naturalcooling

OPTIVENT 2.0

A Natural Ventilation Steady-State Calculation Tool for the Early Design Stage of Buildings.

http://naturalcooling.co.uk/optivent.html

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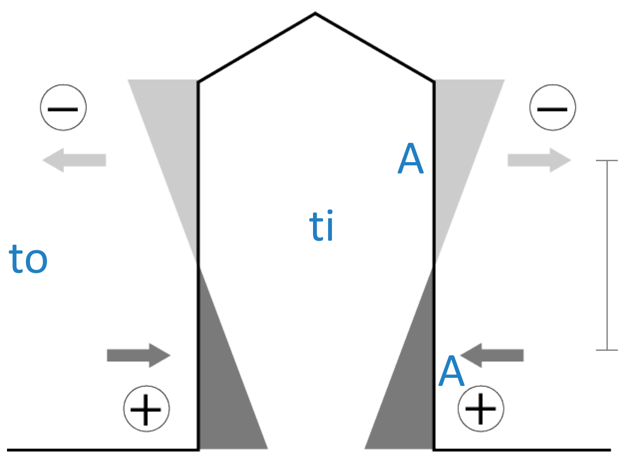
Universidad del BioBio, Chile.

Driving forces of natural ventilation

Thermal force (stack effect)



In absence of wind, air will move between low and high level openings driven by inside-outside temperature difference (Δt) which generates a pressure difference (Δp).

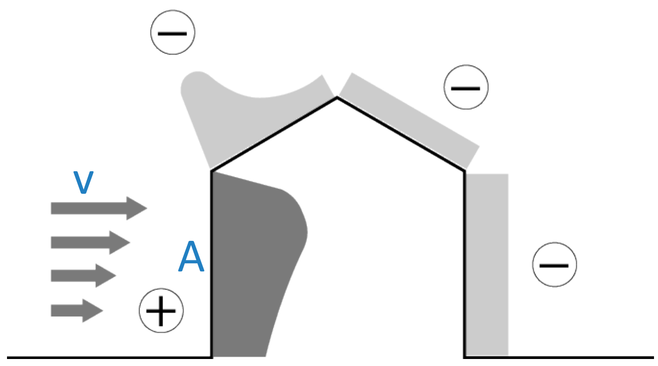
Air flow rate (Q) mainly depends on:

- Opening area (A)
- Inside temperature (ti)
- Outside temperature (to)
- Height between the openings (h)

Δt

Driving forces of natural ventilation

Wind force



When wind blows against the building, a pressure difference (Δp) is generated across the envelope inducing air movement via cracks & openings.

Air flow rate (Q) mainly depends on:

- Opening area (A)
- Wind velocity (v)
- Wind pressure coefficient (Cv)

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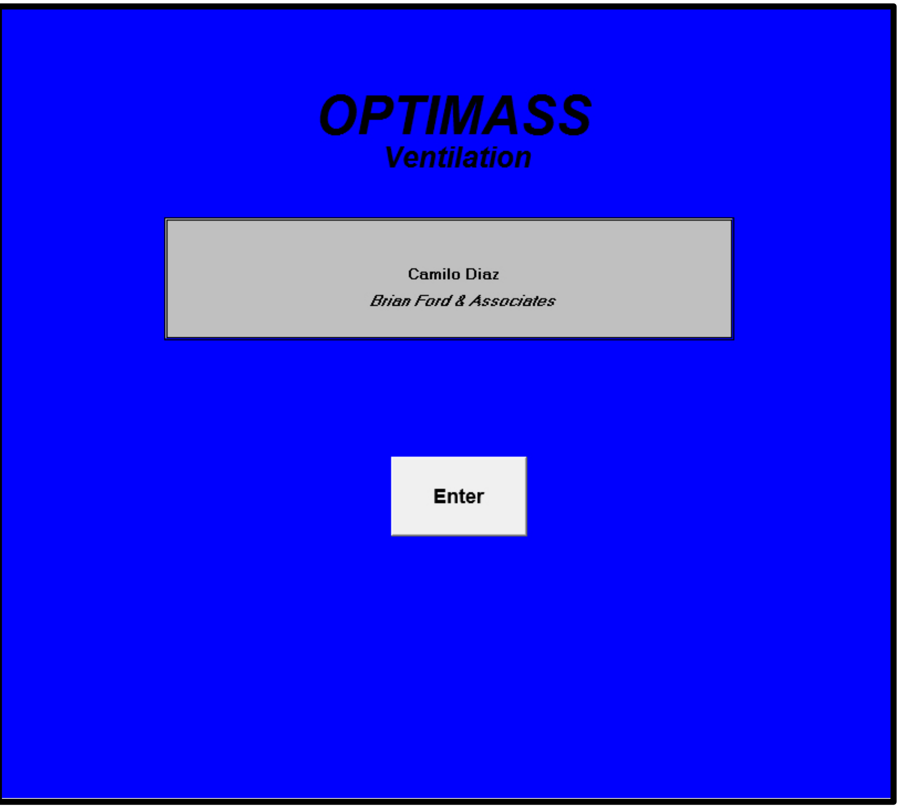
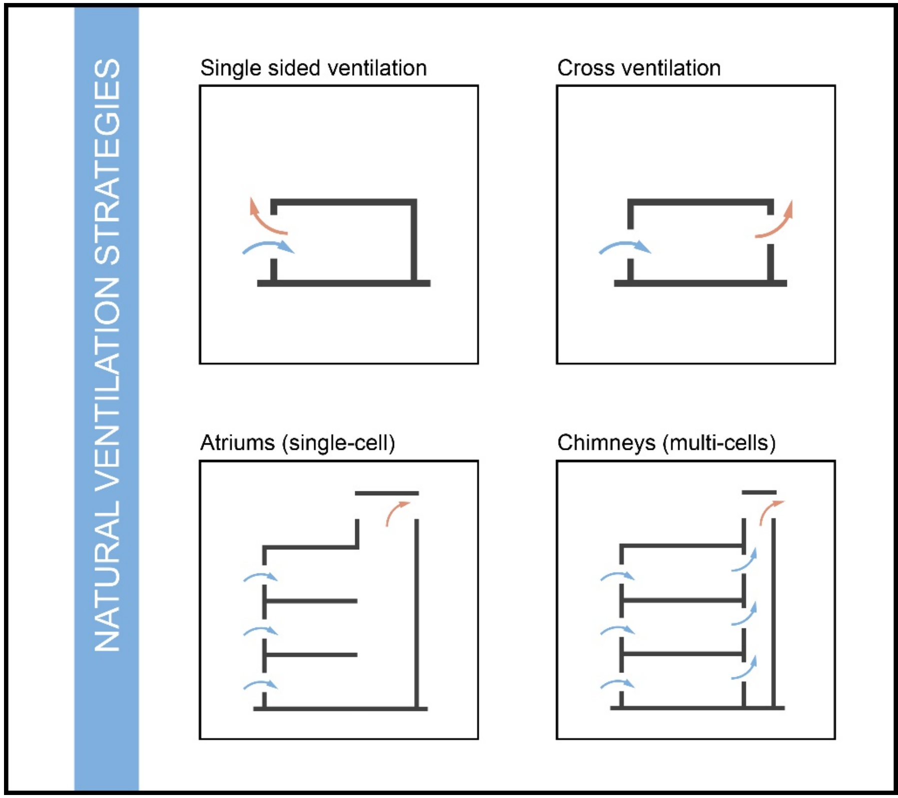
background



2003



2015

http://naturalcooling.co.uk/optivent.html

background

- The objective of this tool is to help in the **decision-making process** regarding the **feasibility of natural ventilation** during the early design stage of buildings.

