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Natural Ventilation Systems

Compiled by

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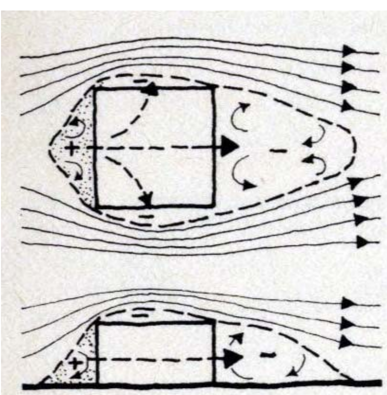


Pressure effect from wind

DESCRIPTION

Natural ventilation uses the natural forces of wind and buoyancy to deliver fresh outdoor air into buildings for ventilation and thermal comfort within a space. With an increased awareness of the cost and environmental impacts of energy use, natural ventilation has become an increasingly attractive method for reducing energy costs and environmental impact, and for providing acceptable or even superior indoor air quality (IAQ) in order to maintain a healthy, comfortable and productive indoor climate.

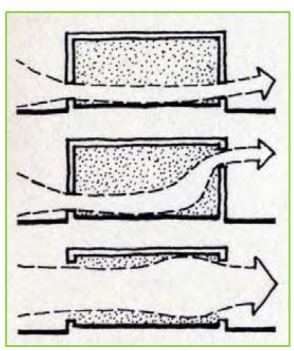
DRIVING FORCES

Natural ventilation systems rely on naturally occurring pressure differences to supply fresh air through an indoor space. Pressure differences can be caused by wind or the buoyancy effect created by temperature differences.

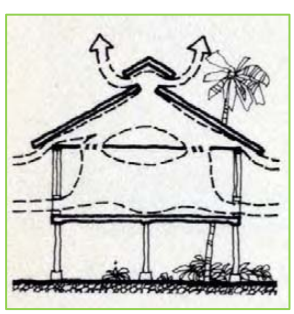
Wind: When wind hits a side of a building (the windward side), air is brought to a rest, creating a positive static pressure while a negative pressure on the opposite side of the building (the leeward side). This pressure difference between inside and outside of the building allows air to enter openings on the windward side and to exit through openings on the leeward side, creating an air movement within the building.

Buoyancy: Buoyancy results from difference in air density, where warm air is less dense than cool air. Indoor/outdoor temperature difference causes density difference and therefore pressure difference that creates exchange between indoor and outdoor air.

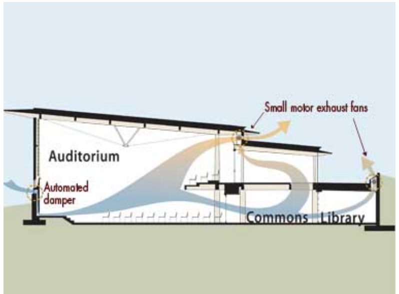
IMPLEMENTATION STRATEGIES



Cross Ventilation: Pressure difference caused by wind is utilized in cross ventilation. Outdoor air enters through openings at high pressure and flows across the space and exits through openings at low pressure. To take advantage of this ventilation scheme, it is best to have openings on opposite sides (the windward and leeward sides, for example). The effectiveness of this strategy is a function of building location and orientation, outdoor air conditions, opening size, shape and orientation.

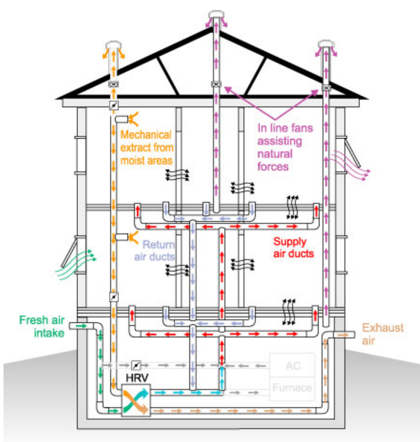


Stack Ventilation: Pressure difference caused by temperature difference between indoor and outdoor is utilized in stack ventilation. In winter, cold outdoor air comes in and is heated. The heated air rises and flows out from openings on the upper portion of a building. In summer, hot outdoor air flows in and is cooled down, creating a downward flow to the lower portion of the building.



Fan-assisted natural ventilation

Solar chimney



Hybrid ventilation

A greater temperature difference yields a larger pressure difference between inside and outside of a building. In order to take advantage of this scheme, it is best to have large vertical distance between inlet/outlet openings because the greater vertical distances, the greater pressure difference.

Some of the factors affecting the effectiveness of stack ventilation are building height, and indoor/outdoor temperature difference, size and location of the openings. Because it does not rely on wind direction, there is a greater control on locating the air intake. However, stack ventilation is limited to a lower magnitude than wind-driven, cross ventilation.

