

HYBRID AIR-CONDITIONING SYSTEM AT LIBERTY TOWER OF MEIJI UNIVERSITY

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ABSTRACT

During design phase, Liberty Tower of Meiji University, a high-rise building located at the center of Tokyo Metropolitan area, several testing methods were applied to ensure the effectiveness of the various components used in the principle of hybrid ventilation system design.

Its special design feature is the "wind-floor", whereby the central core is planned to induce natural ventilation for every floor by creating stack-effect. Other measures are also taken to improve the quality of indoor environment including the use of natural ventilation windows controlled automatically, automatic outdoor air intake, and a proper building environment and energy management system that takes advantage of the optimum outdoor air quality and temperature to cut energy consumption costs of the building.

In this paper, the outline of the system of this building and some verification are promptly reported.

1 INTRODUCTION

1.1 Outline of the building

In Japan, the middle-height and high-rise buildings have usually been designed with a fixed (permanently close) window, in order to reduce the infiltration of outdoor air. Here, in this paper, semi-open indoor space of university, which is located in the center of Tokyo Metropolitan area, is reported. This building is introducing the hybrid air-conditioning (cooling) system, utilizing the natural ventilation for controlling the indoor climate in spring and fall seasons. During the middle season, it is reasonable to supply the outdoor air into the indoor room directly, especially the room with high population density and high cooling



Figure 1 Bird's-eye view of Liberty Tower

Liberty Tower of Meiji University

Architects and Engineers: Nikken Sekkei Ltd.

Building type: lecture room, hall and cafeteria

Completed: Sep. 1998

Site area: 11,148 m²

Gross floor area: 59,011 m²

Usable floor area: 53,000 m²

Typical building population: 8,000 persons

loads by computers, such as lecture room, because during that period the fresh outdoor air is thermally comfortable enough. And this can contribute to improve the indoor air quality and save the air-conditioning energy consumption. (Chikamoto et al. 1998, Kato et al. 1999)

1.2 Outline of Hybrid Ventilation System of this Building

The plan utilizes center core formed by escalator space between 1st and 17th floor, a major means of mass transit of students, as a course of airflow for natural ventilation, called “wind core”. Figure 2 shows the section of the tower. The wind core (escalator void) also causes the stack effect, which promotes the natural ventilation. Above the wind core, on 18th level, the “wind floor” is planned to induce the natural ventilation for every floor. Figure 5 shows the plan of wind floor, and figures 3 the details of opening on the top of the wind core. Near the opening, wind fence is set to prevent the outdoor air passing through the wind floor from disturbing smooth exhaust through the opening on the top of the center core. It maintains steady condition in the natural ventilation system, regardless of wind direction.

On 18th floor, there are openings to exhaust the air, which passes through 4 wind paths designed toward 4 different directions, and is led to outside the building (see figure 5). The airflow of the wind floor on 18th level was simulated by CFD (see figure 6), and found that the outdoor air flows on the wind floor at a speed without declining. Therefore the wind floor creates driving force for ventilation that stimulates air intake via perimeter counter units and exhaust through the opening at the top of wind core. As the wind floor open to 4 directions, the driving force is expected to be stable through the year with regardless of wind direction.