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- In 2015, OPTIVENT 2.0 was submitted to rigorous **peer review** involving professionals and academics in the UK, ,Chile, Spain and Italy.

background

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- Since 2003, OPTIVENT has been applied in a series of buildings in the UK and abroad, proving to be **reliable and quick to use**.

- In 2015, OPTIVENT 2.0 was submitted to rigorous **peer review** involving professionals and academics in the UK, ,Chile, Spain and Italy.

- OPTIVENT 2.0 is a licensed product and **available via the internet** to both students and practitioners who register on the website.

NATURAL VENTILATION STRATEGIES | PROJECT LOCATION | AIRFLOW DATA INPUT | BUILDING GEOMETRY & SOLAR GAINS | INTERNAL CONDITIONS | RESULTS

methodology

user profile: the **architect/designer**

inputs

- Building layout.
- Aperture areas.
- Stack heights.

outputs

- Airflow rates

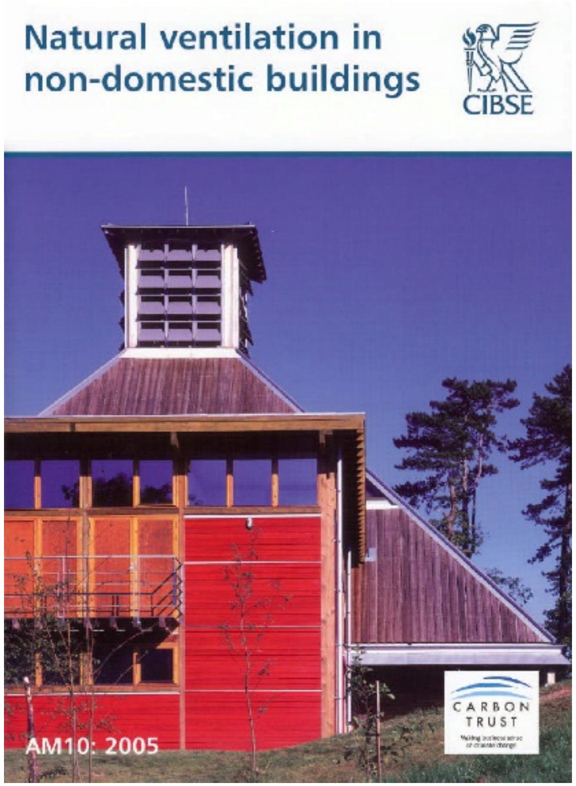
↓

QUICK INPUT PROCESS

natural ventilation strategies

The following space arrangements (**single and multi-cells**) can be evaluated.

All the expressions used for the calculations are aligned with the **CIBSE AM10 (2005)** document.



natural ventilation strategies

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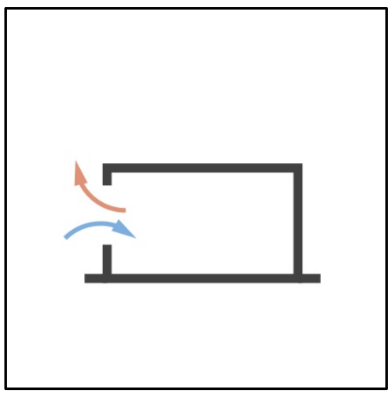
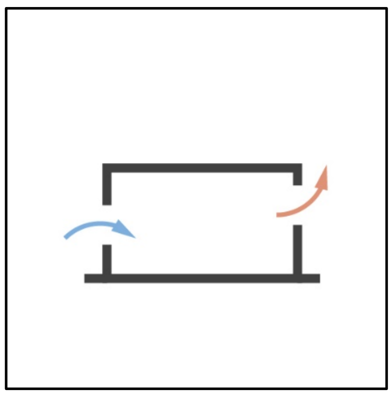
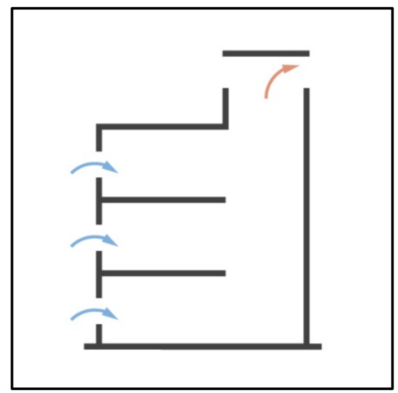
Single sided ventilation



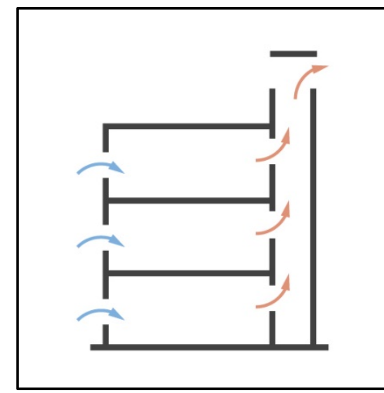
Cross ventilation

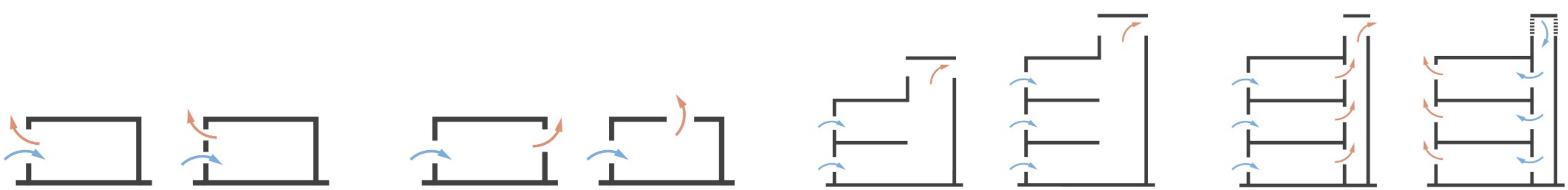


Atria (single-cell)



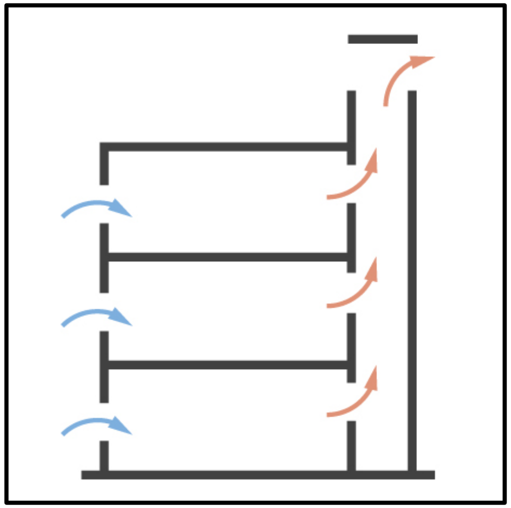
Chimneys (multi-cells)

