RESULT 378

CADDET IEA OECD energy efficiency

Office HVAC system uses frost prevention fans and natural ventilation

Summary

Kakegawa City Hall, completed in March 1996, contains a six-storey high glass-walled atrium integrated into the open-plan main office areas via stepped terraces. To save energy while still providing a comfortable indoor environment, the type of HVAC system adopted required careful consideration. Frost prevention fans normally used for tea plantations were installed on the terraces to blow warm air downwards during the heating season. Transferring air from the ventilation windows in the office spaces to those in the upper parts of the atrium also acheived effective natural ventilation.

Highlights

- Glass-walled six-storey high atrium with stepped terraces
- Frost prevention fans returning warm air downwards
- Effective natural ventilation via breeze passage

View of the atrium.

Aim of the Project

With a view to being architecturally open to the public, the new Kakegawa City Hall (six floors above the ground and one underground basement level, with a total floor area of 16,135 m^2) includes a glass-walled six-storey high atrium. Stepped terraces integrate the atrium with open-plan offices on the west side. These spacious terraces, extending from the office areas on the second, third and fourth floors, were designed to facilitate communication between members of the public or between the public and staff.

To save energy in this large space, carefully thought-out HVAC features were introduced, such as frost prevention fans that blow the rising warm air downwards, as well as effective natural ventilation via a breeze passage that uses the stack effect of the atrium. The building also makes maximum use of natural daylight and rainwater (e.g. for flushing toilets). The hill on the west side blocks out the afternoon sun and reduces heating loads on the building. This enables the new city hall to reduce energy consumption and mitigate environmental loads.

The Principle

The atrium is approximately 50 m wide from east to west, 30 m from north to south and 21 m in height, forming an integrated unit with main office areas (first to fifth floors) on the west side. The decks (corridors) along the north and south glazed walls connect each office floor on the east and west sides. This large space is air conditioned by three air-conditioning units: one for the lower level and two for the north and south decks of the fifth floor, with 47 fan coil units dispersed around the activity areas. The excess conditioned air (containing fresh outdoor air supplied to the main office area) is fed to the atrium.

In the cooling season, the uppermost part of the atrium accumulates heat, from which the exhaust air is expelled to the outside air. Warm air gathering under the decks naturally rises upwards through the slits between the decks and the glazed walls.

In the heating season, cold air tends to accumulate in the lobby of the first floor and the terraces, while warm air rises to the top of the atrium. To counter this, six frost prevention fans, normally used for tea plantations, are installed on the second, third and fourth floor terraces. These fans blow warm air downwards, thereby reducing the temperature difference between the upper and lower levels. The fans can be operated in two modes: weak wind operation (92 rpm) and strong wind operation (184 rpm) by inverter control.

In the heating season, exhaust air is expelled from the first floor. Baseboard heaters are installed between the decks and the glazed walls of the third floor to prevent cold draughts from blowing down from the five stories through the slits between the decks and the walls. Floor heating systems (using inexpensive

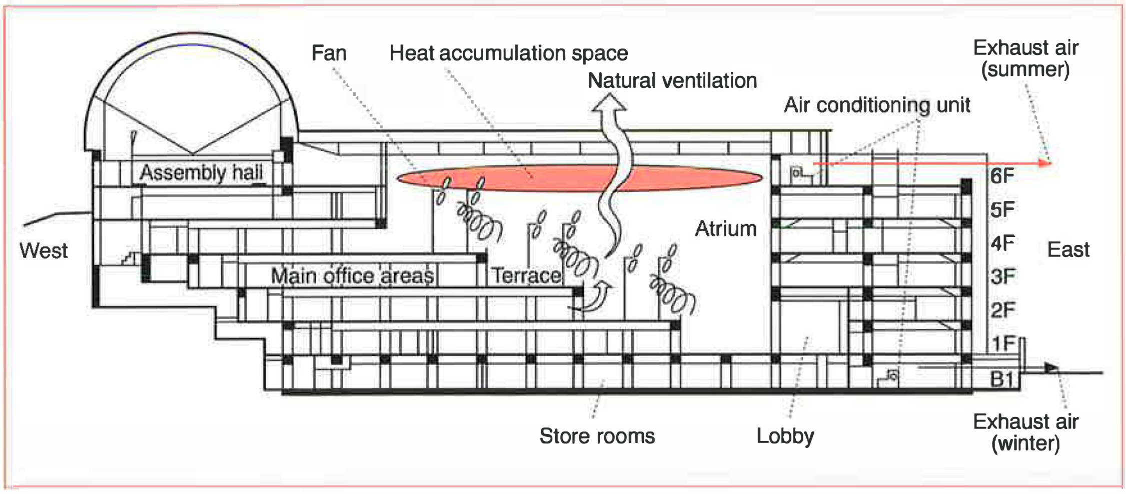

Figure 1: East-west cross section and airflow around the atrium.

