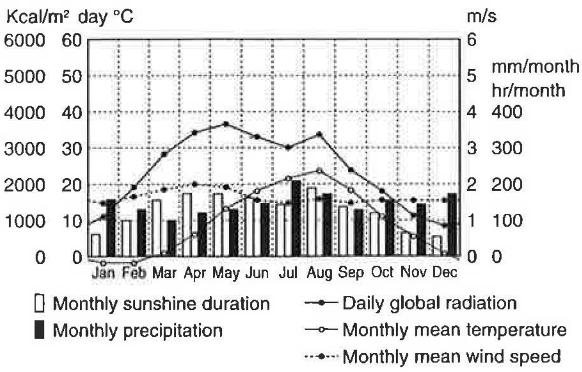
Passive solar system for a school in a snowy region

submitted by the Japanese National Team

The new buildings of Kaneyama Town Junior High School demonstrate that a well-planned and adequately designed passive solar system can work effectively even in a snowy and cold area. The OM solar system of an air heating type applied here, which is characterised by heat collection through roofs, and underfloor heating and heat storage, provides the pupils with a comfortable thermal environment in winter.

South exterior view of the school.

Figure 1: Annual climate of Kaneyama-machi.



(Average between 1978-1987, observed by AMeDAS)

Introduction

Kaneyama-machi is a small town with a population of less than 8,000, located in a basin of northern Yamagata. It is covered by up to two metres of snow every winter, and the summers can be very sultry. This climate is typical of basin regions.

The new buildings of the town junior high school, jointly designed by Mr Akio Okumura, professor emeritus in architecture at Tokyo National University of Fine Arts and Music, and Mr Yoshihiro Masuko, professor in architecture at the same university, were completed in March 1992 to replace the former 'freezing-in-winter' school buildings damaged by the harsh climate. After installing the OM solar system, which Professor Okumura has studied and developed for many years, the new school buildings provide a comfortable thermal environment for pupils, even under bitter weather conditions. The following describes the air-heating passive solar system implemented at the school.

Climate of Kaneyama-machi

Anyone would have doubts about the use of solar systems in such a snowy and cold place as Kaneyama-machi, with thin winter sunshine lasting just a few hours. However, meteorological data (**Figure 1**) at an observation point of the AMeDAS (Automated Meteorological Data Acquisition System) close to the school site showed that, although the short hours of daily sunlight in winter are not enough to use the solar system during the heating period from the middle of October (11.3°C average monthly temperature) to May (13.3°C), solar energy can supply a significant amount of thermal energy for heating in the warmer months. It was also inferred that effective solar shading measures would provide a pleasant thermal environment in the summer, owing to relatively low average outside air temperatures during these months (23°C average monthly temperature in August, the hottest month).

Solar heating system

The major buildings of the Kaneyama Town Junior High School, built of reinforced concrete (RC), consist of a schoolhouse (total floor area of 5,343 m^2: mainly 2 stories high) and a gymnasium (1,872 m^2). The OM solar system, characterised by heat collection through roofs, and underfloor heating and thermal storage, is used to heat general and specific classrooms in the schoolhouse and the gymnasium.

Figure 2 shows the workings of the system in the classroom. In winter, when the surface of the roof is sufficiently warmed by solar radiation, a forced draft fan in an OM air-handling box (24 boxes in total) starts to run, drawing outside air in under the roof from the edge of the eaves, and