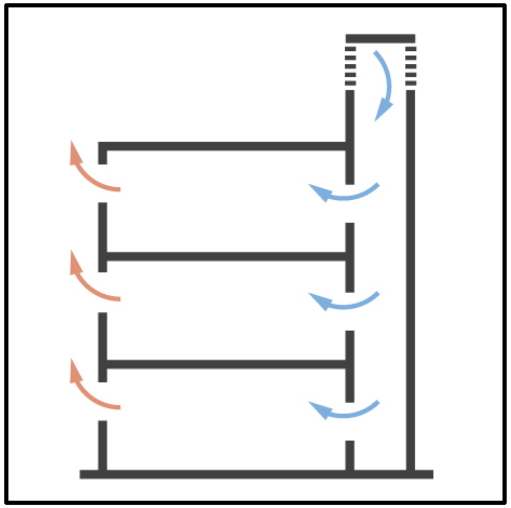




natural ventilation strategies

The **multi-cell** scenario (not covered in CIBSE AM10, 2005) emulates more than one space connected to each other.





natural ventilation strategies

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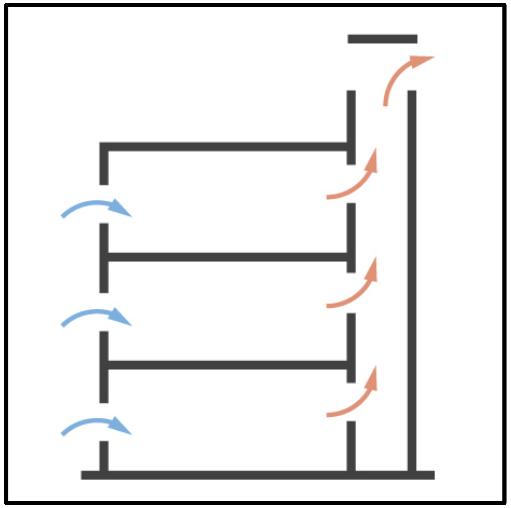

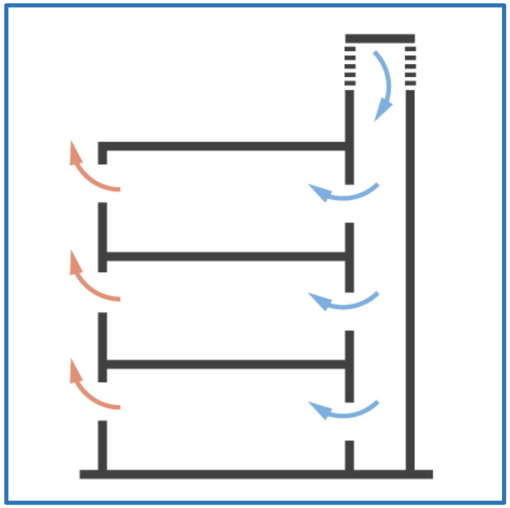

A **downdraught scenario** is also available to emulate a direct evaporative cooling system.

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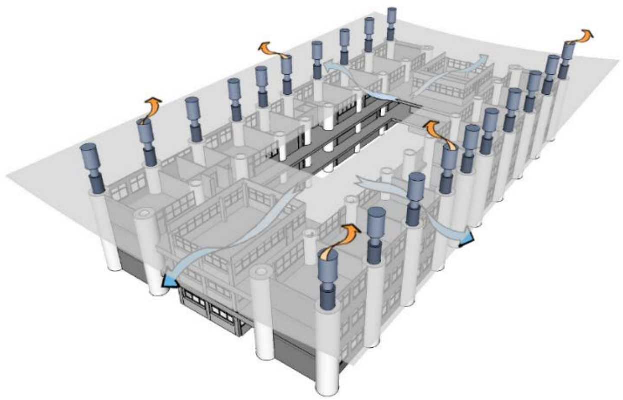
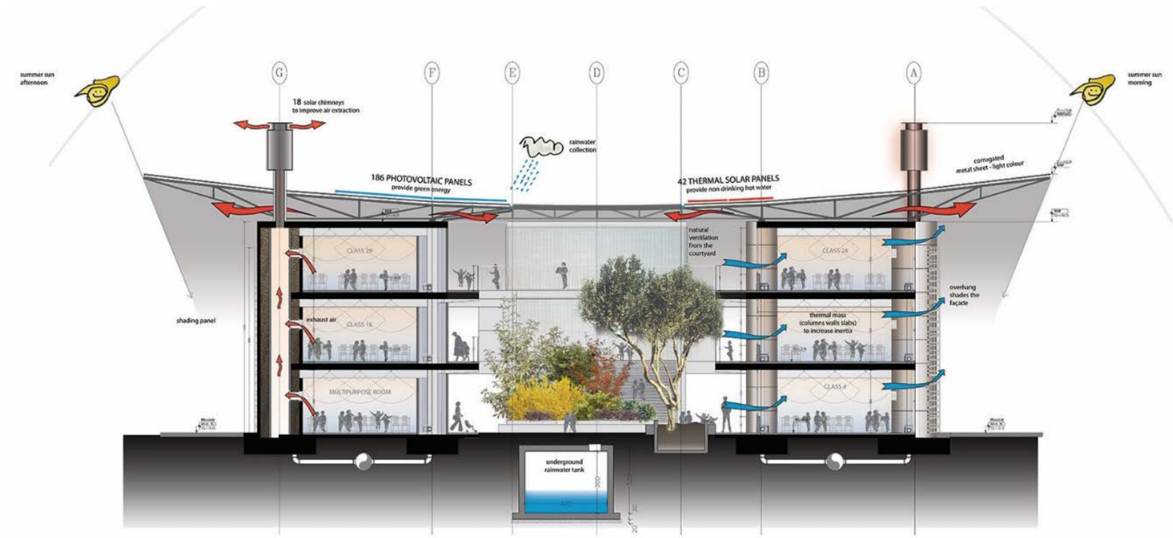