Figure 2: Frost prevention fan normally used for tea plantations.

night-time electric power) are also installed in the lobby and terraces to cope with cold radiation from the glazed walls.

To provide a comfortable working environment for the staff, the corridors in the main office areas are laid out along the perimeter zones that are more easily affected by outside influences. These areas are air conditioned by five units installed on each floor (for outdoor air) and 50 units installed in the ceilings of the north and south perimeter corridors (for internal heating loads). In the intermediate seasons, the stack effect in the atrium creates a breeze passage between ventilation windows fitted into the fanlights of the perimeter corridors and at the top of the north and south walls. This natural ventilation can refresh the air in the main office areas, even under windless conditions, at rates of 10-20 times/hour. This breeze passage can also be used on cooler summer nights.

The Situation

The information required to evaluate the winter thermal environment in the atrium was collected in February 1997. During the three-day evaluation period, the frost prevention fans were stopped on the 19th, operated in strong wind mode (184 rpm) on the 20th and in weak wind mode (92 rpm) on the 21st of the month.

The smallest normal deviations measured on the 20th indicate that the frost prevention fans are effective in equalising the indoor environment. The vertical temperature difference of 4°C between the top of the sixth floor and the first floor on the day when the fans were not operated narrowed to 3.5°C on the day of weak wind operation (21st) and 2°C on the day of strong wind operation (20th). The vertical temperature difference is shown in Figure 3.

On the day of strong wind operation, the amount of solar radiation was relatively small due to cloudy weather conditions. The heat input from the air-conditioning equipment was therefore slightly greater, while the heat gain from outside the building (daytime) was the lowest over the three days. Nevertheless, the total amount of heat gain in the atrium was the smallest, which indicated that the efficiency of the air conditioning was improved by using the fans.

The Organisation

The Kakegawa City Government in Shizuoka Prefecture, Central District, covers a population of just under 80,000. It is Japan's leading area for producing green tea.

Economics

Energy-saving measures introduced into this new city hall, such as the efficient heating of the atrium using frost protection fans and effective natural ventilation using the stack effect of the atrium, have succeeded in reducing energy costs.

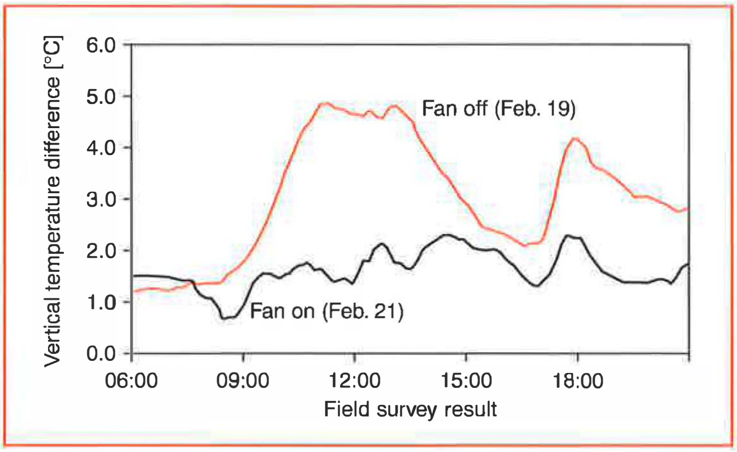

Figure 3: Vertical temperature difference.

Based on the vertical temperature difference, the energy saved by using the frost prevention fans is calculated to be around 2,400 kWh/year, which is around 1% of the total energy required for heating. Looking at the natural ventilation using the stack effect in the atrium, the expected natural ventilation is around 92 million m^3/year, resulting in expected annual savings of 10,700 kWh. This is approximately 1.5% of the total energy required for air conditioning.

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* IEA: International Energy Agency
OECD: Organisation for Economic Co-operation and Development

IEA

The IEA was established in 1974 within the framework of the OECD to implement an International Energy Programme.
A basic aim of the IEA is to foster co-operation among the 24 IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology, and research and development (R&D).

This is achieved, in part, through a programme of energy technology and R&D collaboration currently within the framework of 40 Implementing Agreements, containing a total of over 70 separate collaboration projects.

The Scheme

CADDET functions as the IEA Centre for Analysis and Dissemination of Demonstrated Energy Technologies. Currently, the Energy Efficiency programme is active in 12 member countries and the European Commission.

This project can now be repeated in CADDET Energy Efficiency member countries. Parties interested in adopting this process can contact their National Team or CADDET Energy Efficiency.

Demonstrations are a vital link between R&D or pilot studies and the end-use market. Projects are published as a CADDET Energy Efficiency 'Demo' or 'Result' respectively, for ongoing and finalised projects.

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