Cutting edge natural ventilation of high-rise buildings in Japan

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Natural ventilation in Japan

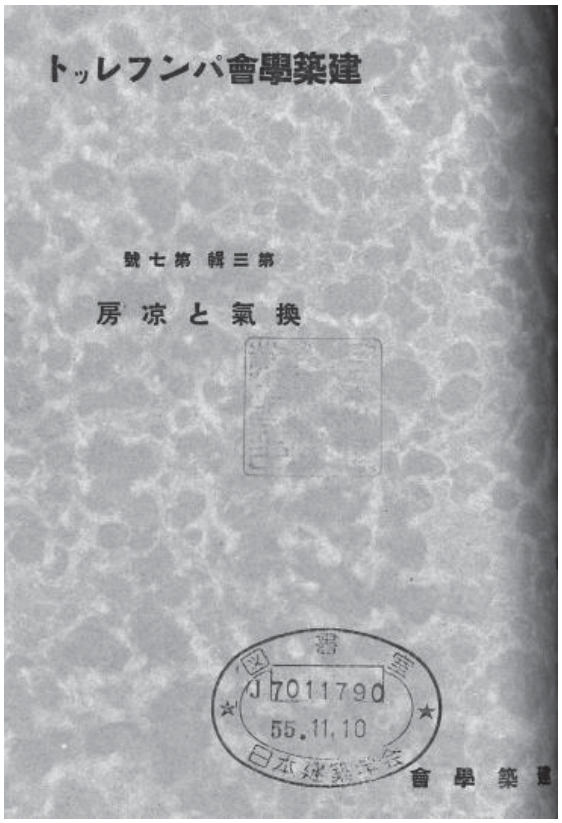
- **Natural ventilation and cross-ventilation have been noticed as an important issue in Japan for long time because of its hot and humid climate in summer time.**
- **Researches on natural ventilation and cross-ventilation has been conducted in the early days in Japan.**
- **Architectural Institute of Japan (AIJ) was founded in 1886.**

Natural ventilation in Japan

- **The first volume of AIJ Transactions, 1936,**
  - **2 papers for ventilation and cross-ventilation,**
  - **1 for acoustics**
  - **4 for daylight in the field of building environment**
- **Volume 5 of AIJ Transactions in the next year, 1937**
  - **3 papers for ventilation and cross-ventilation,**
  - **2 for moisture,**
  - **1 for thermal comfort**
  - **3 for acoustics**
  - **'ventilation path' and 'cross-ventilation' were titled in the papers in Volume 5.**

Natural and Cross ventilation research in Japan

- AIJ Pamphlet Vol.3, No.7 (1930)
  "Ventilation and cooling"
  exactly the same concept with "ventilative cooling" !!
- Main discussions are standard of ventilation rate and calculation theory.



Natural and Cross ventilation research in Japan

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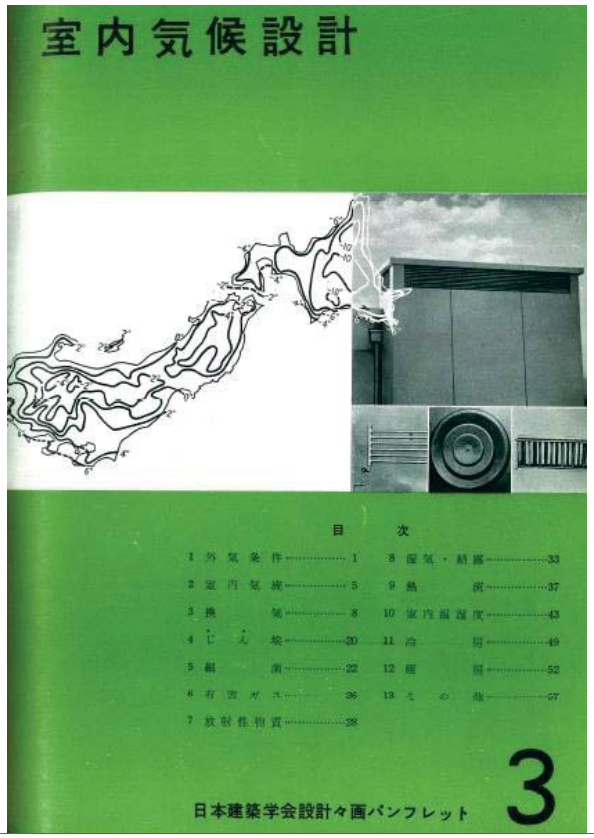
- AIJ Design Planning Pamphlet Vol.3 (1957) "Indoor climate design"
- Cross-ventilation designs were discussed.



Natural and Cross ventilation research in Japan

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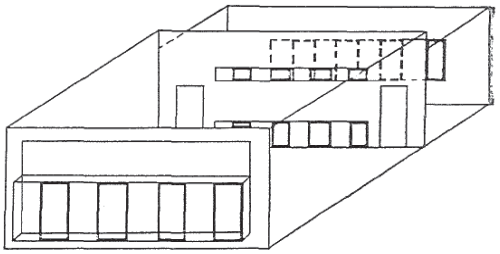
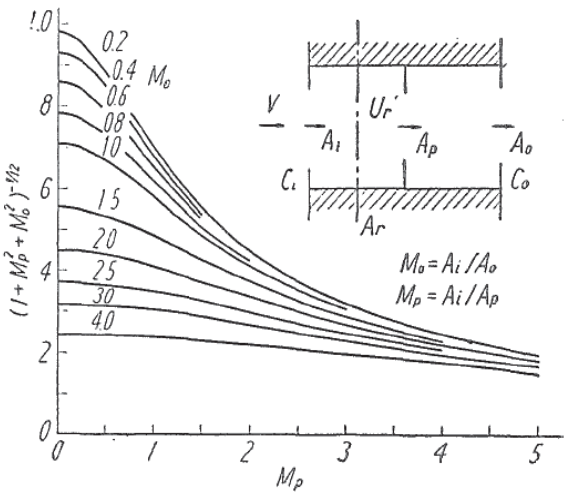


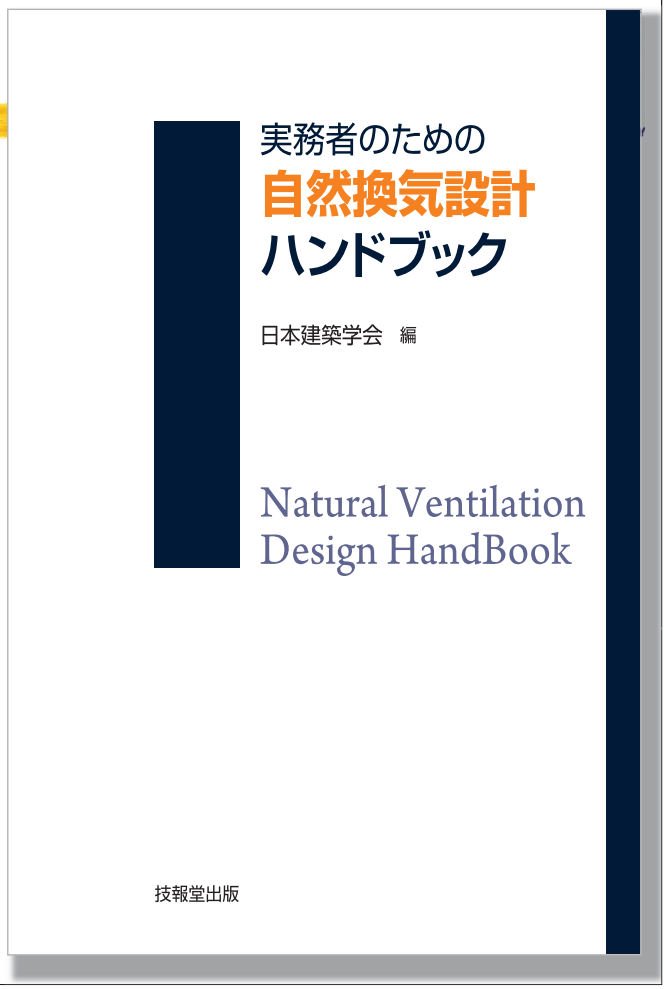


Natural research in Japan

- Some results by Japanese researchers in the early days are useful even at the present days but almost all papers were written in Japanese unfortunately.

Brand-new book

- Published by Natural ventilation design WG, AIJ (Architectural Institute of Japan), 2013
- Focuses on non-residential buildings, company offices, public offices, school buildings…
- Now preparing to translate to English



Contents

Case studies sheets

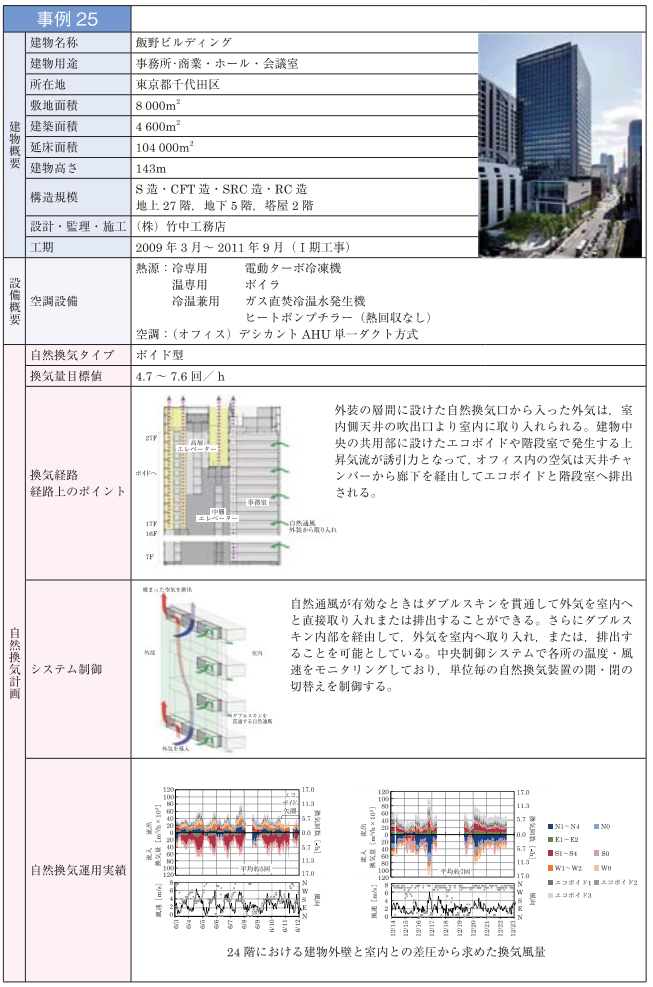
- Building outline
- Building service outline
- Natural ventilation design

  natural ventilation type

  main point of ventilation route

  system control method

  performance evaluation



事例 25		
建物概要	建物名称	飯野ビルディング
	建物用途	事務所・商業・ホール・会議室
	所在地	東京都千代田区
	敷地面積	8 000m^2
	建築面積	4 600m^2
	延床面積	104 000m^2
	建物高さ	143m
	構造規模	S 造・CFT 造・SRC 造・RC 造 地上 27 階，地下 5 階，塔屋 2 階
	設計・監理・施工	（株）竹中工務店
	工期	2009 年 3 月～2011 年 9 月（I 期工事）
設備概要	空調設備	熱源：冷専用　電動ターボ冷凍機 温専用　ボイラ 冷温兼用　ガス直焚冷温水発生機 ヒートポンプチラー（熱回収なし） 空調：（オフィス）デシカント AHU 単一ダクト方式
自然換気計画	自然換気タイプ	ボイド型
	換気量目標値	4.7 ～ 7.6 回／ h
	換気経路 経路上のポイント	外装の層間に設けた自然換気口から入った外気は，室内側天井の吹出口より室内に取り入れられる。建物中央の共用部に設けたエコボイドや階段室で発生する上昇気流が誘引力となって，オフィス内の空気は天井チャンバーから廊下を経由してエコボイドと階段室へ排出される。
	システム制御	自然通風が有効なときはダブルスキンを貫通して外気を室内へと直接取り入れまたは排出することができる。さらにダブルスキン内部を経由して，外気を室内へ取り入れ，または，排出することを可能としている。中央制御システムで各所の温度・風速をモニタリングしており，単位毎の自然換気装置の開・閉の切替えを制御する。
	自然換気運用実績	24 階における建物外壁と室内との差圧から求めた換気風量