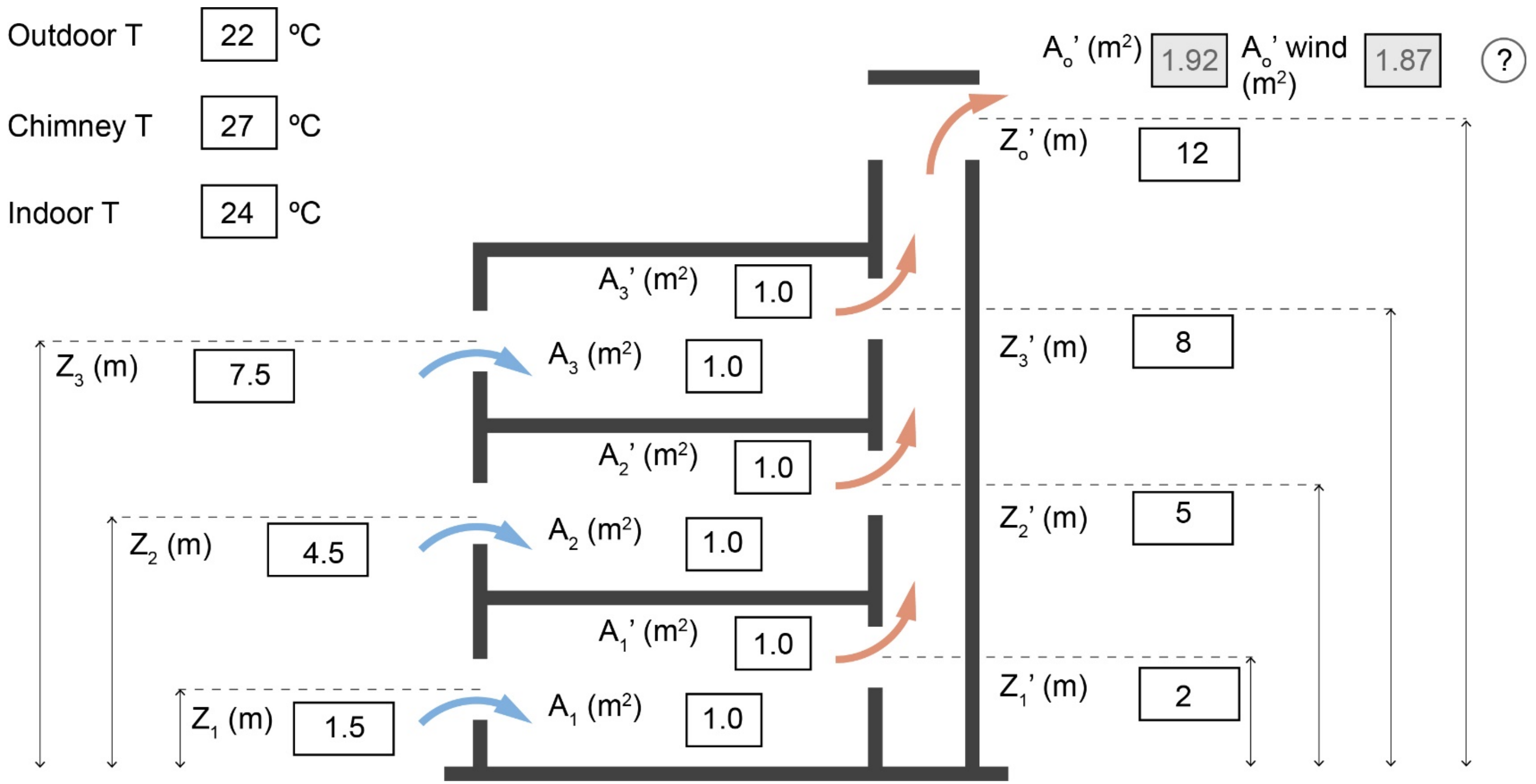


"…the typical air flow path is from the courtyard, across the classrooms and out through the façade and the chimneys."

MC A Kuwait School, Gaza. 2010-current project.

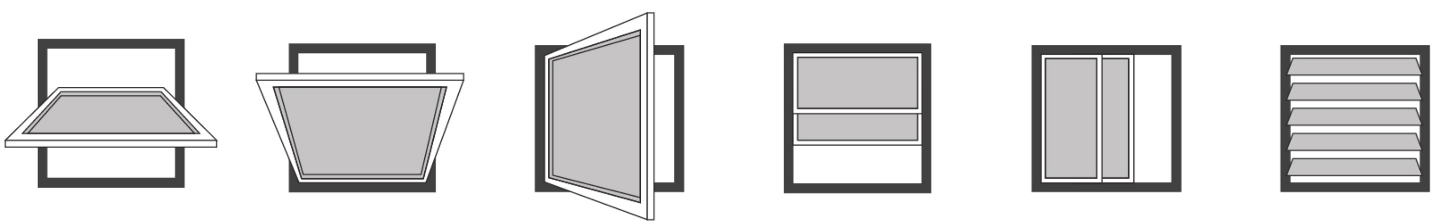
airflow data input

The majority of the user **inputs are shown over diagrams** that help understanding each value.

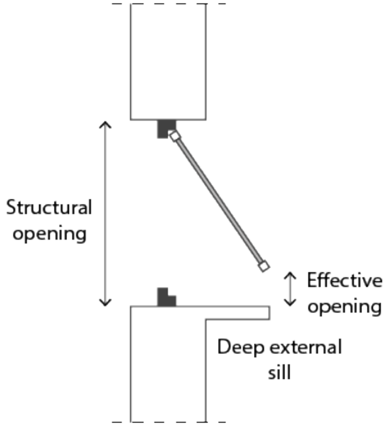


airflow data input

The **effective area** of each aperture is also considered and a range of values are suggested according to the way the window opens and the surrounding head, sill and jamb details.



Effective aperture: 0-90%	Effective aperture: 0-90%	Effective aperture: 0-50%	Effective aperture: 0-90%	Effective aperture: 0-50%	Effective aperture: 0-50%	Effective aperture: 0-30%



solar and internal heat gains

Heat gains need to be addressed to allow a comparison '**airflow required vs achieved**' before considering any natural ventilation strategy as valid.

- The number of people is used to calculate the **minimum ventilation required** for the supply of **fresh air** (10 l/s).
- A quantification of the total heat generated in the space is required to estimate the **airflow rate required for cooling**.

solar and internal heat gains

Internal gains are defined by the number of **occupants, equipment and lighting** gains.

Occupants

at rest (76W)	0	people
office work (85W)	2	people
walking (100W)	0	people
exercising (120W)	0	people

Internal gains

equipment (W/m²)	15
lighting (W/m²)	10

Benchmark allowances for internal heat gains in typical buildings

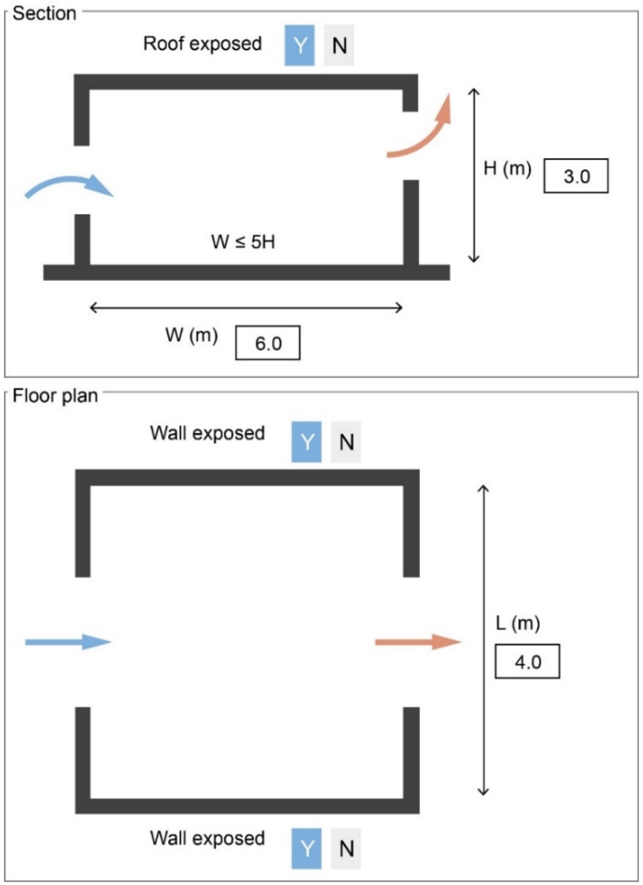
Building type	Use	Density of occupation (m²/person)	Sensible heat gain (W/m²)	
			Lighting	Equipment
Offices	General	12	8-12	15
	Meeting/conference	3	10-20	5
Airports/stations	Gate lounge	0.83	15	5
	Circulation spaces	10	12	5
Retail	Shopping malls	2-5	6	0
	Retail stores	5	25	5
Education	Lecture theatres	1.2	12	2
	Teaching spaces	1.5	12	10
	Seminar room	3	12	5
Leisure	Hotel reception	4	10-20	5
	Restaurant/dining	3	10-20	5
	Bars/lounges	3	10-20	5

CIBSE (2015). Table 6.2, Chapter 6: Internal gains.

solar and internal heat gains

Direct and conductive solar gains are considered and calculated by the tool.