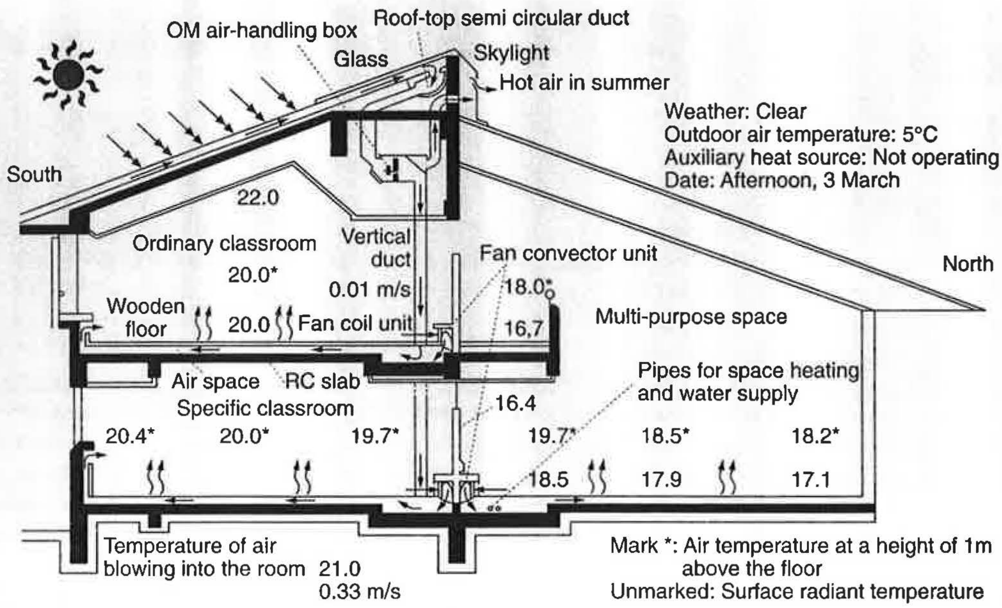


Figure 2: Air flow of OM solar heating system in general and specific classrooms, and the temperature distribution.

collecting the solar-heated air in a ridge air-duct, semicircular in cross section. The upper glass part of the roof further raises the air temperature.

The classroom has a double floor composed of an RC base slab, an air space and a wooden inner floor. The hot air from the roof flows to the window side of the room through the air space and stores the greater part of its heat in the RC slab, while heating the room through the floor. The air passing under the floor enters the room from the lower part of the window-side wall and flows slowly in the room with a speed below 0.01 m/s. The air then flows out through slits in the doors to the corridors and the multi-purpose space adjoining the classrooms on the first floor, and goes outdoors from the lavatories at the end. The solar system heats and ventilates the entire schoolhouse in this way.

When the room becomes cold, the fan stops, the air channel from the roof is closed, and the air from the roof ceases to flow. The heat stored in the RC slab warms the classroom. When the solar heat is insufficient, the fan convector units installed on the corridor side of the classroom heat the air induced from the classroom by hot water from the boiler room, and send the heated air under the wooden floor in the same way as the solar system distributes the hot air from the roof.

In summer, the air-handling boxes switch the flow of hot air from the room and discharge it directly to the outside, thus preventing the heat from flowing into the schoolroom. In the cooking area of the home-economics classes, this hot air is used to heat the feed water for the hot water supply, before being exhausted to the outdoors. The deep eaves also mitigate solar heat gain through the windows during the summer.

The insulation of the schoolhouse is reinforced with 25 mm thick polystyrene foam to the RC floor slab and wall, and 100 mm thick glass wool to the roof. The windows of classrooms, skylights and other sites facing directly to the outdoors have double windows comprising outer aluminium-sash sliding windows, inner wood frame windows and curtains between the double windows, or double glazing. To prevent the heat stored in the building from escaping during the night, the pupils are advised to close the windows and curtains when leaving school.

