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Efficient use of natural energy sources

Efficient use of natural energy sources in an art museum

Summary

The Sun Park Art Museum in Matsuyama, Japan, uses the plentiful natural energy sources from its surroundings for air conditioning. It uses cool water drawn up from a well for space cooling and hot water warmed with solar collectors for heating. The floor slabs are used as radiant panels and for thermal storage. Water is sprinkled over the roof during summer. By these means a 50 to 60 % reduction in energy consumption is achieved compared to a conventional system. The system further ensures a comfortable indoor environment by controlling not only temperature and humidity but also radiant temperature and air velocity.

Highlights

- Use of natural energy sources
- Thermal storage in floor slabs
- Good control of thermal comfort
- Energy saving of 50 to 60 %

The Sun Park Art Museum in Matsuyama, Japan.

Aim of the Project

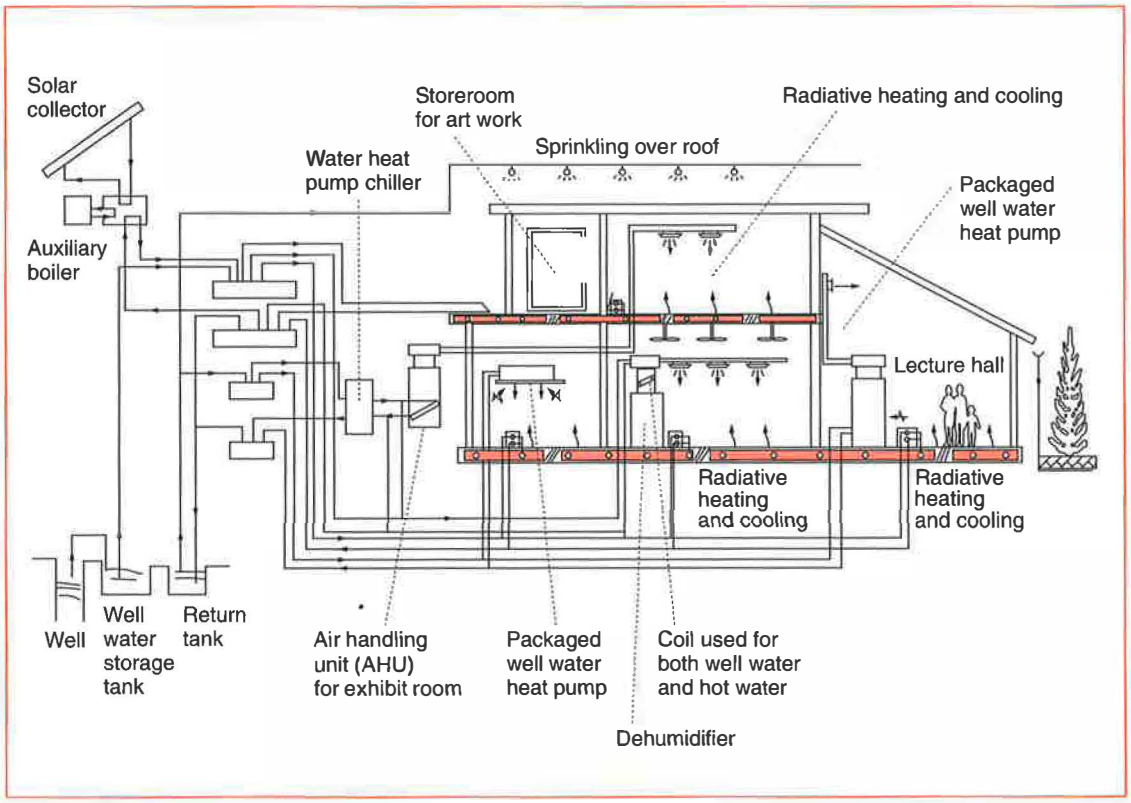
The site for the art museum in this project has access to plenty of cool well water and a large amount of sunlight. The aim of this project was to install an air conditioning system which, in addition to reducing energy consumption, would utilise these abundant natural resources to provide the proper thermal environment for both the people and the artwork inside the museum.

The Principle

The museum is a two-storey, reinforced concrete construction with a total floor area of 1,143 m^2 (the ground floor measures 771 m^2 and the upper floor 372 m^2). Three main design measures have been adopted to assist the building's air conditioning system. Firstly, well water is pumped through the floor slabs to provide cooling. The floor also acts as thermal storage. Secondly, a control system manages radiant temperature, air velocity, room temperature and humidity. Thirdly, a reduction of the heat load from outside is achieved by exterior insulation and sprinkling water over the roof. Figure 1 is a schematic of the complete system.

Using materials with large thermal capacities for the structural components of a building, such as walls and floors, is a very effective way of keeping artwork in good condition and providing a comfortable environment for people. This prevents the inside temperature of the building from being affected by external temperature fluctuations. The museum uses floor slabs in which tubes made of cross- linked polyethylene are buried. Cool well water (about 19 °C) is passed through these tubes during summer. In winter, water heated by solar collectors or an auxiliary boiler to about 30 to 35 °C is circulated through the tubes. Heat is therefore absorbed or radiated by the floor slabs to provide a comfortable thermal environment. In this way it is possible to use the well water for space cooling. Conventional cooling systems could not use water at this temperature.