ENHANCEMENT STRATEGIES

In many cases, natural ventilation cannot alone provide the required airflow rate due to lack of wind and/or temperature difference. When natural ventilation cannot be ensured by wind and buoyancy, the following strategies can be considered to enhance natural ventilation:

- *Fan-assisted:* Fans may be installed to ensure the necessary ventilation flow rate. Such fans may be installed either on stack ducts or in walls or windows.

- *Solar-assisted:* Solar chimneys are a method of enhancing stack ventilation. Solar energy is used to heat the air to increase inlet/outlet temperature difference, causing an increase in airflow within the building.

- *Hybrid/mixed-mode:* Hybrid ventilation takes advantage of natural ventilation when it is available and supplements it as necessary with mechanical ventilation. The main benefit of some augmentation by mechanical systems is that there is less unpredictability with indoor environment conditions, though it will result in greater energy use.

SUITABILITY

Most suited to:

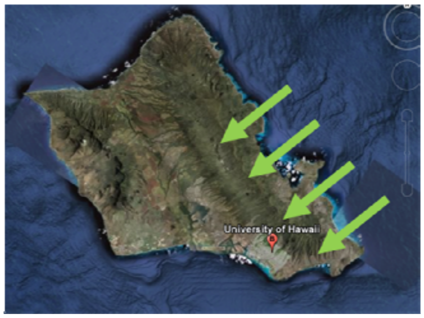
- Buildings with a narrow plan or atria
- Sites with minimal external air and noise pollution
- Open plan layouts—high degree of permeability within the building
- Temperate climate with low average humidity levels

Not suited to:

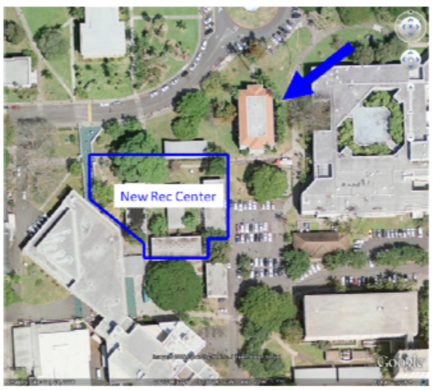
- Buildings with a deep floor plan
- Buildings that require precise temperature and humidity control
- Buildings with individual offices or small spaces
- Buildings with consistent heat loads above 110-125 btuh/s.f.
- Locations with poor air quality (If filtration is required, mechanical ventilation is necessary)

Problems associated with building openings are:

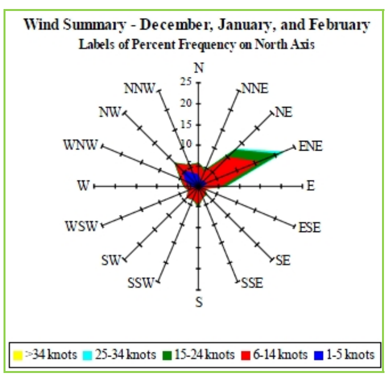
- Security
- Conflicts with fire or safety regulations
- Insects, odors, dust and air pollution
- Fluctuation of internal temperature

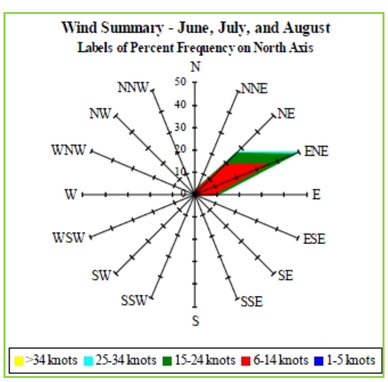


Typical wind patterns in Hawaii



University of Hawaii Recreational Center





GENERAL DESIGN GUIDELINES

Some of the important considerations for natural ventilation design involve:

- Location, orientation and layout of building
- IAQ requirements, ventilation cooling requirements
- Sizes and location of building openings
- Strategic cooling load reductions- shading, heat-rejecting glazing, thermal mass to dampen temperature swings

Design Considerations with Cross Ventilation:

- Cross ventilation cooling is only viable when the outdoor temperature is at least 3°F lower than the indoor temperature.
- To maximize the effectiveness of openings, locate openings perpendicular to prevailing wind.
- Will work well if the width of the room is up to 5 times the ceiling height

Design Considerations with Stack Ventilation

- Locate outlet high above inlet to maximize stack effect. The vertical distance between inlet and outlet should take advantage of stack effect.
- The outlet must be placed on the leeward side to take advantage of negative wind pressure to draw air out.
- Consider the use of vented skylights. A vented skylight provides an opening for heated air to escape in stack ventilation. A well-designed skylight could also act as a solar chimney to enhance airflow.

Design Recommendations for University of Hawaii

The University of Hawaii at Manoa Recreation Center is a good candidate for natural ventilation due to mild climate of Hawaii, open space and no strict temperature and humidity requirements for the space:

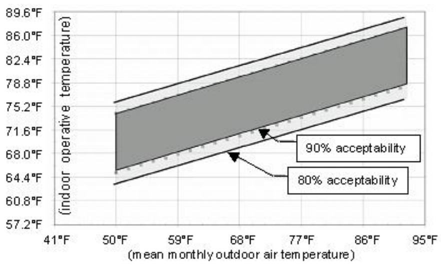
- To maximize cross ventilation, openings ideally would be located to take advantage of the NE wind. Provide inlet openings on the north and the east walls and outlet openings on the south wall. Outlet openings should be high above inlet openings to maximize stack effect.