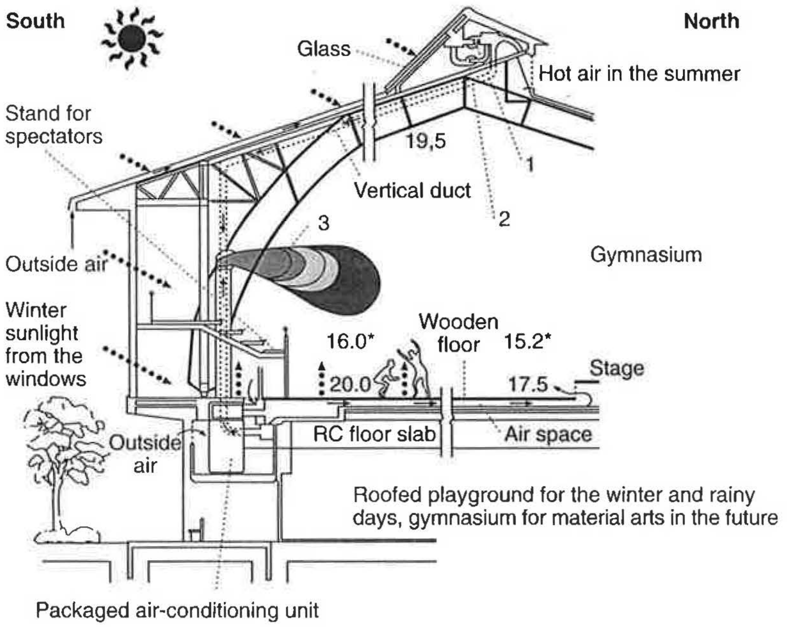
Furthermore, when the snow is piled up on the roof, the warm indoor air is blown under the roof by reversing the fans, to have the snow on the roof slide off. The roof is therefore always ready to collect solar heat from sunny skies.

The solar system in the gymnasium works on the same principle as the schoolhouse. However, to allow the gymnasium to be cooled in summer, a packaged air-conditioning unit for both heating and cooling is used as an auxiliary heat source. In here, only half of the warm or cool air from the air-conditioning unit is distributed under the wooden floor and the other half is blown directly to the gymnasium. The deep eaves keep off direct summer sunlight (**Figure 3, Photograph 2**).

Comfortable thermal environment

The heat storage system maintains the classroom temperature higher than the outdoor temperatures by an average of 17°C (12.8°C in the room at -3.8°C outside temperature) even before the auxiliary boiler starts to operate early on winter mornings.

When the temperature in the classroom falls below the 18°C set by pupils during the heating hours from early morning, before eight o'clock, to half past five in the evening, the fan



Weather: Clear
Outside air temperature: 5°C
Auxiliary heat source: Not operating
Date: Afternoon, 3 March

Mark *: Air temperature at a height of 1m above the floor
Unmarked: Surface radiant temperature

1 Fan blowing heated air into the vertical duct

2 Fan blowing the underfloor air in under the roof to have snow slide down

3 Haif of hot or cold air from the air-conditioning unit is directly blown into the gymnasium

Figure 3: Air flow of OM solar heating system in the gymnasium, and the temperature distribution.

coil units of the auxiliary heating system start to operate. When the heat from the roof is sufficient to warm the rooms, the auxiliary boiler stops operating. The boiler is fired for about three hours per day on average throughout the winter and consumes an average of 300 litres of heating oil per classroom. The entire system is remotely controlled from a centralised control panel in the staff office.

Figures 2 and 3 also show the temperature distribution in the schoolhouse and the gymnasium during the afternoon of 3 March 1994, demonstrating that the OM solar system provides the building with pleasant room temperature levels and a comfortable indoor thermal environment through floor heating and ventilation, with little vertical or horizontal difference in temperatures. The auxiliary boiler was fired from eight o'clock to half past ten in the morning and for one hour during the night to prevent water pipes from freezing.

The temperature measurements during the summer of 1993 also proved that the system could provide a good, homogenous indoor thermal environment even in the middle of summer. Measurements taken on 15 August in a closed classroom showed the diurnal range of room temperatures was approximately 1°C with an average of less than 1°C difference in the horizontal temperature distribution. Measurements taken on 15 August in the closed gymnasium showed that the room temperatures were at approximately the same levels as the outdoor temperatures, even in broad daylight.

For further information, please contact the Japanese National Team (address on back cover).