RESULT 338

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Large-scale glass atrium maximises natural energy

Summary

The Sapporo Factory is a large-scale commercial building complex in the heart of snowy Hokkaido. The complex has a large barrel-roof glass atrium with a comfortable indoor environment, which is maintained by making the most of cool outdoor air in summer and sunshine in winter. The atrium also provides a bright indoor space, which is never covered with snow, even in winter. Any snow falling on the glass roof is removed using the natural characteristics of snowfall. Energy consumption records for the atrium indicate that it is extremely energy efficient due to the effective use of natural energy.

Highlights

- **A large-scale glass atrium in a cold, snowy district**
- **Energy saving by effective use of natural energy**
- **Comfortable indoor environment**
- **Bright indoor space not covered by snow, even in winter**

The barrel-roof glass atrium of the Sapporo complex.

Aim of the Project

The Sapporo Factory consists of six buildings with a total floor area of 123,300 m². The complex was built by Sapporo Breweries Ltd on the site of its oldest brewery as part of an urban redevelopment project. Sapporo has a population of 1.7 million and lies in cold and snowy Hokkaido. A very large glass atrium, rare in snowy districts, was constructed as the central feature of this complex, to provide a bright comfortable space where people can enjoy life all year round – away from the severe weather conditions. Planners and architects aimed to achieve optimum energy efficiency, while creating a high-quality indoor environment.

The Principle

The barrel-roof glass atrium is 84 m long, 34 m wide and 39 m high, with an air volume of 100,000 m³, a glass roof (around 4,000 m²) and two glass gable walls of about 1,000 m² each. Passive solar measures basically condition the indoor environment of the atrium, with some support from mechanical air-conditioning equipment (Figure 1).

In summer, the atrium design makes the most of the cool outdoor air in Hokkaido through natural ventilation. In winter, as much sunshine as possible is brought into the atrium by removing the snow from the barrel roof. The glass roof and walls use double glazing and heat-insulating sashes to prevent heat loss. To reduce the effect of cold outdoor air, the main entrance in winter is via the first basement floor through a draught-proof lobby. An overhang in the middle of each gable glass wall prevents the air from blowing straight through, thus avoiding cold draughts. Planting and ponds also provide plenty of heat buffer space.

It would require a huge amount of energy to uniformly air condition such a large volume. Therefore, the atrium is divided into three zones: a high-, middle- and low-level zone. Only the low-level zone, which is occupied, is mechanically heated and cooled.

The high-level zone has exhaust openings for natural ventilation. Two directed vent (diri-vent) systems, one on the south side and the other on the north side, blow dry hot air against the inside surface of the glass to make snow slide off easily and inhibit condensation in winter. The systems can also blow air for cooling to prevent the glass breaking when the difference between indoor and outdoor temperatures exceeds 30°C.

The middle-level zone is used as buffering space, and is not air conditioned. The zone contains air inlets, which naturally ventilate and cool the zone during the summer and intermediate seasons, as they are linked to the exhaust openings.

The low-level zone is air conditioned all year round. Three air-handling units

Figure 1: Air conditioning in the atrium.