Cell dimensions



Construction materials properties

Glazing

Solar Transmittance Factor (0-1)	0.6
Shading proportion (%)	20

Wall

Surface Absorptance (0-1)	0.6
U-Value (W/m²K)	0.3
Ext. Surf. Transmittance (W/m²K)	4.0

Roof

Surface Absorptance (0-1)	0.6
U-Value (W/m²K)	0.2
Ext. Surf. Transmittance (W/m²K)	4.0

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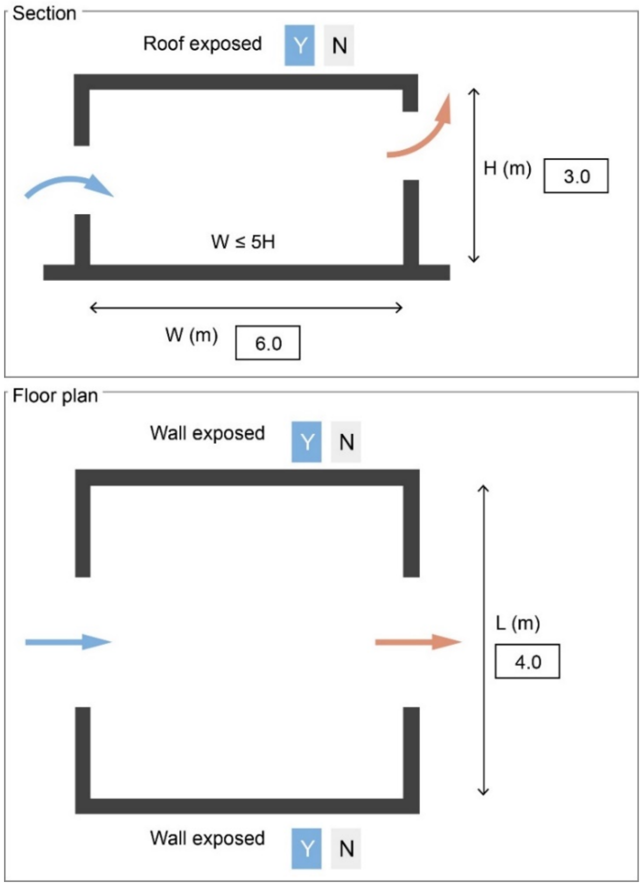

The tool estimates **hourly clear sky beam and diffuse irradiance** on vertical and horizontal surfaces for any month of the year and extends the application of the ASHRAE Clear Sky Model (2005) to both northern and southern hemispheres.

calculation methods

The **principle of mass conservation** is applied in each envelope flow model (equation 4.9, CIBSE AM10, 2005) and the airflow rate through each opening is expressed as a relationship between the pressure difference across the opening by means of the discharge coefficient and the specified effective aperture area (equations 4.10 and 4.11, CIBSE AM10, 2005).

$$\Sigma q_i = 0$$

(equation 4.9, CIBSE AM10, 2005)

$$q_i = Cd_i\ A_i\ S_i \sqrt{\frac{2\ |\Delta p_i|}{\rho_0}}$$

(equation 4.10, CIBSE AM10, 2005)

$$\Delta p_i = \Delta p_0 - \Delta\rho_0\ g\ z_i + 0.5\ \rho_0\ U^2\ Cp_i$$

(equation 4.11, CIBSE AM10, 2005)

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Discharge coefficients and **wind pressure coefficients** have been set to default values optimised for each airflow model.

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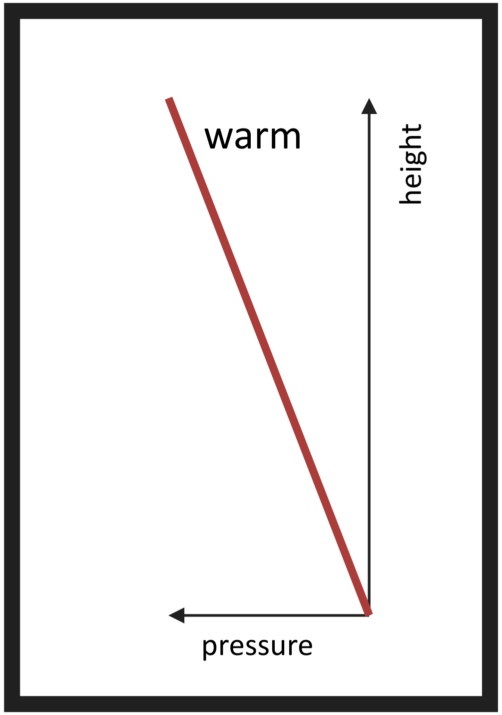
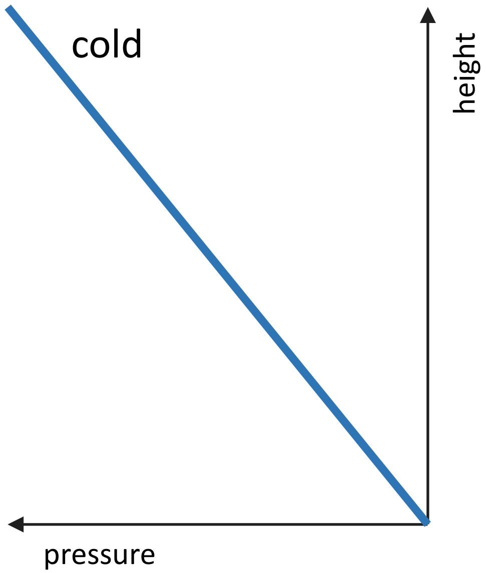
- Temperatures within the space are assumed to be the same at any given height.
- Indoor-outdoor temperature difference is suggested for daytime and nightime ventilation in order to obtain reliable results.
- In scenarios with multiple apertures, the neutral plane has been set at a height between the top inlet and outlet and an estimate of the outlet area required to satisfy the selected flow pattern is calculated based on this assumption and the input data. This avoids unnecessary iterative processes (implicit method) performed by the user to find the required aperture areas and heights to satisfy the selected flow pattern.