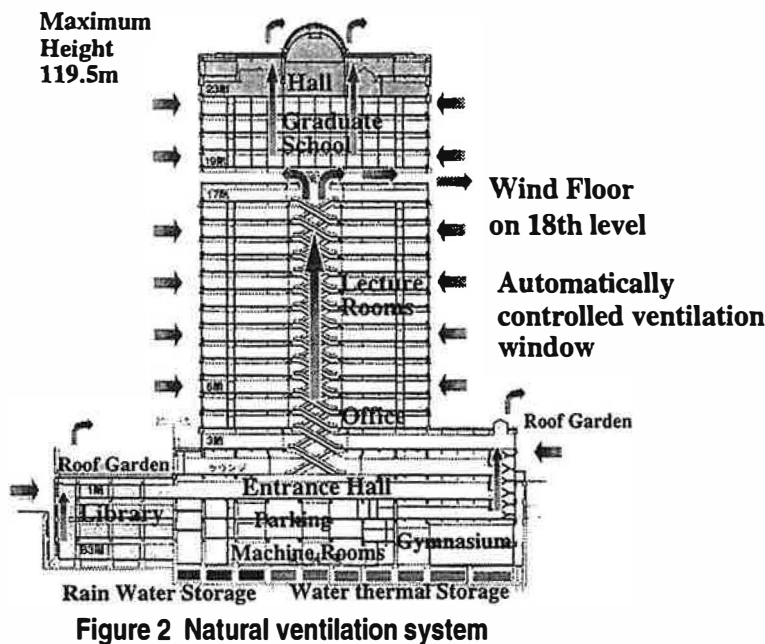
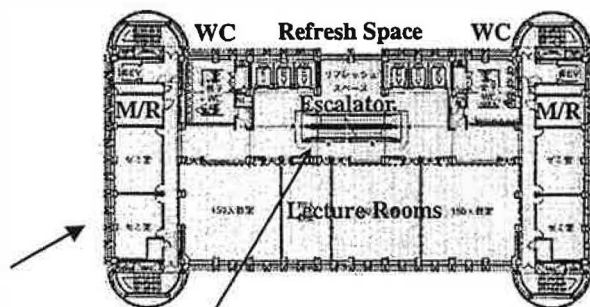


Figure 2 Natural ventilation system



Figures 3 Wind floor on 18th level



Wind is exhausted at the top of Escalator (Wind floor on 18th level)

Figure 4 Typical lecture room floor

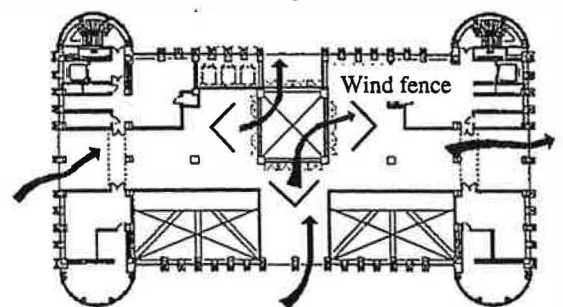
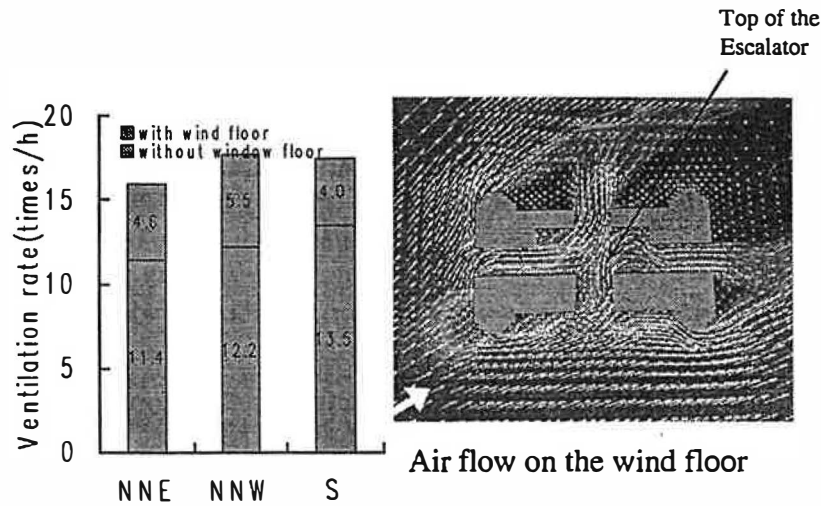


Figure 5 Wind floor on 18th level



Results by Simulation

Figures 6 Wind floor increases ventilation rate by 30 %

Figure 7 shows the details of window and figure 8 the view of the ventilation opening. Each room of occupancy has ventilation openings under the glazed windows along perimeter zone to introduce outdoor cool air. The intake air is led to the wind core through a return path duct in which conditioned air also passes through to return. Figure 10 shows the hybrid natural ventilation and A/C system. Details of the windows allow natural airflow coming into the rooms via the ventilation openings even when blind screens are shut down during lectures using audiovisual sets such as OHP. These openings, with traps to obstruct outer noise, are installed inside window counter units preventing accidents and mischief when the operation is automatically controlled.