Case studies

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事例 25

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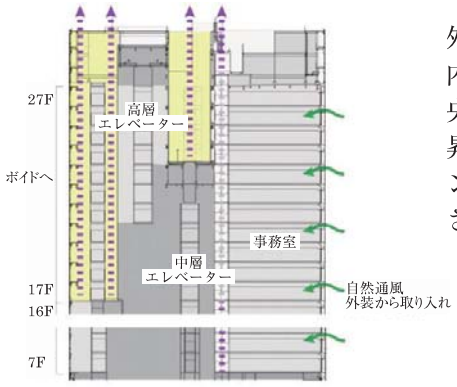

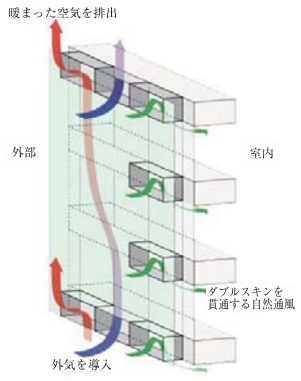

Two cases

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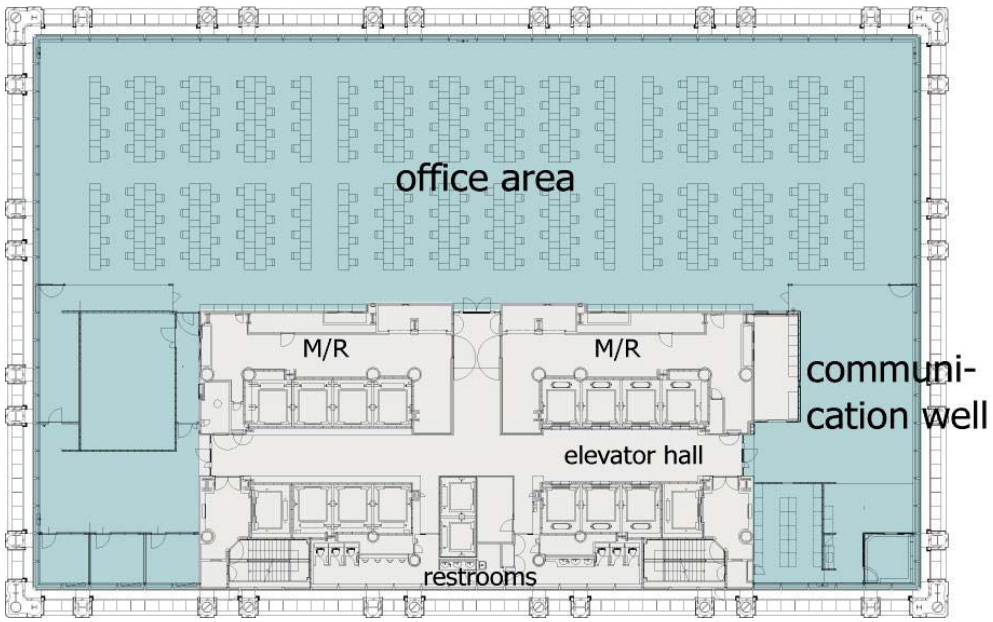
High-rise office buildings using natural ventilation system

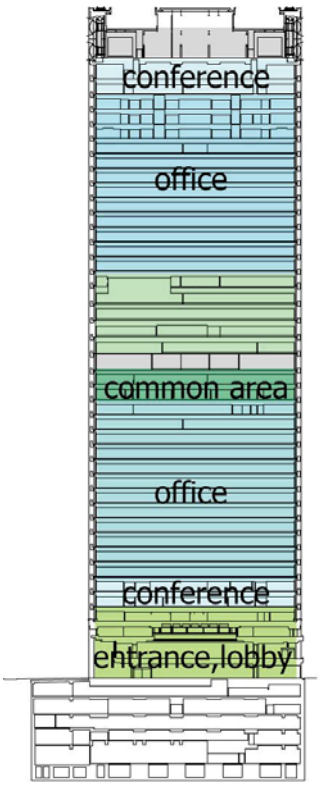
CASE 1: Building outline

- Location : Osaka, Japan
- 41-storied (GL+195m) high-rise office building
- 106,000m^2 in total floor
- Dec. 2004 completed

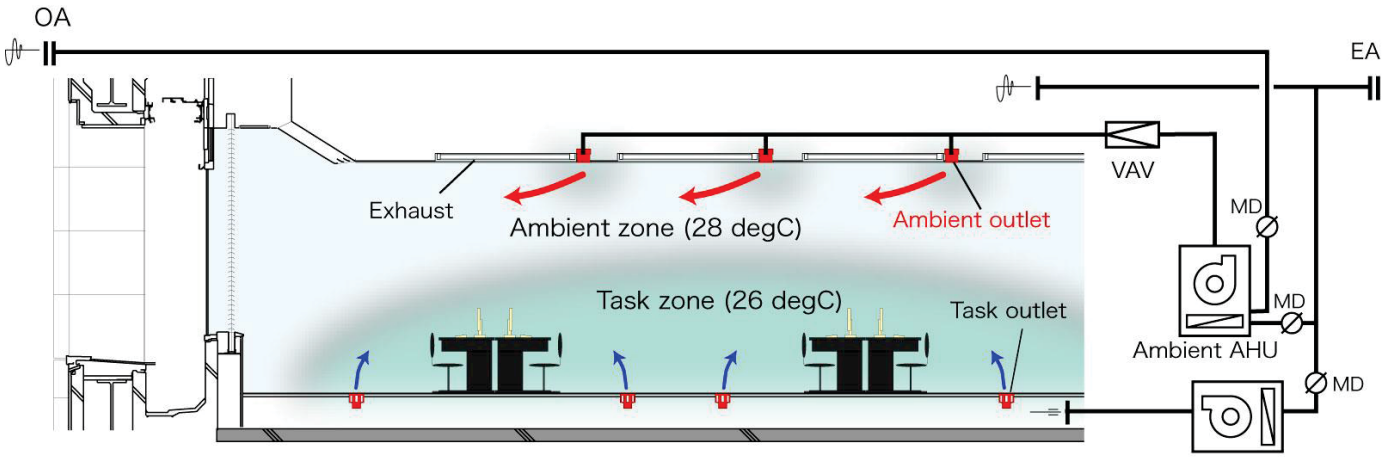
Building outline

⌘57.6m x 36m in each floor





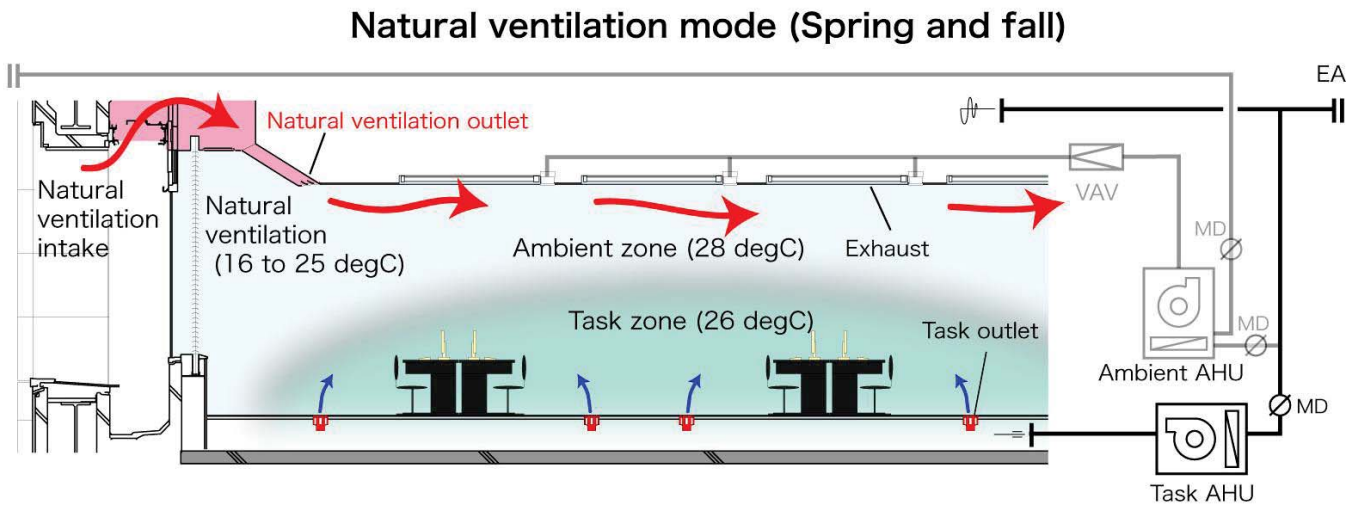
System outline : Task ambient AC mode



Task ambient AC mode

⌘In summer time, task and ambient zone is achieved by under floor air supply (for task zone) and ceiling outlet (for ambient zone)

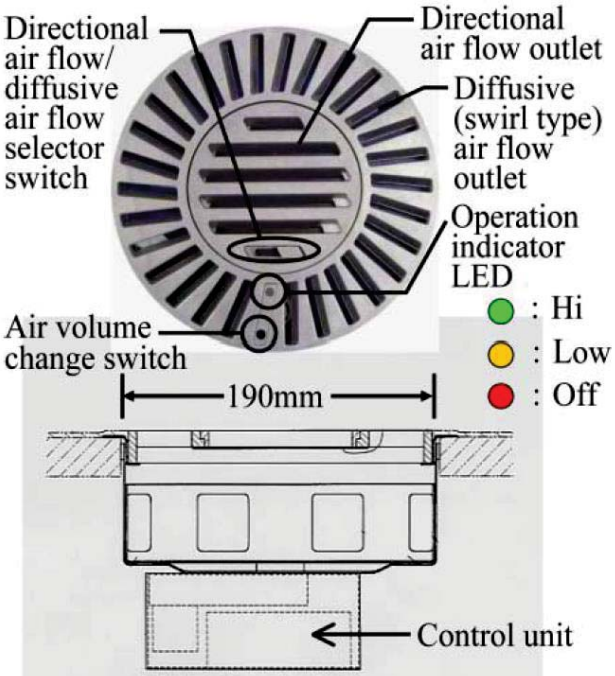
System outline : Natural ventilation mode



⌘Spring and Fall, ambient zone is naturally ventilated if possible (conditions are pressure difference, outside air temperature, humidity and enthalpy).