Figure 1: Schematic of the system.



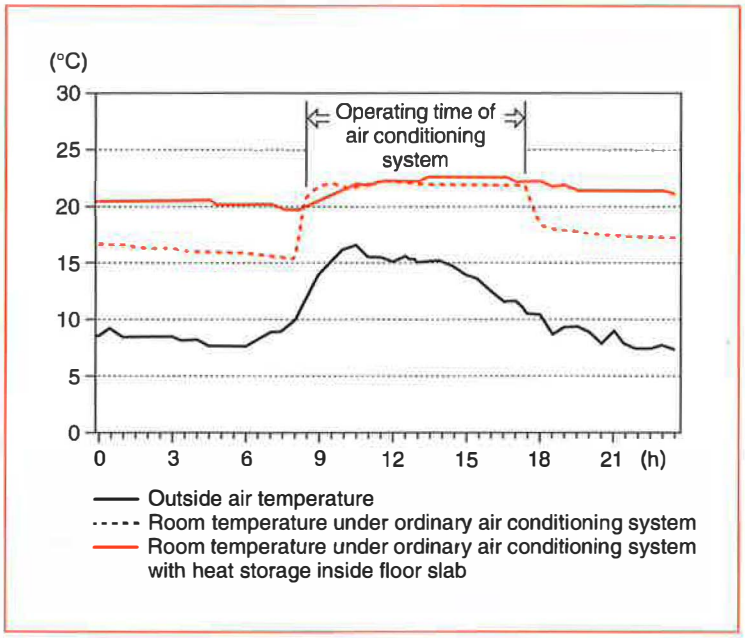


Figure 2: Comparison of indoor temperature changes in a room heated by this system and a room heated by an ordinary system.

To judge the comfort level of the internal environment this system uses the PMV (predicted mean vote) index, which takes into consideration not only room temperatures and humidity but also radiant temperatures, air velocity, the types of activities people are engaged in, and the insulation level of the clothes people are wearing. The system controls this PMV index within the range of +0.5 to -0.5, which is considered to be the most desirable. Humidity is controlled at a constant level to prevent damage to the artwork. Human activity and clothing are assigned fixed values according to the season. The building environment is therefore controlled by manipulating room temperature, radiant temperature and air velocity. By controlling radiant temperature and air velocity it is possible to provide the space with a comfortable environment even when the air temperature is 28 °C.

Exterior insulation was applied to part of the building's second storey, including the repository for works of art, by hanging specially shaped tiles on a metal surface over a layer of insulating material. This ensures that there is ventilation between the tiles and the outside walls of the building. Water is sprinkled intermittently over the roof through nozzles controlled by temperature sensors. Sprinkling this water reduces the heat load from the roof by 40 %.

The Situation

During the summer, the air conditioning system has been able to control the internal air temperature at 26-27 °C and the fluctuations of PMV within the range from +0.5 to -0.5 of the set value. Changes in room temperature throughout the day and night are also regulated and kept to less than 2 or 3 °C.

During winter the comfortable thermal environment with negligible fluctuation in temperature is continued by using water heated to approximately 30 °C by the solar collectors or the auxiliary boiler. Figure 2 shows the fluctuations in the indoor temperature over a 24-hour period during winter. It shows the comparison between the actual figures observed on 3 December 1989 in this museum and calculated figures based on the same conditions of outside air temperature and an ordinary air conditioning system. Owing to the large amount of heat stored in the floor slabs, there is only a small drop in temperature during the hours when the system is out of operation (18.00 to 8.00 hrs.) and the variation in temperature for the whole day stays within 3 °C. This narrow range of temperature fluctuation is important to keep the artwork in good condition. In this case it makes 24-hour air conditioning unnecessary and hence results in a large energy saving.

The Company

The Sun Park Art Museum is owned by the Nankai Broadcasting Co. Ltd., a local broadcast company in Shikoku, in the south-west of Japan. Shimizu Corporation is one of the largest construction and civil engineering companies in Japan. Its sales for the year ending in March 1992 were JPY 2,130 billion with orders

received for JPY 2,500 billion. The company employs about 16,500 people.

Economics

The measured energy consumption of this museum is about 185 MWh, a saving of about 60 % compared with the energy that would be consumed if the museum was air conditioned using an ordinary air-cooled heat pump chiller (about 480 MWh). There was no extra capital cost compared to a conventional system.

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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 22 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 35 Implementing Agreements, containing a total of more than 60 separate collaboration projects.

The Scheme

CADDET functions as the IEA Centre for Analysis and Dissemination Demonstrated Energy Technologies for all IEA CADDET member countries.

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

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

This brochure is printed on 100% chlorine-free bleached paper *February 1994*