Switching of the openings depends on several factors, such as comparison of temperature and humidity between interior (occupancy rooms) and exterior, rain condition and wind velocity, then natural ventilation is operated only when it is found to be effective considering these factors. The system can be used to remove heat and pollutants from the rooms during nights, while switching of several openings is possible and is remotely controlled by the central monitoring room.

1.2 Estimation of Hybrid Ventilation System

The wind floor on 18th floor improves the number of air change Figure 6 shows the result of

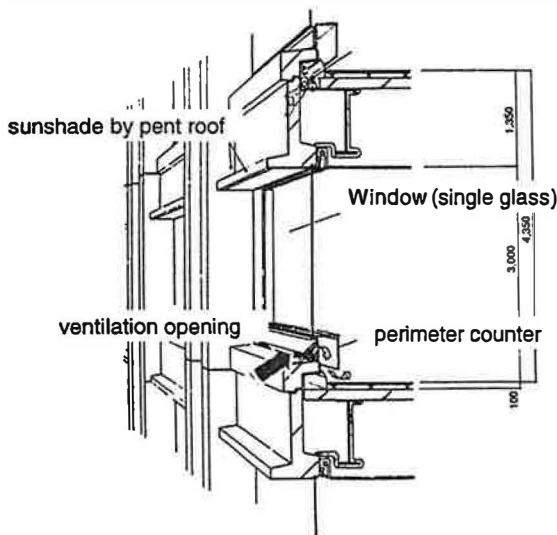


Figure 7 Detail of the window

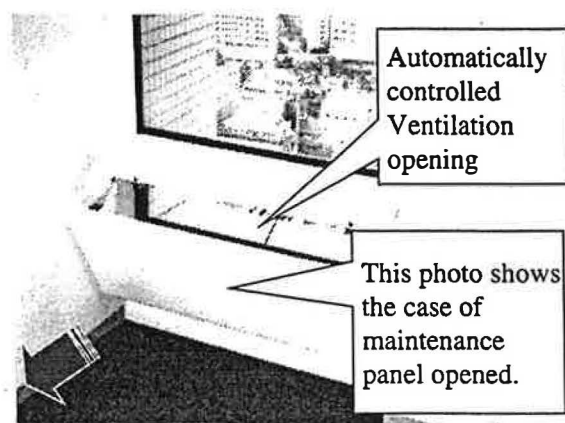


Figure 8 Automatically controlled ventilation window

air change rate by simulation. By building the wind floor on 18th floor, the number of air change rate per hour increased 4 more times than that of building without wind floor where the number of air change rate is about 11-13 times per hour.

This natural ventilation system cuts the cost of electric consumption for cooling. The reduction in electric consumption is expected especially on mid-season (April, October, November) by 60 – 90% because of natural ventilation. It is estimated that the annual electric consumption for cooling will reduce by 35% approximately. (see figure 11)

In this building, many energy saving methods are applied, and it is estimated that the total CO₂ emissions are reduced by 1/2. (see figure 12)