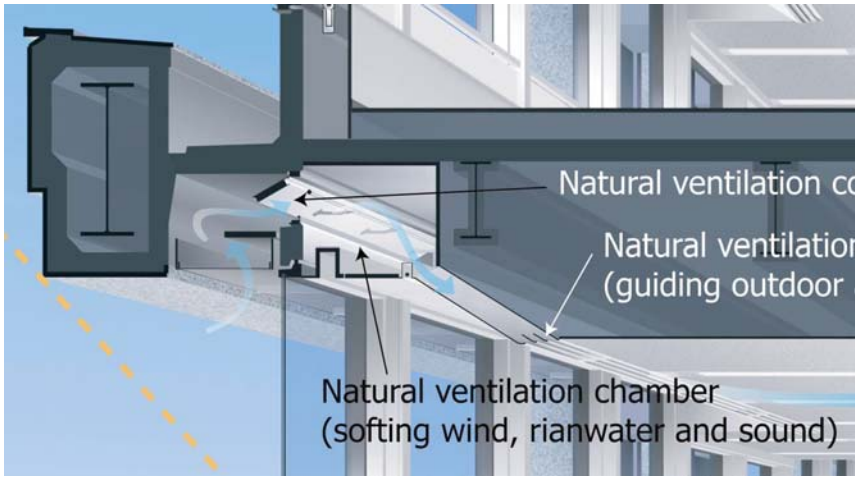
System outline : Selective task flow

⌘Occupants can select ‘directional’ or ‘diffusive’ airflow and flow rate of task outlets.



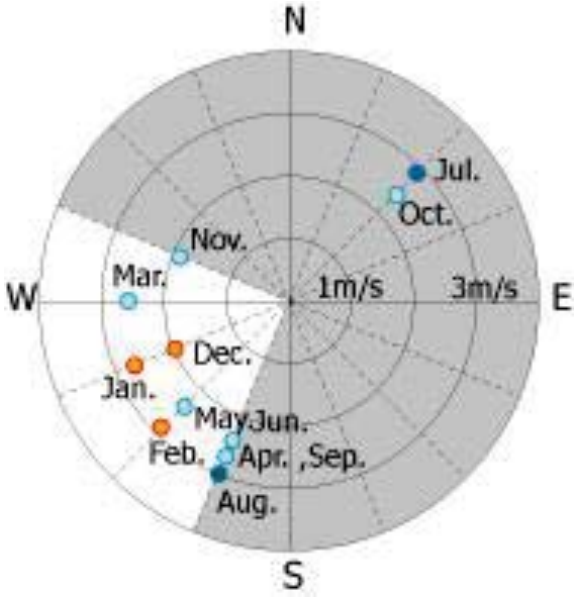
System outline : Natural ventilation outlet

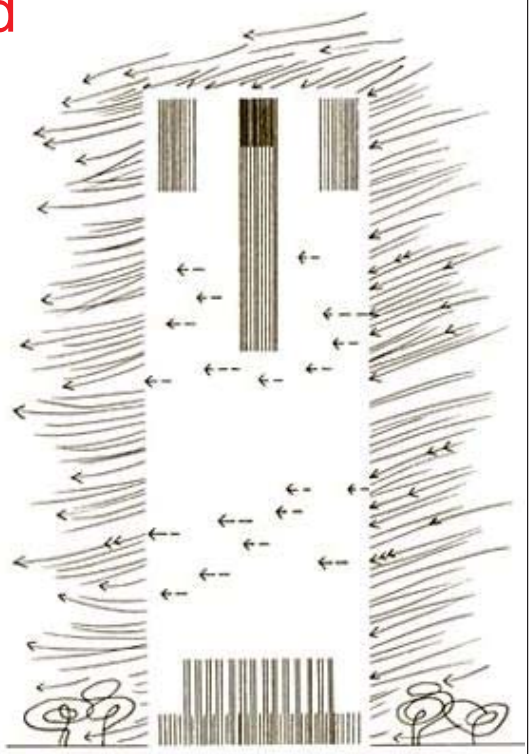
- Air outlets surround office room.
- Shape of air outlets are well-designed to guide the air to interior by Coanda effect.



System outline : Natural ventilation concept

- Challenge to use Wind-induced natural ventilation in high-rise office building.





Controlling system

1.Natural ventilation system begins working when:

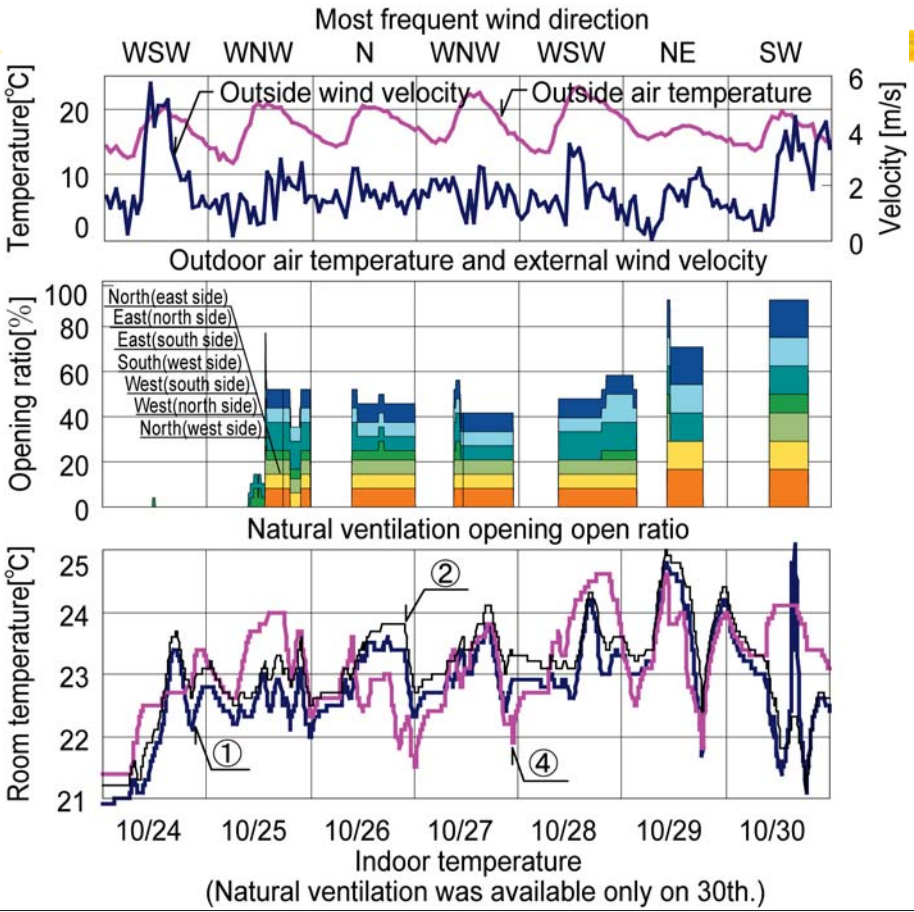
1)Indoor-outdoor pressure difference 50 Pa or less
2) Outside air temperature: 18ºC or more
3) Outside air humidity: 90% or less
4) Outside air enthalpy: Less than indoor enthalpy
5) Room temperature:
−2℃≦ Preset temperature ＜+1 ºC： Partly open
+1℃≦ Preset temperature ＜+3 ºC： Fully open

2.Task/ambient air-conditioning system control system

1)Task air-conditioning:
Constant supply air temperature and static pressure control

2)Ambient air-conditioning:
VAV control to constant indoor temperature

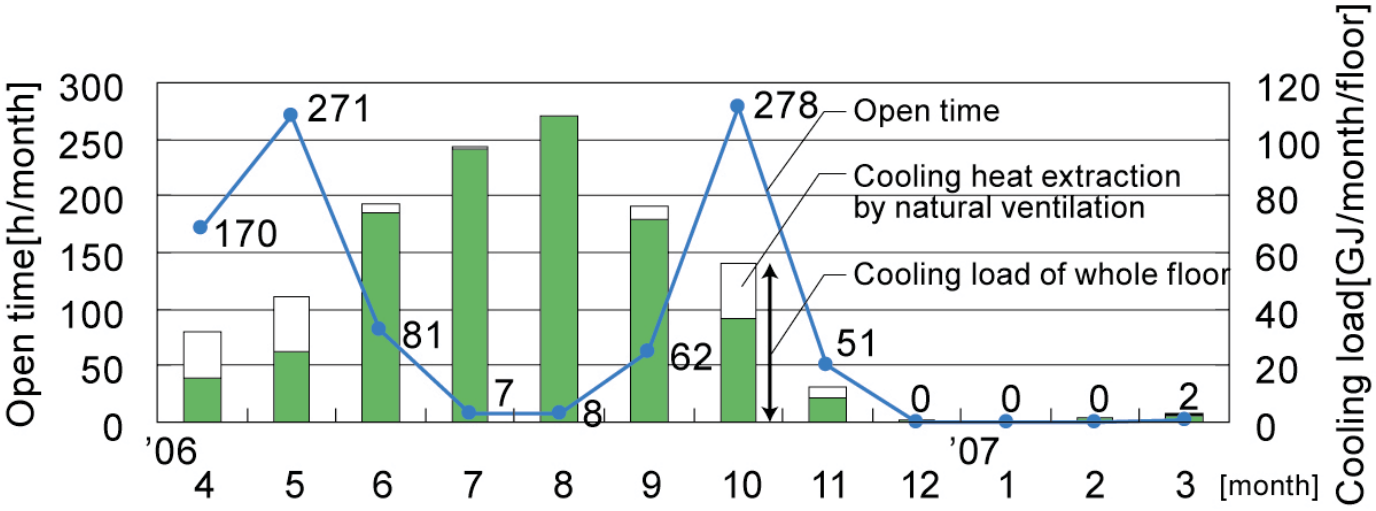
9 years ago: Natural ventilation performance in a week



About 50% of natural ventilation openings were opened.

Temperature difference between the east ① and the west ② was 0.2℃ on an average.

