performance of Buildings and DL192/2005)Conclusion from simulation with EnergyPlus: a ventilated façade acts like a thermal damper
- For specific cases a ventilated façade appears to be an efficient solution that can increase thermal efficiency of residential buildings
- Ventilated façade can reduce summer cooling loads
- A detailed analysis on how different material and geometry configurations affects thermal performance should be developed
- Other (non-residential) building type cases should be studied