- Consider the use of vented skylights. A vented skylight will provide an opening for warm, stale air to escape. The light well of the skylight could act as a solar chimney to augment stack effect. In order for stack ventilation to work properly, sunlit areas should be confined to upper region of the building.

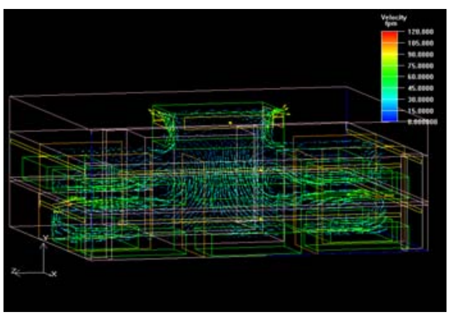
ENERGY IMPACT

Designing around a natural ventilation system presents a tremendous energy savings opportunity. In Hawaii, outdoor air temperature is between 70-80 degrees for 61% of annual hours. Assuming that thermal comfort standards include elevated humidity criteria, the use of a hybrid natural ventilation system could realize HVAC system energy savings of 35%-60%

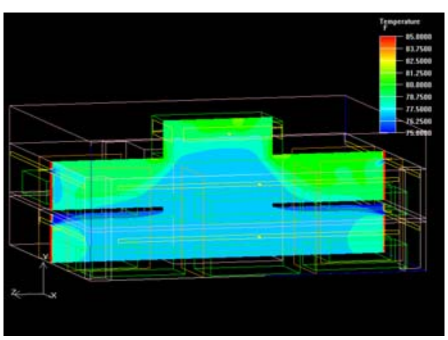
Average annual temperatures
for Honolulu, HI



Indoor thermal comfort criteria by
ASHRAE 55

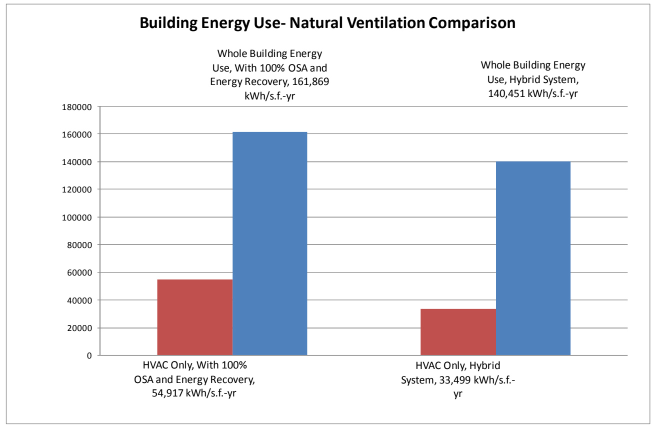


Natural Ventilation: Velocity vector
distribution acquired by CFD analysis



Natural Ventilation: Temperature
distribution acquired by CFD analysis

over a well designed traditional 100% OSA system with economizer and energy recovery. This estimate is based on analysis of bioclimatic factors, typical system performance, and experience from other projects- at this point in time, we cannot guarantee any level of performance. The figure below compares energy use in this example:



COMPUTATIONAL FLUID DYNAMICS (CFD) ANALYSIS

CFD uses numerical methods to solve the fundamental governing equations that describe fluid flow for predefined geometries and boundary conditions. The result is a wealth of predictions for flow field parameters for any region where flow occurs. CFD modeling can be used effectively to predict flow rate of outdoor air coming into the space and to evaluate system performance. With information acquired, ventilation requirement and thermal comfort criteria in ASHRAE Standard 62, 55 can be checked. When modeling natural ventilation, it is necessary to take into account other buildings around it as they will affect the effectiveness of the wind hitting the building to create the pressure difference needed.

The following steps are suggested:

1. Conduct external flow CFD analysis to evaluate flow parameters (velocity, flow rate) on openings

2. Subsequently conduct internal flow CFD analysis to predict detailed flow field for the conditioned space with predicted air flow from external flow simulation

Additional Resources

- Hawaii Commercial Building Guidelines for Energy Efficiency
http://www.archenergy.com/library/general//chapter2_nat_vent_030604.pdf
- BEDP Environmental Design Guide: Natural Ventilation in Passive Design
http://www.environmentdesignguide.net.au/media/TEC02.pdf
- Walker, A., Natural Ventilation: Whole Building Design Guide
http://www.wbdg.org/resources/naturalventilation.php
- Natural Ventilation Systems
http://www.resourcesmart.vic.gov.au/documents/Natural_Ventilation_Systems.pdf