9 years ago: Natural ventilation performance in a year

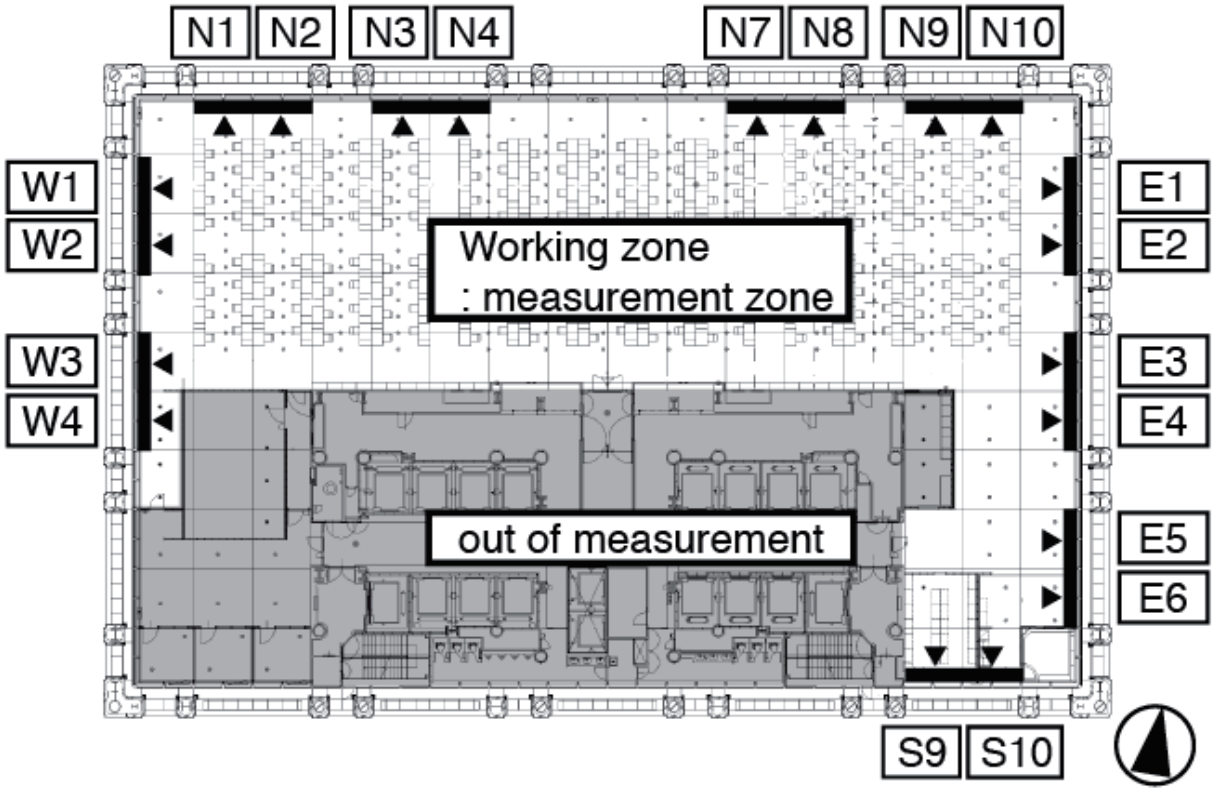


The annual open time was 918 hours.
Natural ventilation could reduce cooling load on a typical floor by 13.3%.

9 years ago in the planning stage

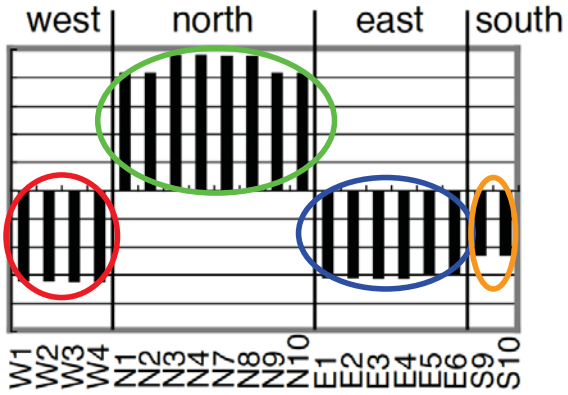
- Calculation of natural ventilation rate for 16 wind directions using wind pressure coefficient obtained by wind tunnel tests.
- Measurement of natural ventilation rate in the real building.
- CFD analysis using measured ventilation rates as boundary conditions.