calculation methods

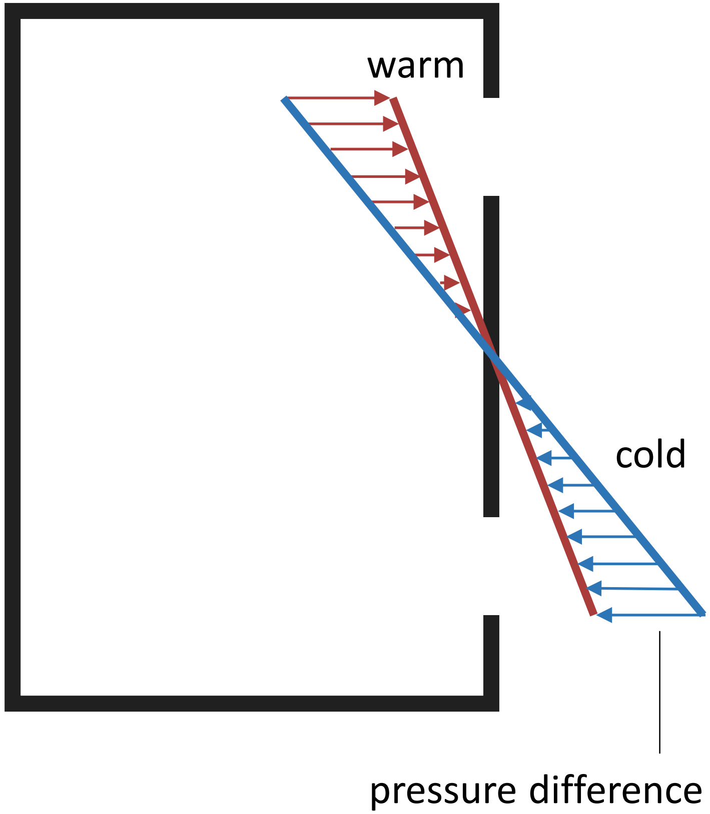
neutral plane





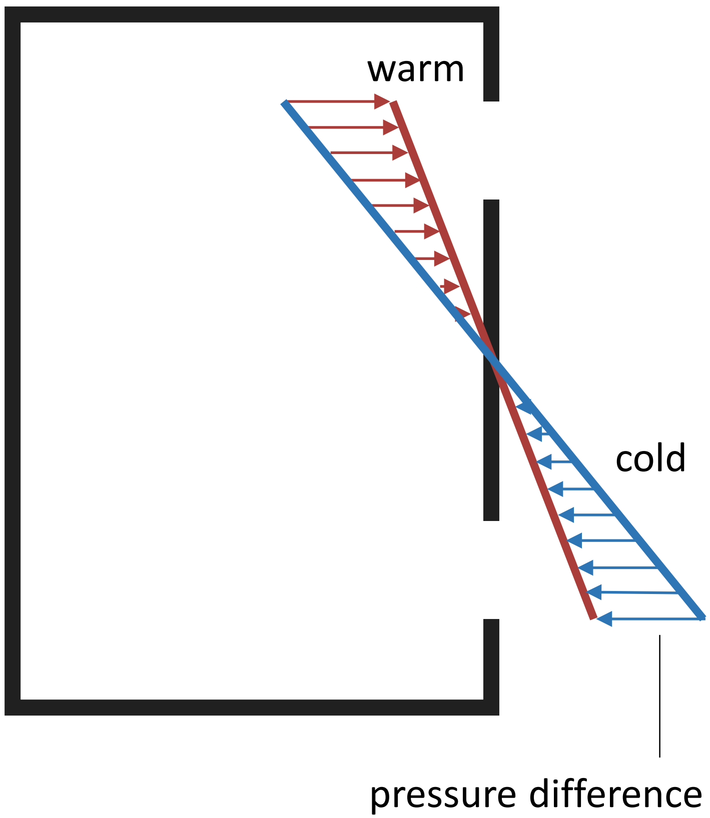
calculation methods

neutral plane



calculation methods

neutral plane



When two apertures are the same size, the pressure drop across each opening must be the same in magnitude to satisfy the law of the conservation of mass.

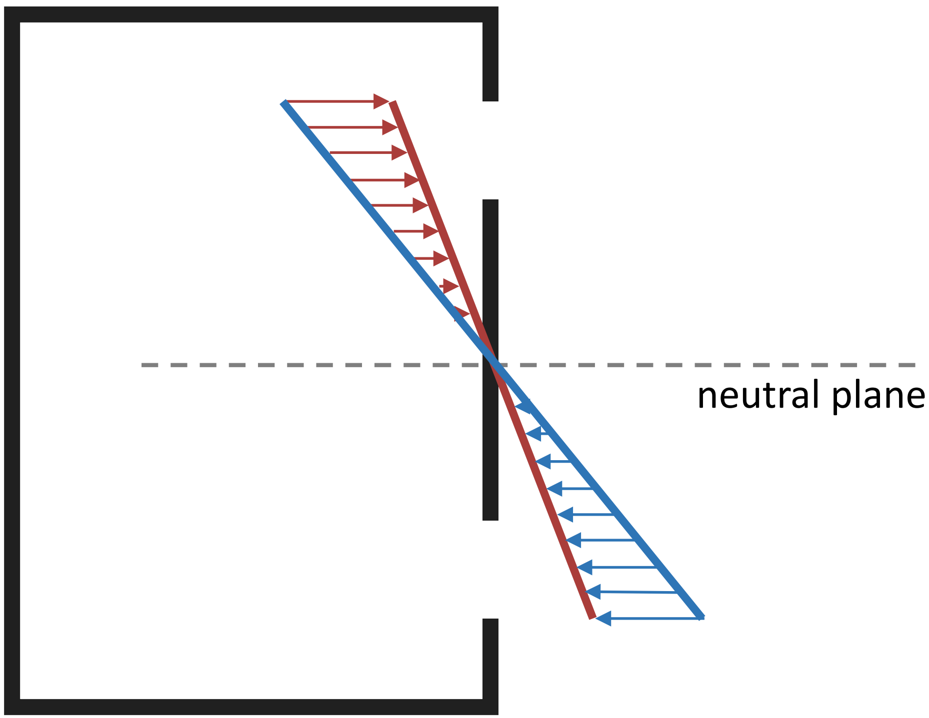
$$q_i = q_o$$

$$Cd_i\, A_i\, S_i \sqrt{\frac{2\,|\Delta p_i|}{p_0}} = Cd_o\, A_o\, S_o \sqrt{\frac{2\,|\Delta p_o|}{p_0}}$$

$$\Delta p_i = -\Delta p_o$$

calculation methods

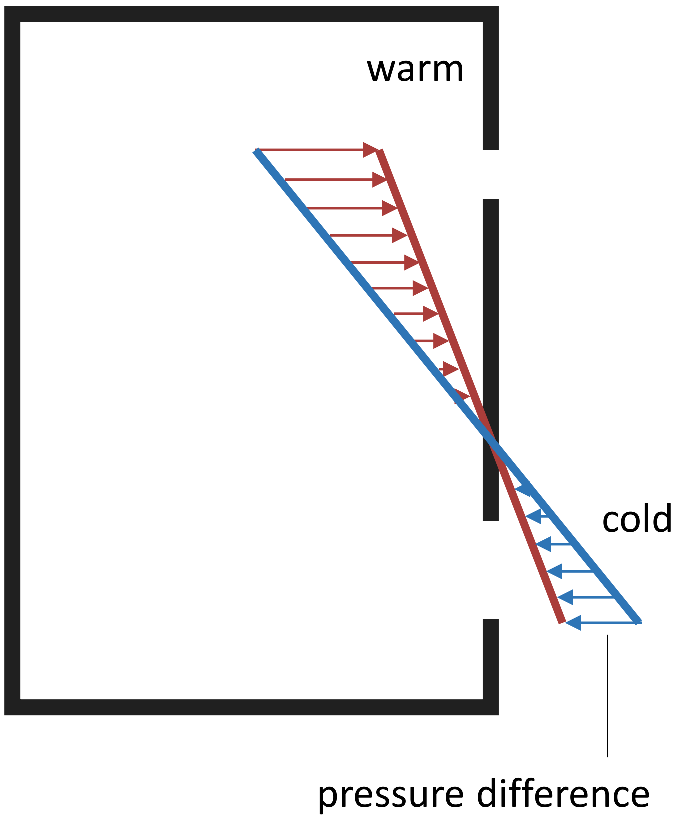
neutral plane



The neutral plane is the height at which the two gradients intersect ($\Delta p = 0$).