2 METHODS

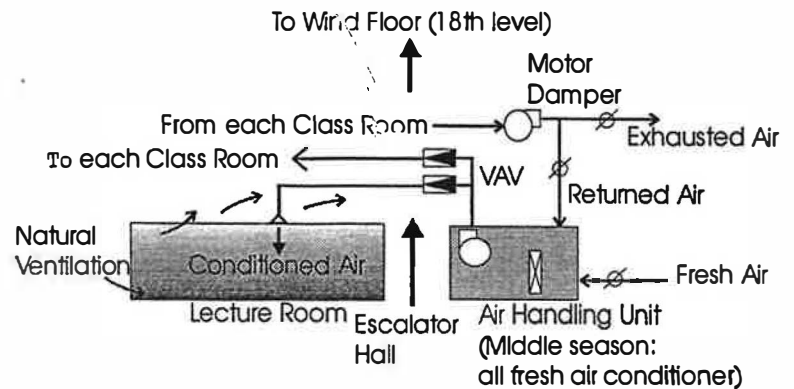
Full scale field monitoring and measurement are now undertaken in respects to the various components designed to the working of the natural ventilation of the building especially the automatically controlled ventilation windows and wind floor design on the 18th floor.

The measurements are done by 2 ways. One is long-term automatically recorded measurement. The other is short-term measurement.

2.1 Long-term field measurement

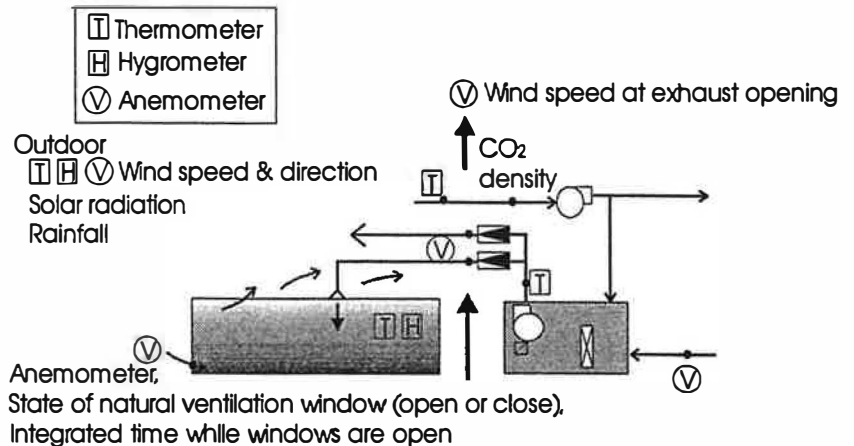
Long-term measurement has been carried out since last September and is now continuing. Measurement is automatically recorded (every 10 minutes) by over 2000 points sensors of building energy management system. In this measurement, energy consumption of each building equipment (heat pump, air handling unit, pump, lighting and consent etc.), temperature, humidity and velocity of each room and air handling unit (see figure 10) and outdoor conditions. Objectives of the measurement are as follows:

1) Inspection of the realities of the hybrid air-conditioning system



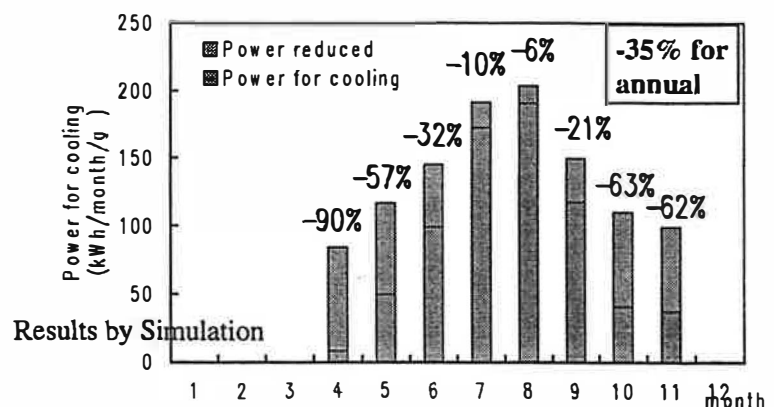
Figures 9 Hybrid natural ventilation and A/C system

The system, which combines wind induced natural ventilation with the usual mechanical air-conditioning system



Figures 10 Sensors

These data (total 2000 points) are recorded automatically every 10 minutes



Figures 11 Natural ventilation reduces power for cooling by 35%

2) Inspection of energy saving effect both at each time and all year round

Figure 13 shows the example of the energy consumption of this building. By making a comparison between the actual results with hybrid air-conditioning system and expecting energy consumption without the system, the effect of the system will be calculated. The result will be reported at the presentation.