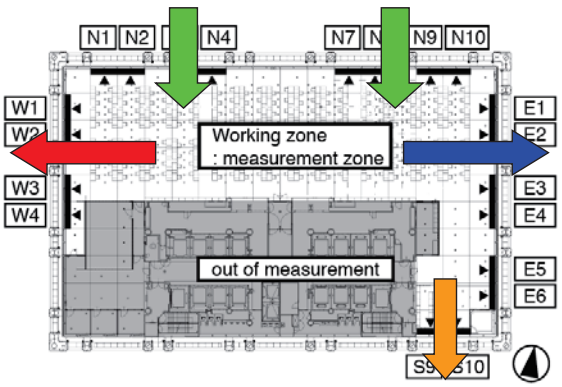
Natural ventilation openings



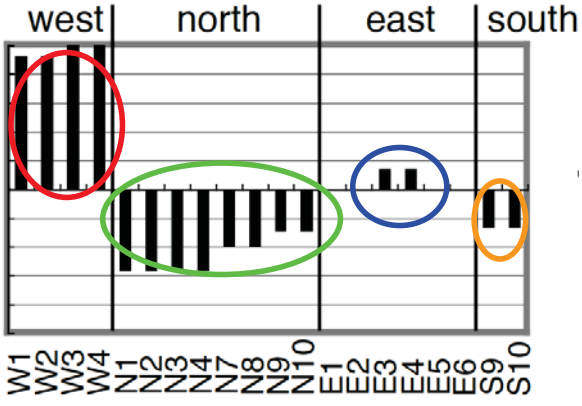
Calculation results

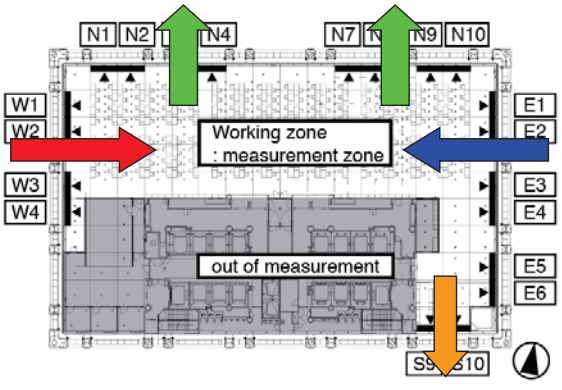
North wind



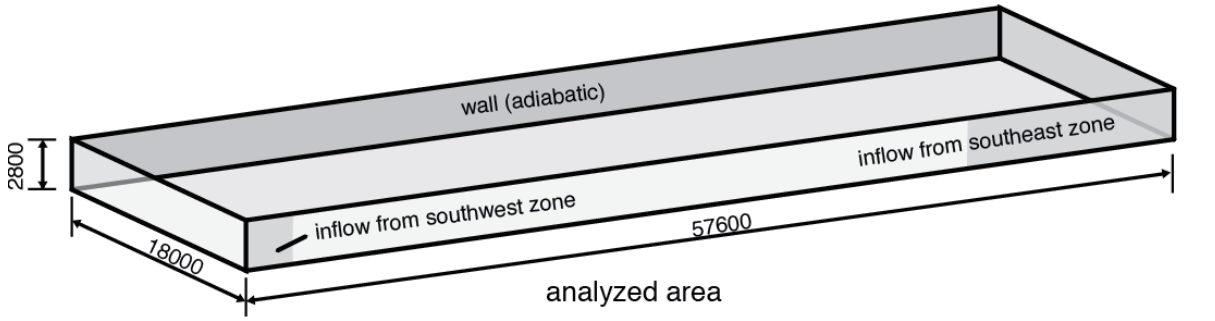


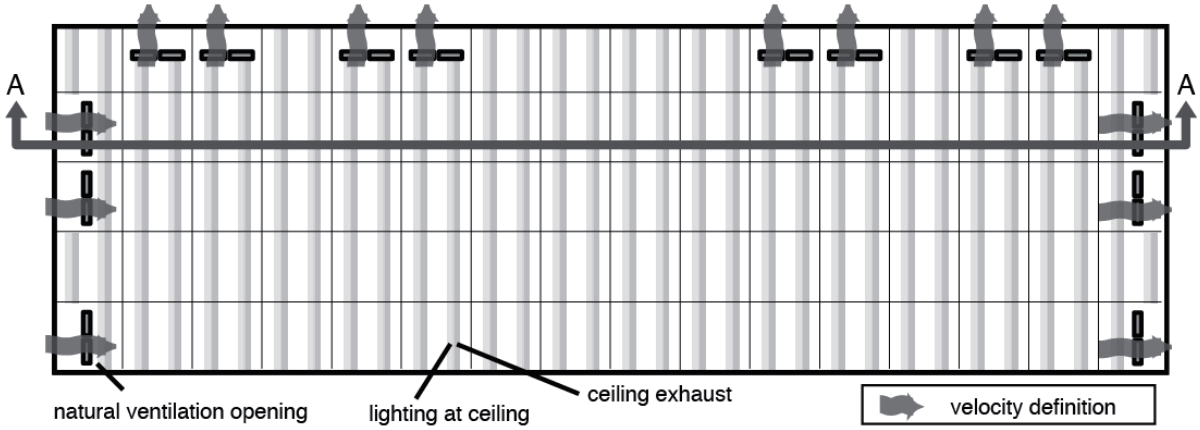
West wind





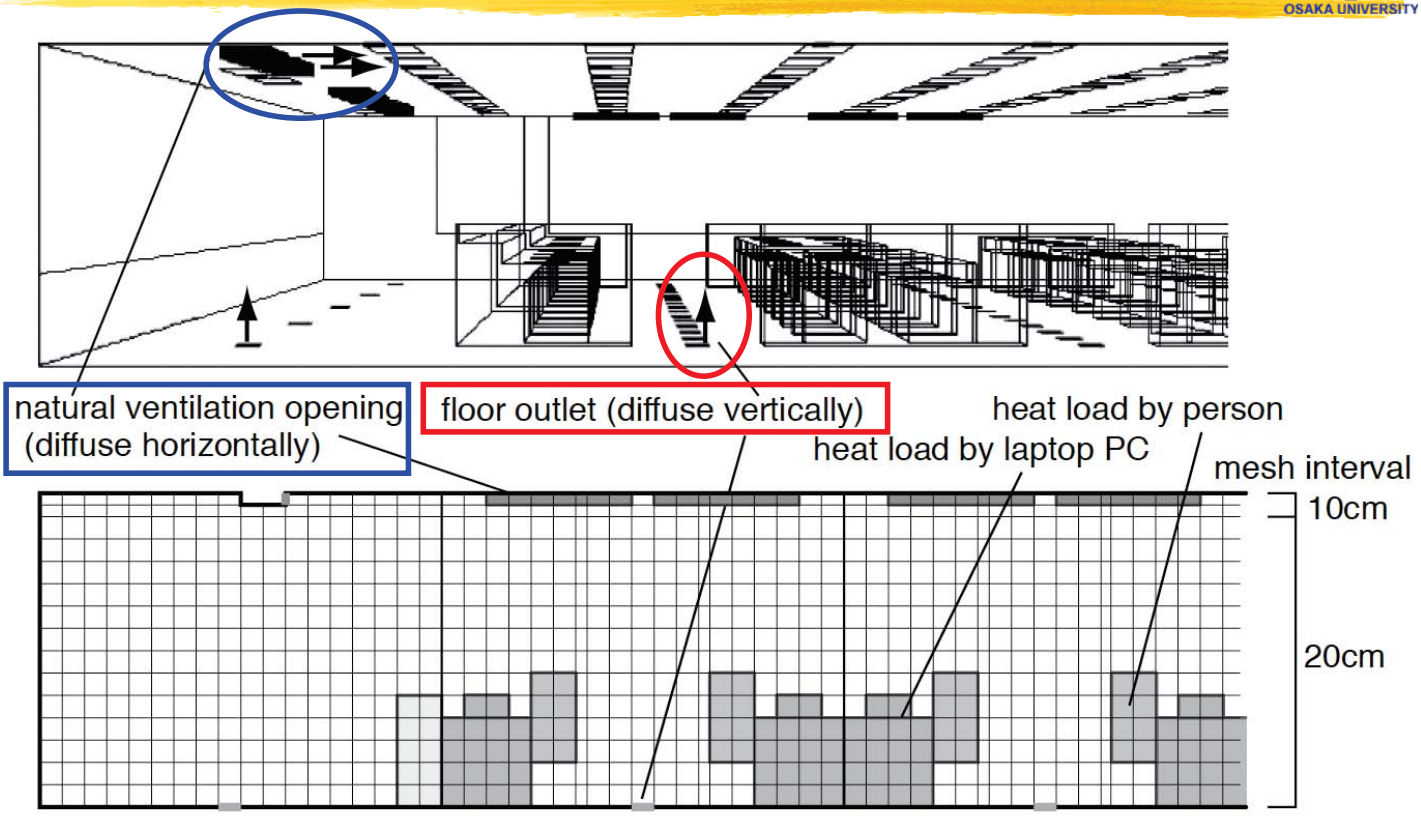
CFD Analysis using measured data





ceiling plan

CFD Analysis using measured data



CFD Results : Wind velocities along the ceiling

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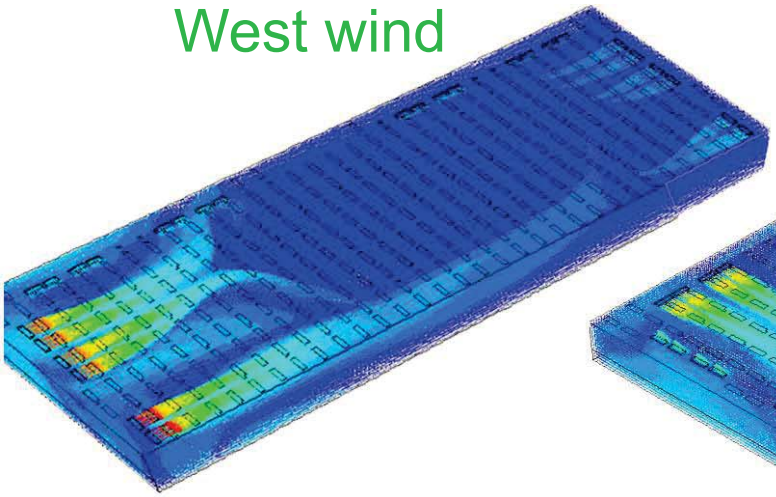
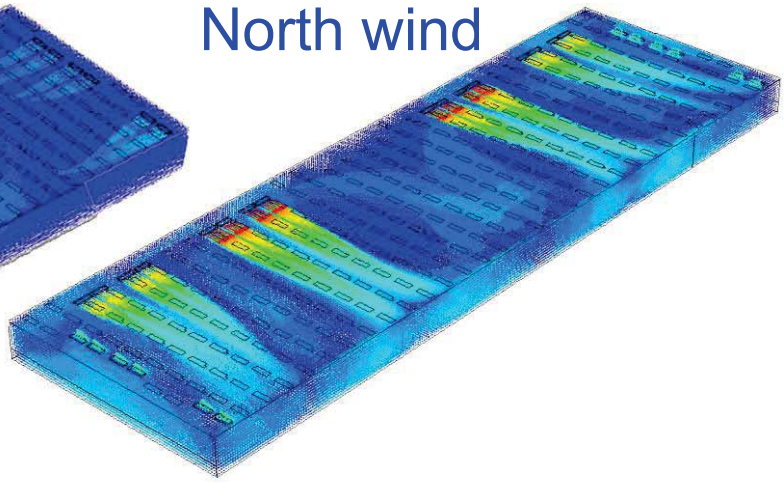
West wind



North wind



- West wind: Supplying air flows from west-side openings to north-side along the ceiling , a part of flow cannot reaches the interior zone.
- North wind: Well supplied to the whole room.

Flow visualization vs CFD analysis

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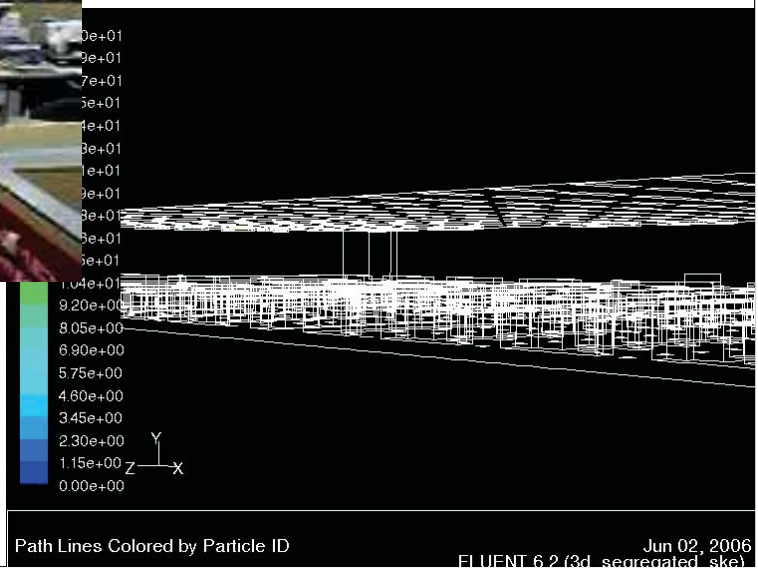
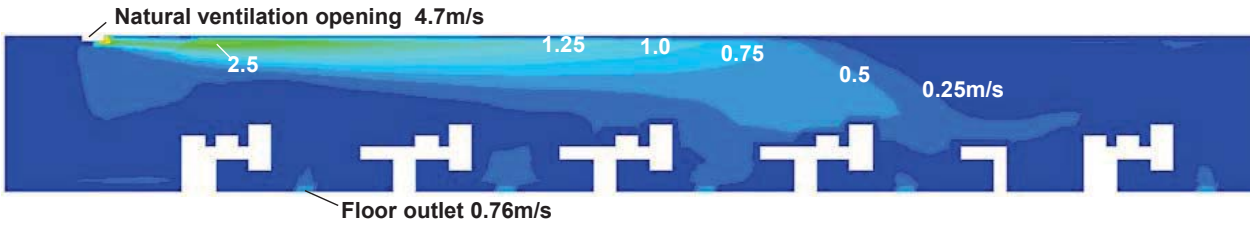
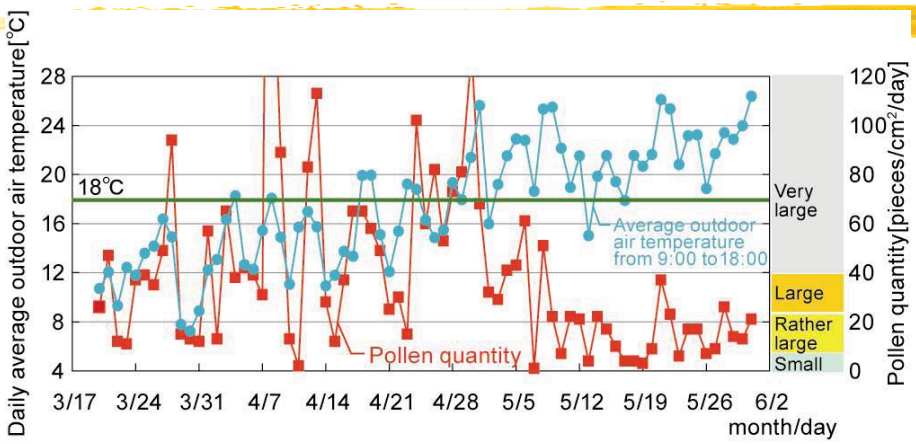


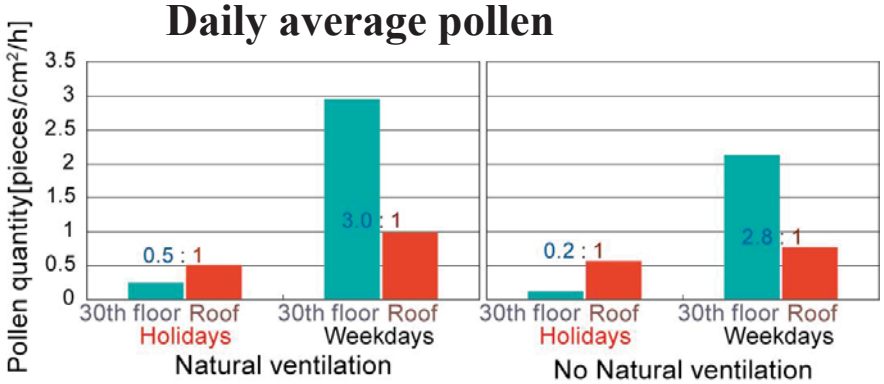
Flow visualization vs CFD analysis



Pollen measurement



Daily average pollen



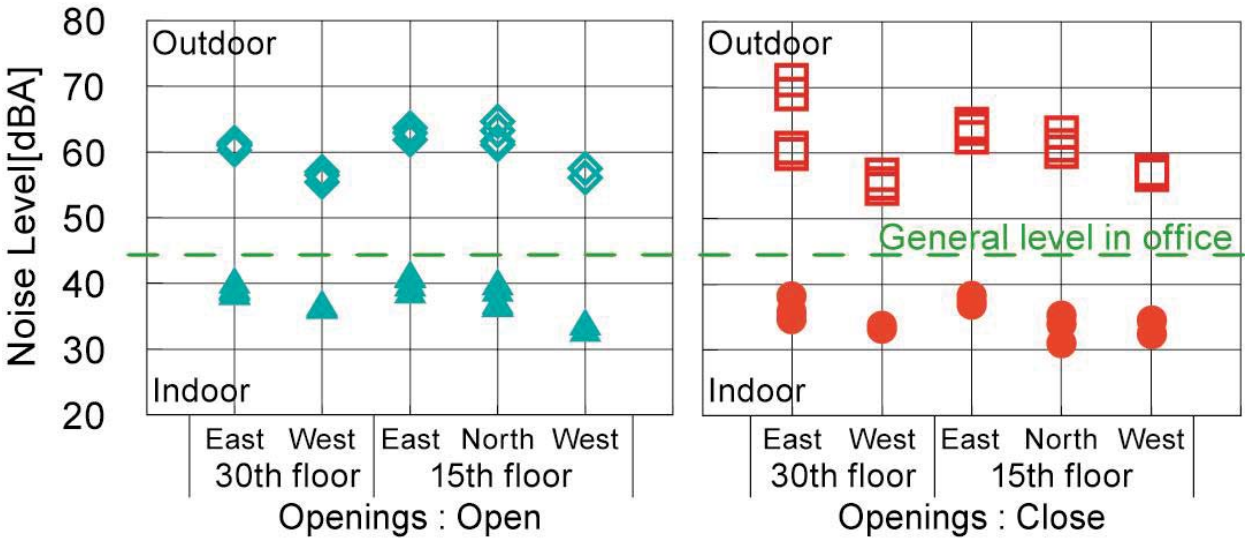
Pollen on Holidays and weekdays

- Pollen increases in the half of April.

- Pollen carried by people is larger than those coming trough natural ventilation openings.