calculation methods

neutral plane



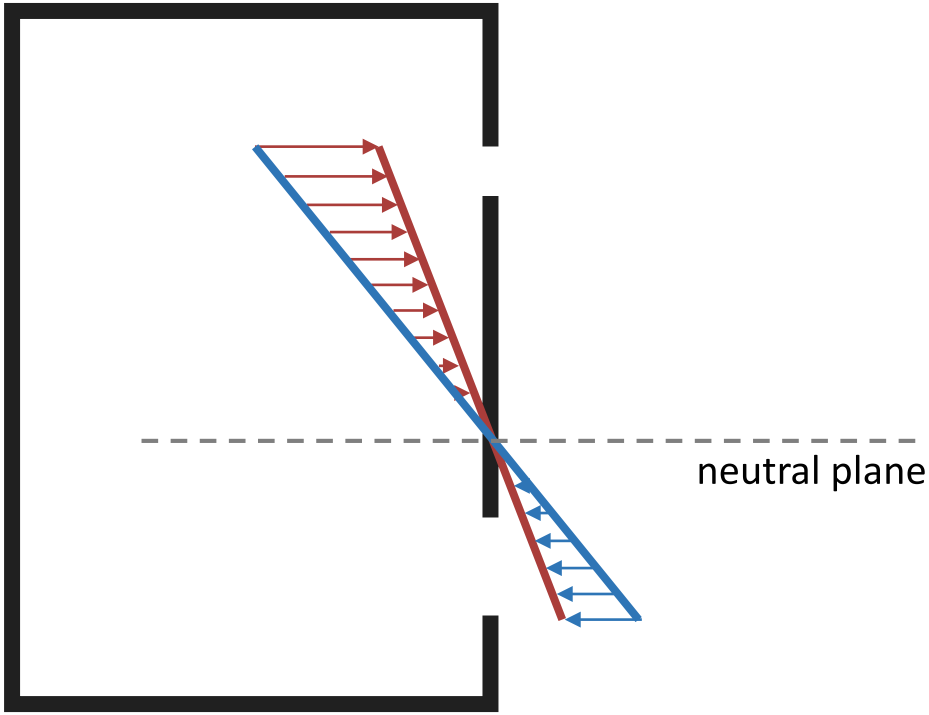
$$q_i = q_o \quad ; \quad A_i = 2A_o$$

$$Cd_i\, 2A_o\, S_i \sqrt{\frac{2\,|\Delta p_i|}{p_0}} = Cd_o\, A_o\, S_o \sqrt{\frac{2\,|\Delta p_o|}{p_0}}$$

$$4\Delta p_i = -\Delta p_o$$

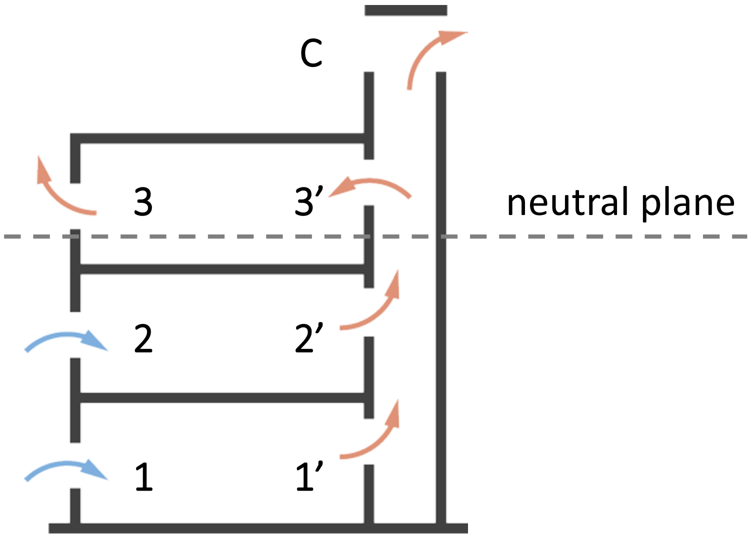
calculation methods

neutral plane



calculation methods

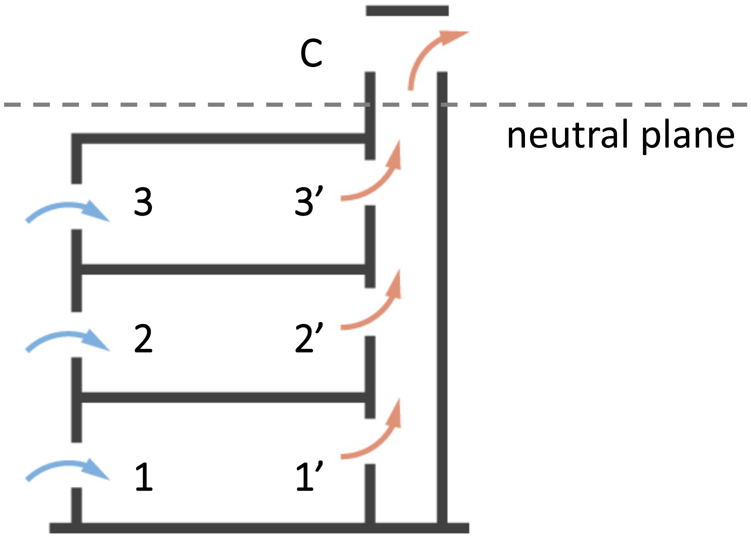
Example: **multi-cell scenario**



Undesired **flow reversal** is a common problem in buildings when the feasibility of a natural ventilation has not been evaluated during the design process.

calculation methods

Example: **multi-cell scenario**



Inputs

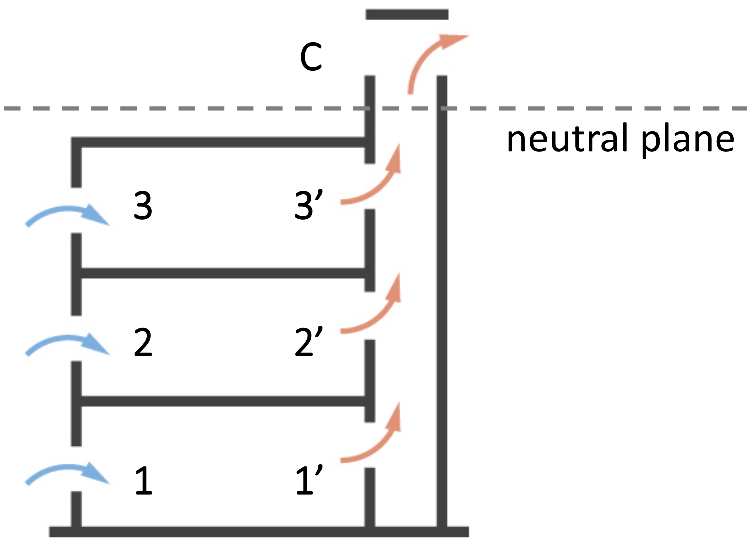
- Building layout
- Inlet areas
- Stack heights
- **Neutral plane**

Outputs

- Airflow rates
- **Outlet area**

calculation methods

Example: **multi-cell scenario**



The pressure drops across the openings for the flow pattern shown are:

$$\Delta P_1 = P_E - P_1 - (\rho_E - \rho_I)gz_1 + 0.5\rho_E U^2 Cp_I$$

$$\Delta P_2 = P_E - P_2 - \rho_E gz_2 + \rho_I gh_2 + 0.5\rho_E U^2 Cp_I$$

$$\Delta P_3 = P_E - P_3 - \rho_E gz_3 + \rho_I gh_3 + 0.5\rho_E U^2 Cp_I$$

$$\Delta P_C = -P_E + P_C + (\rho_E - \rho_C)gz_C - 0.5\rho_E U^2 Cp_C + \rho_E gL - \rho_C gL$$