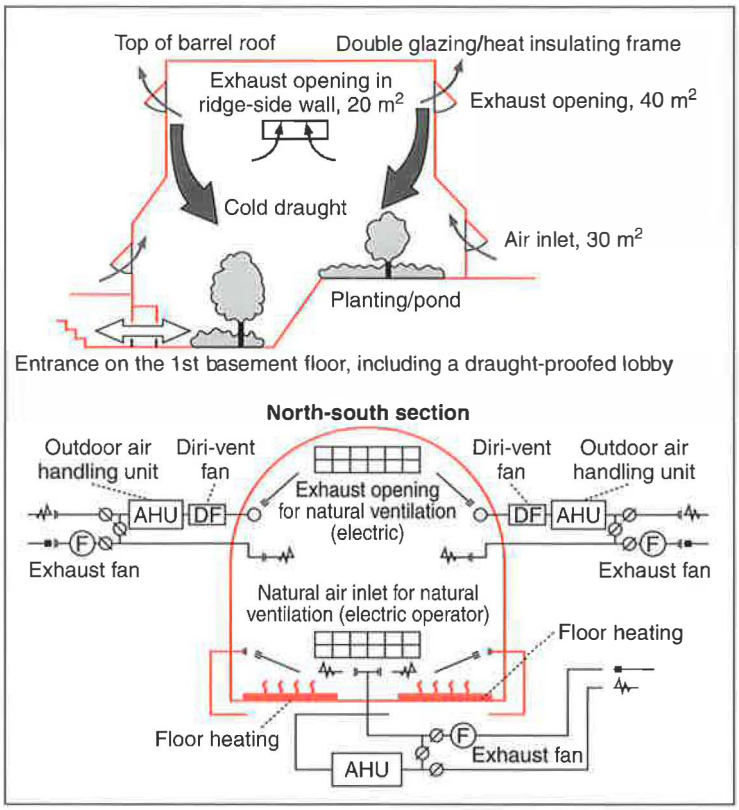
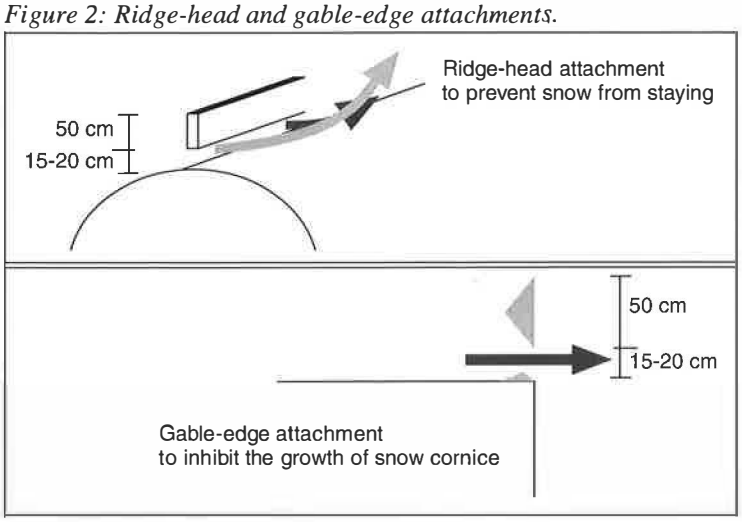


Figure 2: Ridge-head and gable-edge attachments.



(AHUs), east, centre and west, cool the zone in summer and heat and humidify it in winter. The zone also has a floor-heating system and two panel heaters (installed on the east and west gable walls) to prevent cold draughts.

Snow is basically allowed to slide off the roof. Normally, melted snow gathers at the sashes of the roof and freezes to form ice plates, preventing the snow from sliding down. However, improved sash design prevents this. A ridge-head attachment speeds up the wind passing over the roof, thereby blowing off snow and preventing it from laying. A gable-edge attachment also inhibits the growth of a snow cornice in the same way (Figure 2). These measures provide a brightly lit space even during the snowy season.

The Situation

To fully exploit cool outdoor air in summer and sunshine in winter, model experiments were carried out in a climate chamber and numerical simulations based on these results were performed during the planning phase. These studies resulted in positioning extra air inlets in the ridge-side walls.

Once the atrium was completed, the thermal environment was monitored and quantitative studies on the natural ventilation were carried out. Visitors were also asked their opinion on the amenities in the atrium. These studies confirmed that the atrium is successful in providing a very comfortable indoor environment.

The annual energy consumption per m^2 is 30 kWh for cooling and 220 kWh for heating (71 kWh for the floor heating, 69 kWh for the AHUs and 80 kWh to remove the snow). The total annual energy consumption is therefore 250 kWh/m^2. If we exclude the energy to remove the snow, the total annual energy used purely for heating and cooling is 170 kWh/m^2. This is a lot less than the 'S atrium' building in Tokyo, which annually consumes a total of 338 kWh/m^2, with 163 kWh/m^2 for cooling and 175 kWh/m^2 for heating (Table 1).

An energy-efficient district heating service system, based on a cogeneration system with two 1,100 kW gas turbine generators, provides heating and cooling for the entire Sapporo Factory.

The Company

Sapporo Breweries Ltd originates from the Colonists' Beer Brewery established by the Japanese government in 1876. Annual sales in 1996 totalled around JPY 620 billion.

Table 1: Comparison of annual energy required for heating and cooling two large atria.

	Annual thermal load (kWh/m^2)					
	Energy for cooling	**Energy for heating**				**Total**
	cooling	floor heating	AHU	to remove snow	sum	
Sapporo Factory Atrium	30	71	69	80	220	250
S Atrium/ Tokyo	163	_	_	_	175	338

The company has approximately 3,900 employees. Sapporo Breweries Development Co. Ltd is a subsidiary company founded especially for this project.

Economics

The high level of energy efficiency produces considerable economies in energy needs for the atrium, as shown in Table 1. The atrium is also supplied with heating and cooling from a very energy-efficient district heating service.

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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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