Noise level measurement

-Natural ventilation openings can reduce noise level by 20dB(A) when opened, and 25dB(A) when closed.
-Noise entering from the outside does not spoil working conditions.



remarks

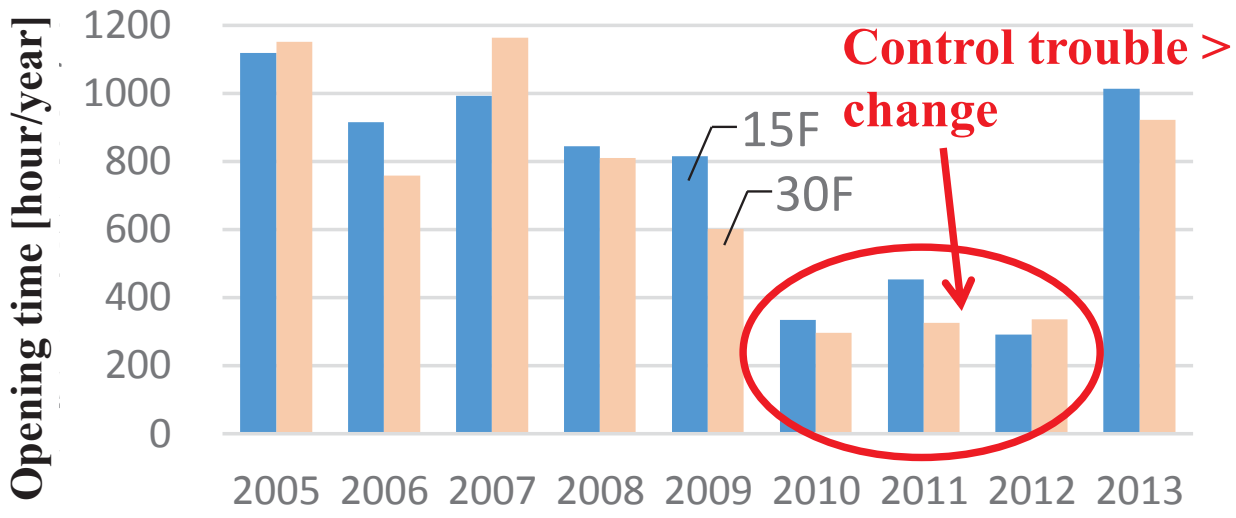
- Wind-induced natural ventilation in high-rise office building was achieved.
- Characteristics of supplying the fresh air from natural ventilation opening depends on the wind direction.
- CFD analysis for natural ventilated room using measured data or calculated flow rate by wind pressure coefficient is useful.
- Some measurements are conducted concerning the estimating problem when used NV system but it has no problem.

more..

- More interesting measurements and analyses have already conducted.
  - Long-term measurement of natural ventilation by pressure differences, we can use the “big data” of BEMS.
  - Mean age of air for task ambient AC mode and natural ventilation mode.
  - Domination or contribution ratio of each outlets (task, ambient and natural ventilation opening).
  - Modeling of outlets in CFD to improve the accuracy.

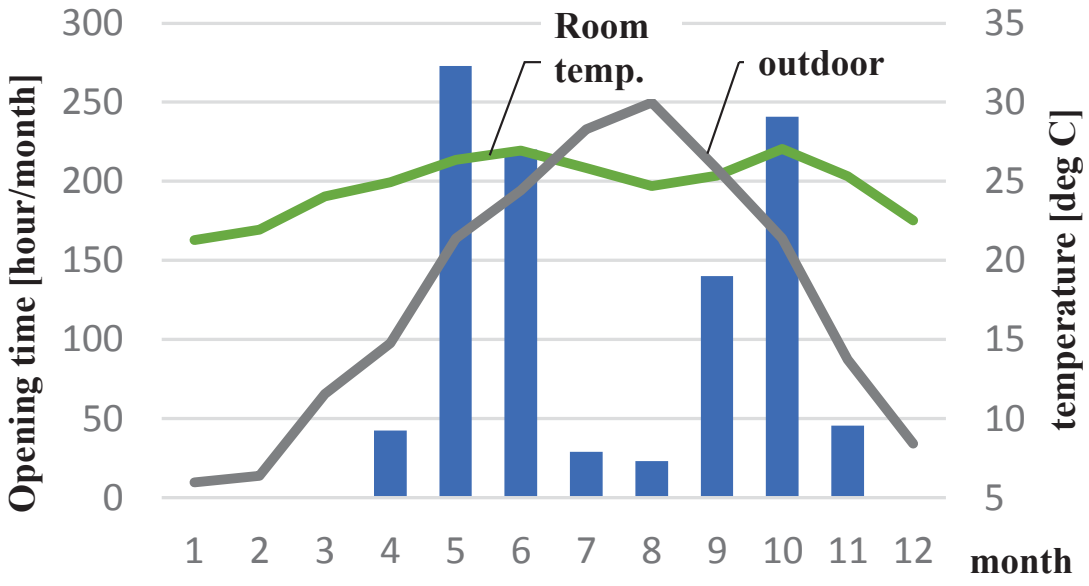
Now, 9 years after…

- It still works well.
- Social demand for saving electricity is very strong after earthquake and nuclear accident 2011.



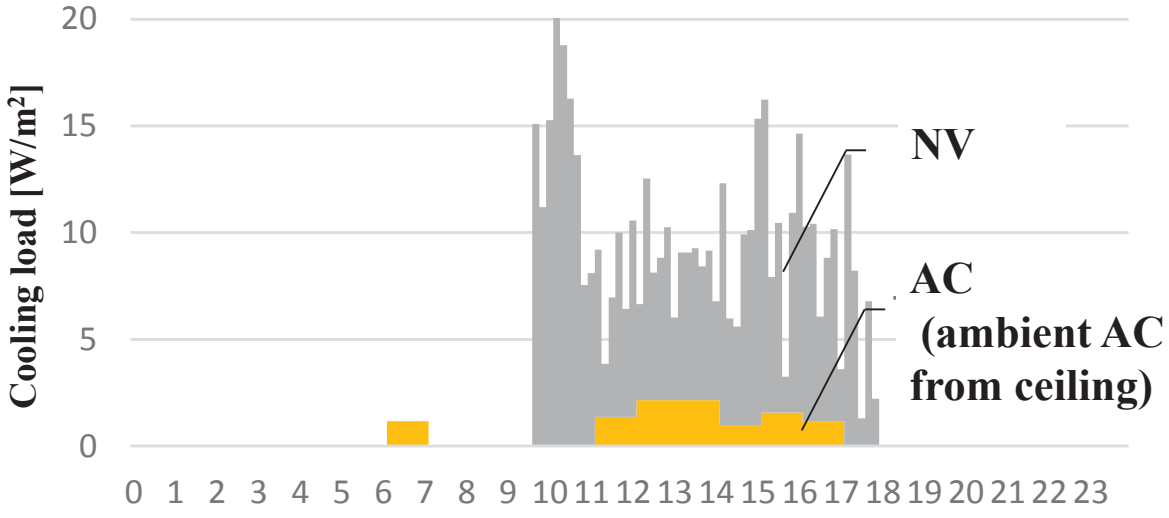
Now, 9 years after…

- Night purge by natural ventilation also works in the night of summer time.



Now, 9 years after…

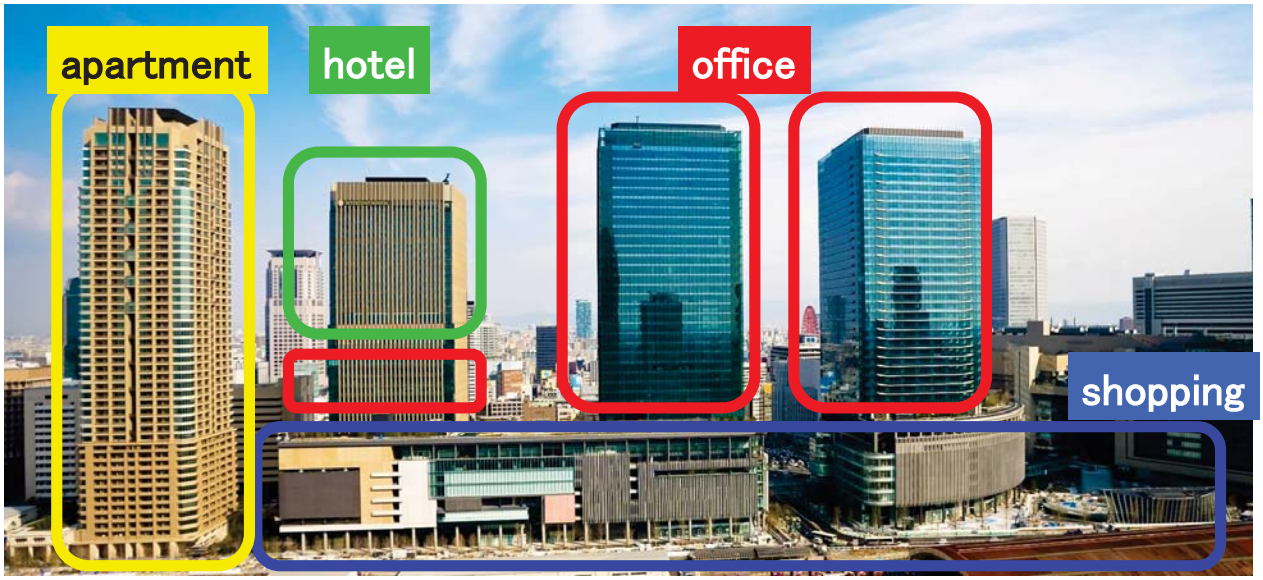
- Not exactly NV but hybrid ventilation system.
- Most of the cooling load is removed by natural ventilation.



Daily change of cooling load (one day in October, 2013)

CASE 2: Building outline

- Location : Osaka, Japan
- 4 buildings, 600,000m^2 in total floor
- Feb. 2013 completed, brand-new bldg.

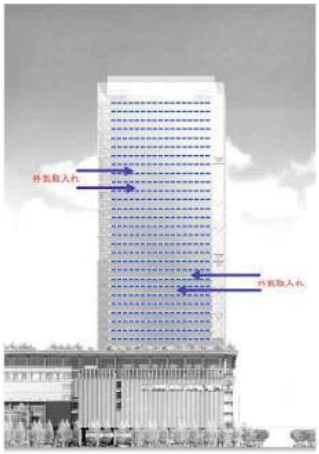


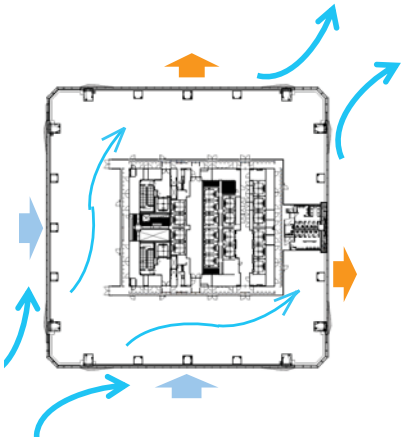
CASE 2: Building outline

- Many sustainable technologies are used.
- Different types of natural ventilation.
- Original naming and send messages and visualization of technologies to the people.