2.2 Short-term field measurement

Short-term measurement will be carried out this October, the middle season in Japan. Objectives of the measurement are as follows:

- 1) Inspection of energy saving effect by hybrid air-conditioning during day-time
- 2) Inspection of energy saving and improvement of indoor air quality by night-purge
- 3) Inspection of effect of increase in ventilation rate by wind floor
- 4) Evidence showing significance of adaptive air-conditioning system by questioner survey
- 5) Reinforcement to 2000 automatic measurement points data

Operating patterns during this measurement are 1) measurement comparing rooms with air intake on standard control from others with closed air intake, and 2) comparing measurement of the case when exhaust openings at the wind floor are closed manually.

Contents of this measurement are as follows:

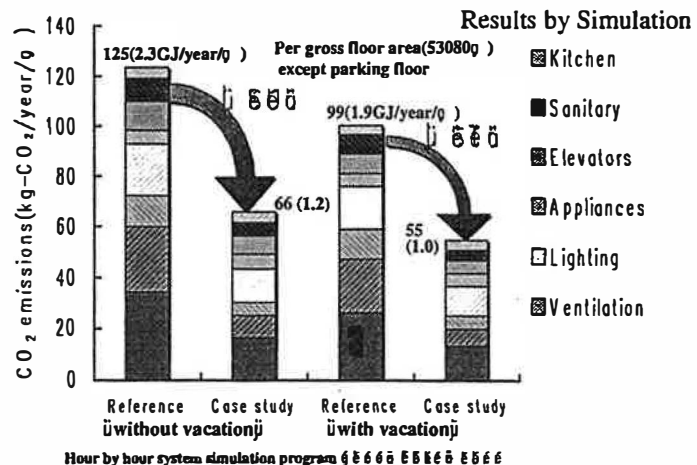
- 1) Detailed measurement around ventilation openings to estimate airflow rate by data from wind velocity sensors set at 14 points near the openings under the window in each room
- 2) Detailed measurement of airflow patterns of the wind floor, especially the measurement of exhaust airflow rate at the openings of each 4 direction on wind floor
- 3) Measurement of ventilation characteristics (i.e. air change rate) in lecture room and wind paths (the openings on the top of the wind core)
- 4) Measurement comparing indoor air quality and room temperature change of the rooms with air intake on standard control from others with closed air intake
- 5) Questioner survey on adaptive air-conditioning

The results of the short-term measurement will be reported in near future.

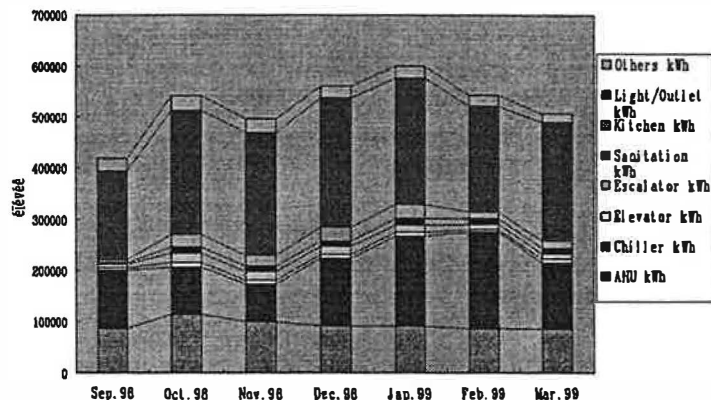
3 REFERENCING

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Figures 12 CO₂ emissions are reduced by 1/2



Figures 13 Example of energy consumption