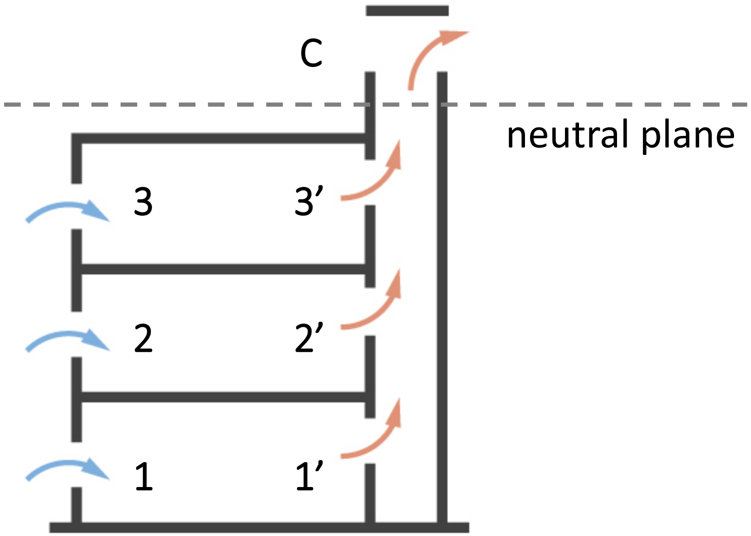
$$\Delta P_{1'} = -P_C + P_I + (\rho_C - \rho_I)gz_{1'}$$

$$\Delta P_{2'} = -P_C + P_2 + \rho_C gz_{2'} - \rho_I gh_{2'}$$

$$\Delta P_{3'} = -P_C + P_3 + \rho_C gz_{3'} - \rho_I gh_{3'}$$

calculation methods

Example: **multi-cell scenario**



The relationships between pressure drops are:

$$\Delta P_C = \Delta P_3 + \Delta P_{3'}$$

$$A_1^2 \Delta P_1 = A_{1'}^2 \Delta P_{1'}$$

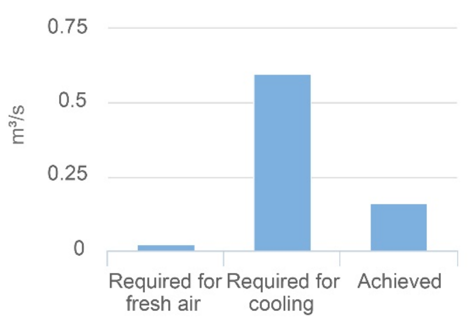
$$A_2^2 \Delta P_2 = A_{2'}^2 \Delta P_{2'}$$

$$A_3^2 \Delta P_3 = A_{3'}^2 \Delta P_{3'}$$

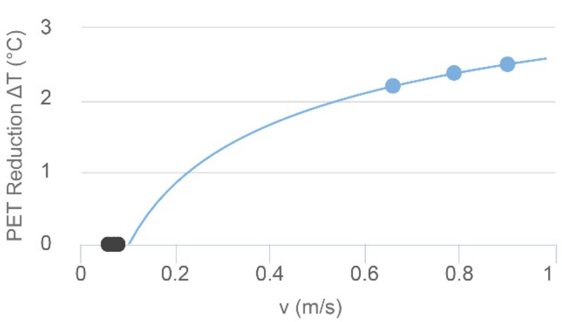
results

The calculation process outputs airflow rates driven by **buoyancy** and driven by **buoyancy + wind**.

airflow rate

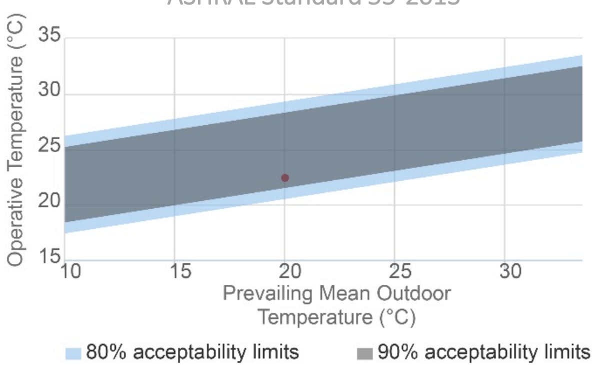


cooling effect of air movement



adaptive comfort band

ASHRAE Standard 55-2013



results

The results and the user inputs are summarised in one A4 page which can be downloaded in PDF format for future revisions, presentations, etc.

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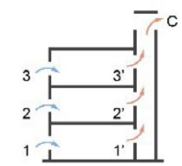
A Natural Ventilation Steady-State Calculation Tool for the Early Design Stage of Buildings.

Proyect Data:

Proyect Name:	**Proyect Name**
Version:	**Run 1**
Date:	**2015-05-17**
Consultant:	**Consultant**

Natural ventilation strategy:

Chimneys (multi-cells)



Location Data:

Latitude (decimal degrees):	**52**
Month:	**January**
Hour:	**12**
Prevailing mean outdoor temperature (°C):	**20.0**
Meteorological Wind Speed (m/s):	**1.0**
Terrain data:	**1**
Inlet (surface) Azimuth:	**N**

Building Data:

Cell - Floor area (m²):	**24**
Cell - Volumen (m³):	**72**
Outdoor temperature (°C):	**22**
Indoor temperature (°C)	**24**
Chimney temperature (°C):	**27**

Construction Data:

Glazing:	
Solar Transmittance Factor (0-1):	**0.6**
Shading Proportion (%):	**20**
Wall	
Surface Absorptance (0-1):	**0.6**
U-Value (W/m²·K):	**0.3**
Ext. Surf. Transmittance (W/m²·K):	**4.0**
Roof	
Surface Absorptance (0-1):	**0.6**
U-Value (W/m²·K):	**0.2**
Ext. Surf. Transmittance (W/m²·K)	**4.0**

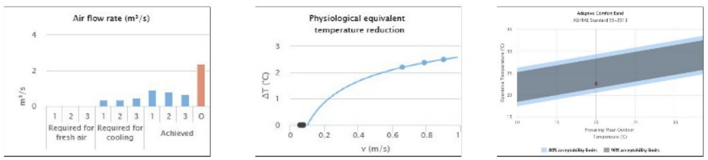
Cell - Heat Gains:

Number of people:	**2**
occupant gains (W/m²):	**7.08**
Equipment gains (W/m²):	**15**
Lighting gains (W/m²):	**10**
Total internal gains (W/m²):	**32.08**
Total Solar Gains (W/m²)	
Cell 1:	**4.41**
Cell 2:	**4.41**
Cell 3:	**12.96**
Total heat generated (kW)	
Cell 1:	**0.88**
Cell 2:	**0.88**
Cell 3:	**1.08**

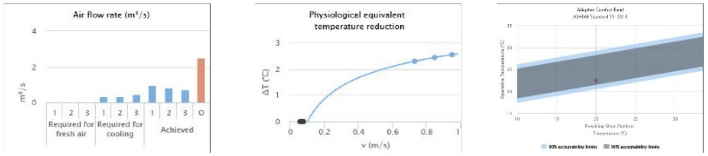
Apertures Data:

	Effective Area (m²)	Height Zn (m)	Airflow Rate (m³/s) B	Airflow Rate (m³/s) B+W
Inlet 1:	**1**	**1.5**	**0.9**	**0.95**
Inlet 2:	**1**	**4.5**	**0.79**	**0.85**
Inlet 3:	**1**	**7.5**	**0.66**	**0.73**
Outlet O:	**1.91 - 1.87**	**12**	**-2.35**	**-2.53**

Bouyancy driven



Bouyancy + Wind driven



THANK YOU

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naturalcooling

http://naturalcooling.co.uk/optivent.html

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