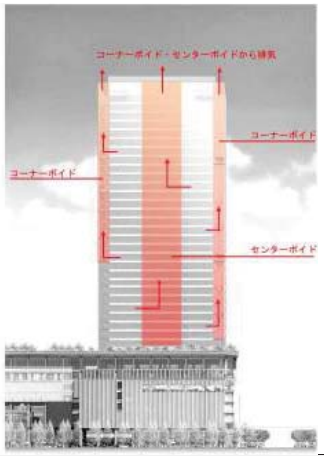
wind-induced "sky slit"	buoyancy-induced "center void"	buoyancy-induced "corner void"	wind-induced "air intake"

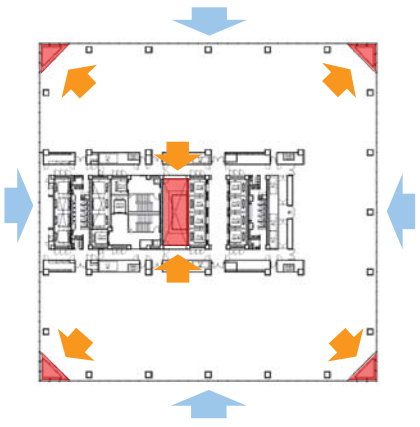
CASE 2: Building outline named “air intake”





CASE 2: Building outline named “corner void”





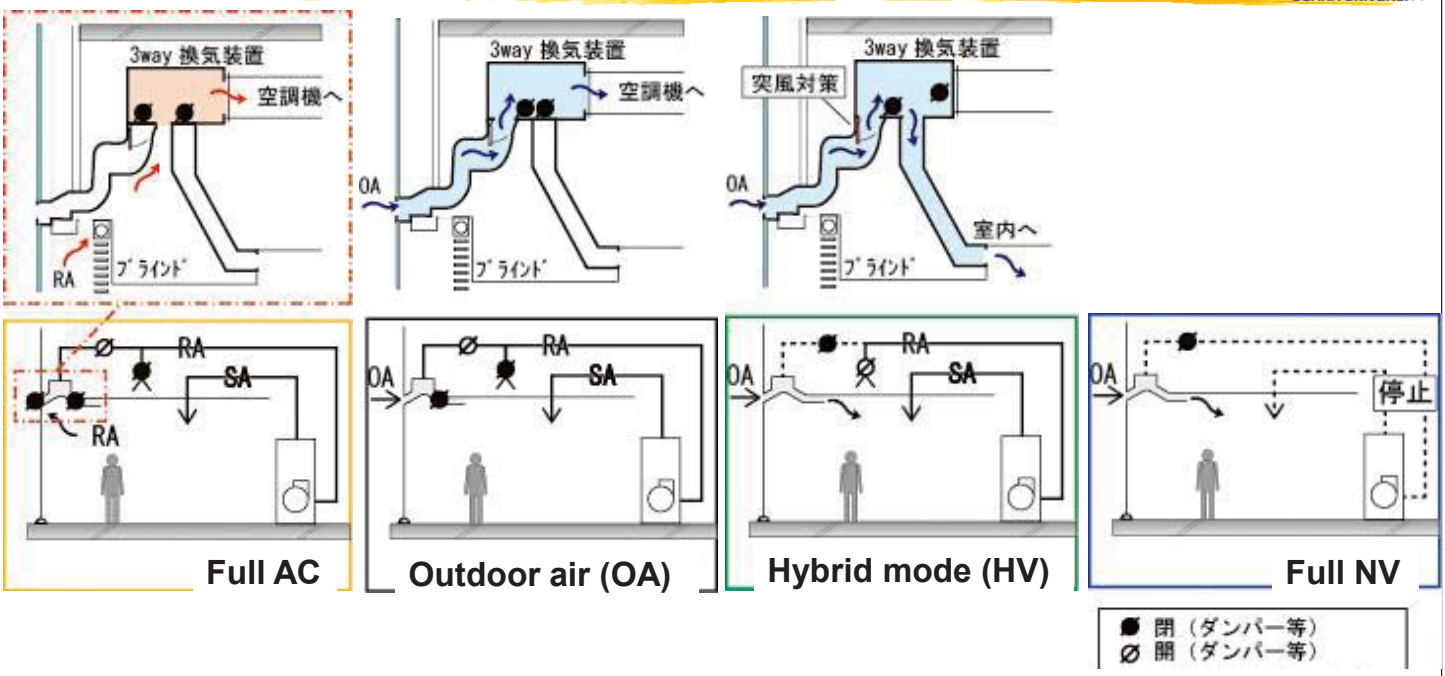
CASE 2: Building outline

CASE 2: “corner void” type

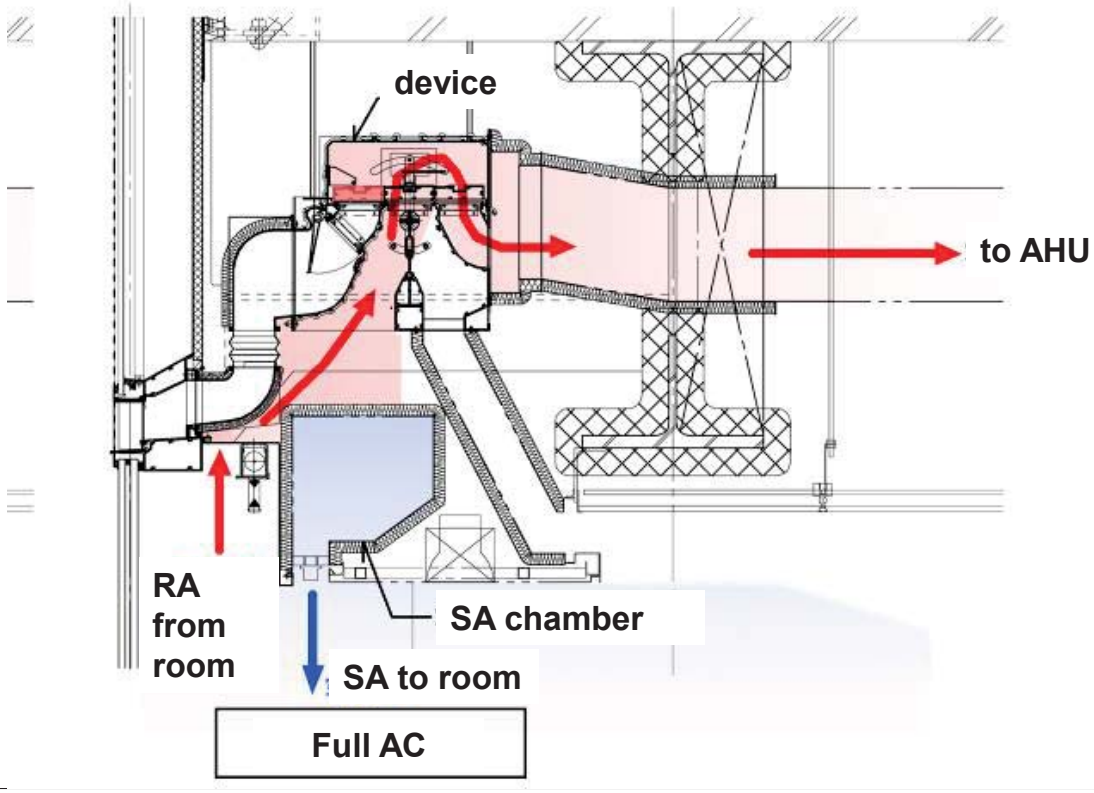
- **Occupants can select to use NV or not.**
  - **if YES, move to Full NV mode (NV)**
  - **If NO, move to three mode depending on control conditions.**
    - **Hybrid mode (HV)**
    - **Directly cooling by outdoor air (OA)**
    - **Full AC mode (AC)**

	NV	HV	OA
Outdoor temp.	10 – 20 degC Select by occupants	Over 18 deg C	10 – 24 degC
Outdoor RH	Under 90 %RH		Under 90 %RH Over 7.8 deg C in Dew temp
Outdoor air velocity	Under 15m/s (controlled by pressure differences)		
enthalpy	Outdoor < Indoor		

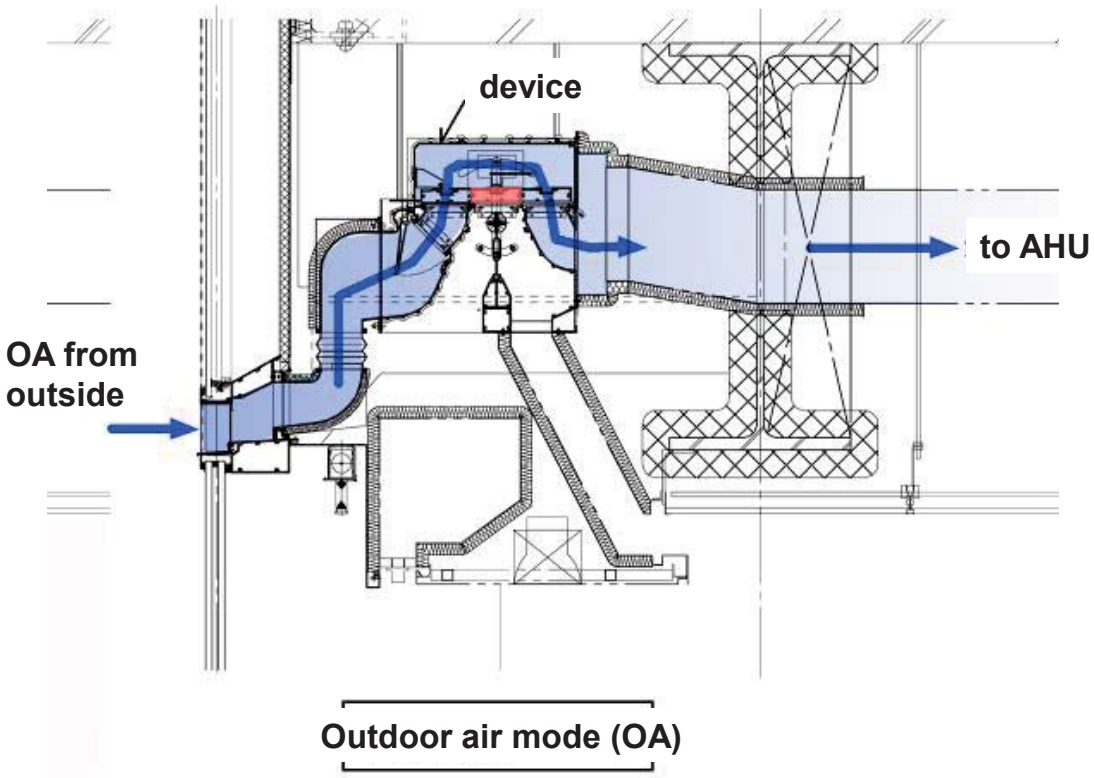
3 way moving device for NV opening



3 way moving device for NV opening

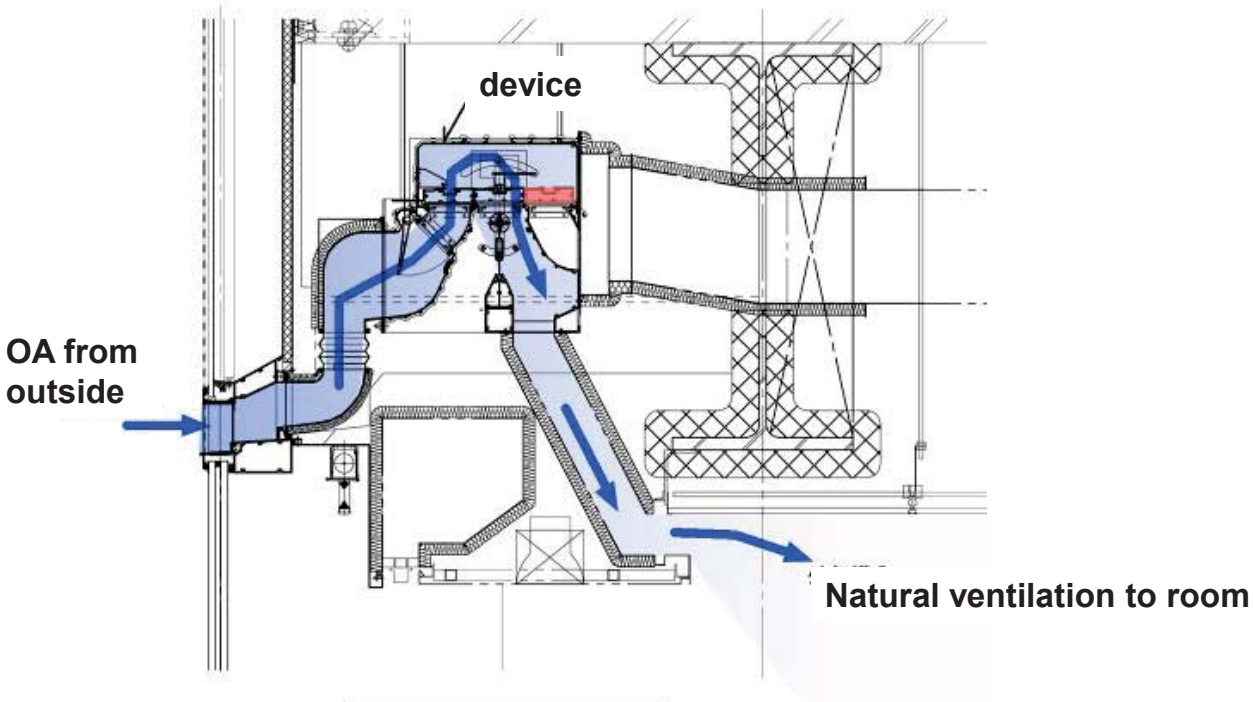


3 way moving device for NV opening



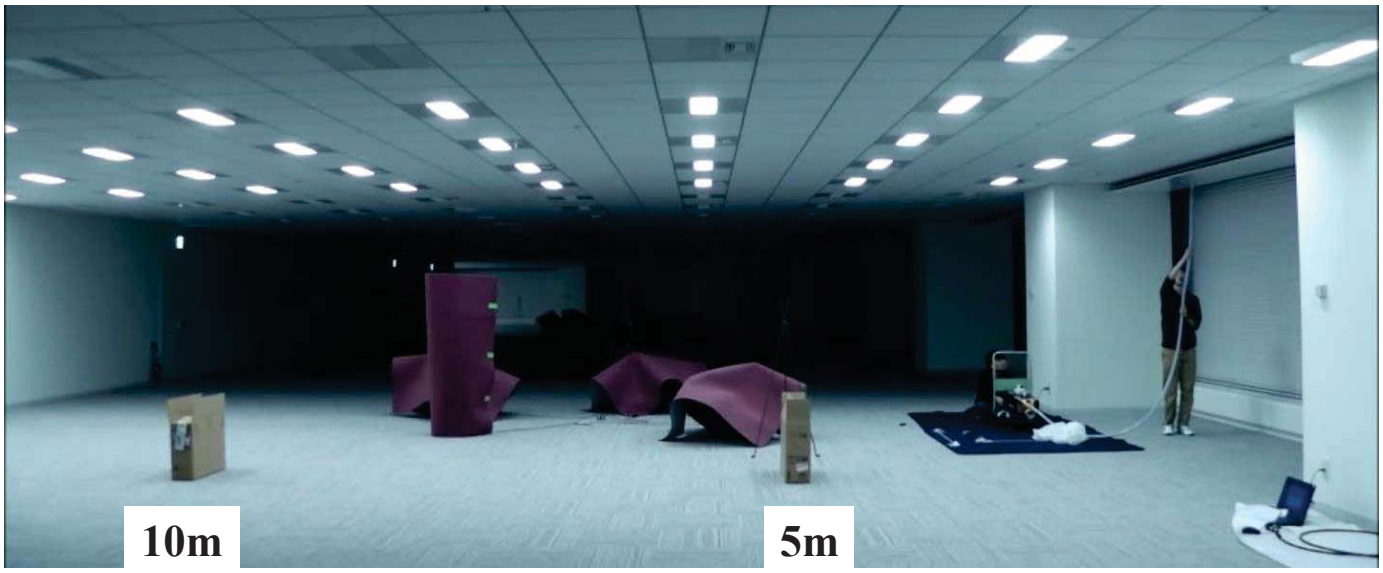
Outdoor air mode (OA)

3 way moving device for NV opening

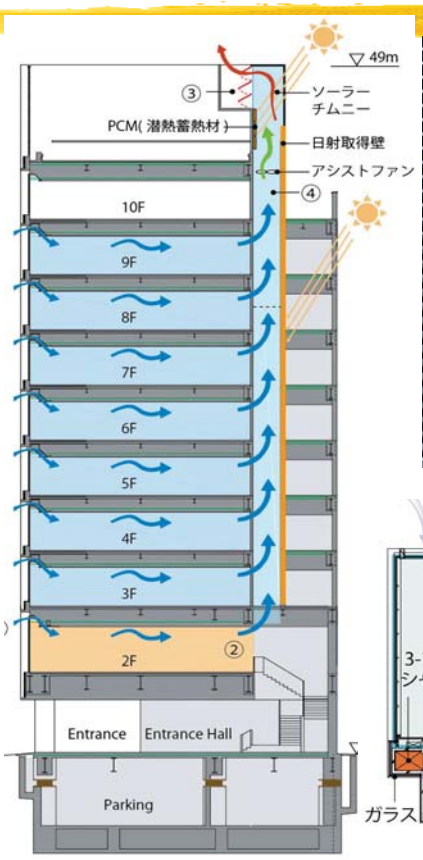


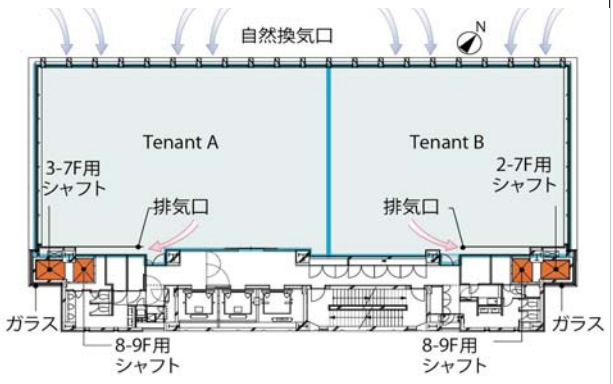
Hybrid (HV) and Natural ventilation (NV) mode

Measurements and calculations.

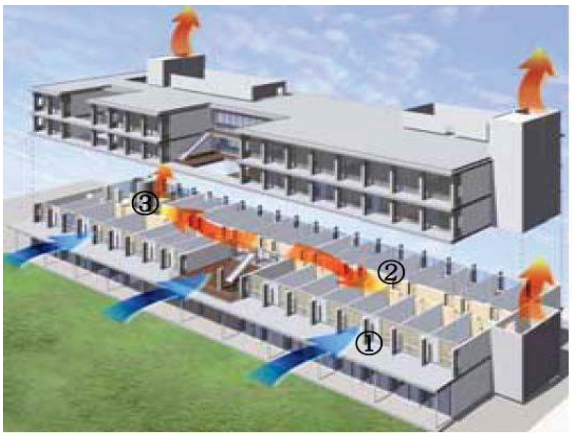


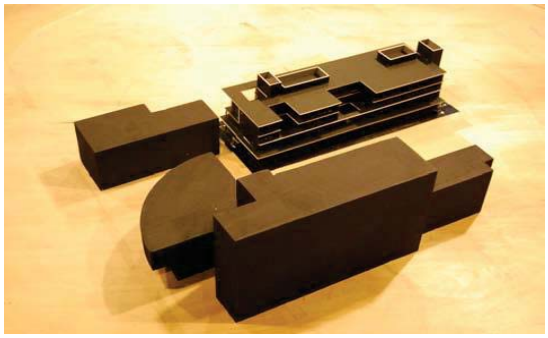
Annex 62 pilot buildings (2012, Tokyo)

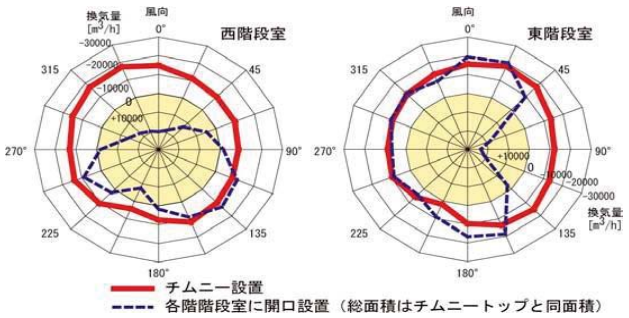




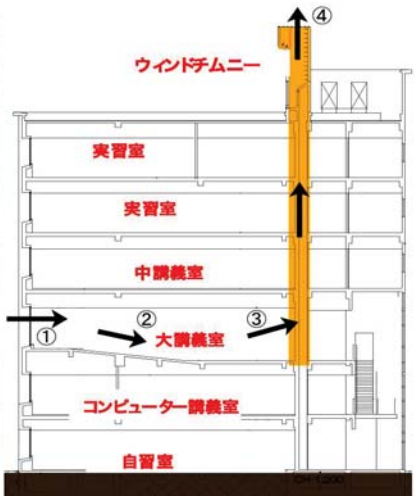
A college building (2008, Kagawa), using staircases

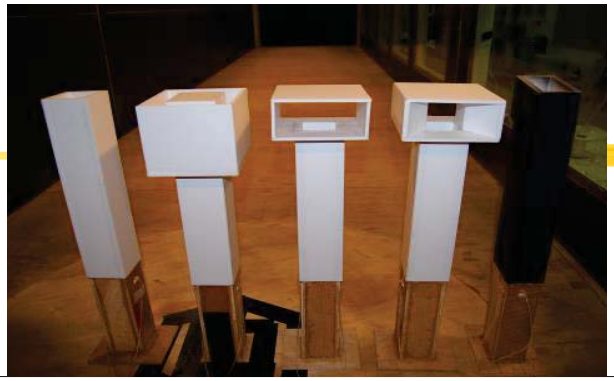






College building (2008, Kobe), shape of the chimney





remarks

- We have many interesting buildings in Japan.
- Natural ventilation and hybrid ventilation technologies are developed in these 10 years.
- Calculation in the design stage is enuogh.
- Simple long-term performance evaluation (commissioning) is needed.
- The measurement of ventilation rate (long-term, simple, toughness..) is still the problem.