VENTILATED WINDOWS AS SOLAR COLLECTORS, AIR AS THERMAL MEDIA AND THERMAL STORAGE IN HOLLOW CORE CONCRETE FLOOR SLABS

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ABSTRACT

In this paper we will describe a theoretical study, full scale tests and a building under construction, using ventilated windows as solar collectors. Air as thermal carrying media and thermal storage in hollow core concrete floor slabs.

Radiators or other heating units are not required. Temperature control is maintained solely by means of the floor and celling surfaces, i.e. by the supply air temperature in the duct inside the floor slabs.

Temperature sensing elements, embedded in the concrete, control the room temperature.

The paper discusses the magnitude of the energy conservation and the resulting thermal comfort during summer and winter conditions. The investment cost and the operating costs of the system are discussed. Both the ventilated window and the hollow core concrete slabs are well known building elements in Scandinavia and commonly used.

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INTRODUCTION

The research described in this paper has been carried out in Sweden and firstly we should give you some orienting information about the country. Sweden is situated between latitude 55 N and 69 N, but due to the Gulf Stream the climate is not too severe.

In table no. 1 we have shown the climatological conditions for Stockholm compared with a few American cities.

Sweden's total energy requirements for the heating of buildings during a year is approximately 170 TWh (1975).

During the winter months the sun does not rise much over the horizon and in northern Sweden not at all during mid-winter.

For this reason vertical solar collectors work well and the mean solar radiation through a two pane window in Stockholm is as shown in table 2. In this paper we describe a method to utilize all the sun radiation available on the facade of a building and if necessary use it for the immediate energy requirements, but also be able to store part of it for use during the coming night.

The purpose of the project is to attain an economical installation using only well known and tested building components. No sophisticated steps are taken in order to increase the solar collecting performance.

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Even during a Swedish winter day the solar radiation through the window of a well insulated building can be more than enough to compensate for the heat losses through the walls.

The system discussed is not as much a solar collecting system, but a system optimizing the building in order to utilize all uncontrolled heat gain from solar radiation, lighting, electrical office machines and people. Table 3.

The thermal climate of the building is allowed to vary within existing regula tions and what human comfort permits.

SYSTEM DESCRIPTION:

The two main components involved in the project, the ventilated window and the hollow core concrete slab, are in common use and well tested in Scandinavian building technology. These two elements are combined in a system in which air is the carrying medium.

No new and untested components that can fail are included in the system loop.

In the ventilated window, Fig. 1, about 50% of the solar heat falling onto it is taken up by the air circulating through the window.

The great mass of the hollow core concrete floor slab, Fig. 2, permits the storage of considerable quantities of heat in spite of limited temperature variations.

The floor slabs can be prefabricated hollow core or cast on site with embedded airducts.

Most office buildings in Sweden are built with cellular rooms towards the outside walls and with one or two passageways on each floor. The system presented in this paper is suited for that kind of building.

The current Swedish regulations regarding the heat losses through the building envelope makes well insulated walls and three pane windows obligatory.

The small heat losses through the building envelope in a modern office or institutional building makes it interesting to utilize the modest solar heat flow through the windows.

The solar heat that is trapped by the window is primarily utilized for the inmediate heating of a building as well as compensating for transmission losses and the heating of air required for the ventilation of a building. Should this additional heat be greater than immediate needs, surplus heat can be stored in the concrete mass of the building until required.

The first completed phase of this research project consisted of a theoretical study, and due to the interesting result it was decided that a full scale test room should be constructed.

The theoretical study showed that in an ideal building utilizing this system, the energy requirements can be reduced to about 25 kWh/m^2 of floor area per annum.

This is less than half of what is required for a building in the Stockholm area constructed in accordance with current Swedish regulations. For the comparative cost analysis that was made, an existing 14 floor building near Stockholm was used.

The analysis shows that construction/installation costs for the system described in this paper are similar to those for a conventional building heated with a hot water radiator heating system.

Due to high energy costs architects and consultants try to avoid mechanical refrigeration and the building used for comparison does not have any installed.

DESCRIPTION OF THE PROPOSED SYSTEM IN AN OFFICE BUILDING

Air is taken from a central air handling unit on the roof and distributed to the different floors of the building and then drawn through the ducts embedded in the concrete slabs between each floor. The air then passes through the outside wall and between the glass panes of the window. Above the window there is a duct collecting the air, which is then again conducted to the air-handling unit on the roof. In the air-handling unit the air will be treated in a filter, in a heating coil and may be in a cooling coil. In the damper section of the unit the circulated air can be exchanged for outside air, thus cooling or heating the building when the outside conditions so permit.

Part of the air can be drawn through the room to give the hygienic airflow needed. In this case the air-handling unit must always supply the building with the proper amount of outside air.

In order to verify the interesting results from the theoretical study, we decided to make full scale tests.

The test facilities used are situated on the premisis of the Department of Building Technology, headed by Professor Bo Adamsson, at the Lund University in southern Sweden.

The data logging system and the computer used for the tests also belongs to Mr. Adamsson's department.

DESCRPTION OF TEST FACILITIES

The test room is 3.6 m wide, 4.5 m deep and 2.8 m high. See Fig. 3.

The facade is facing east and the three remaining walls are protected by a surrounding room as shown in the figure. The floor and ceiling concrete slabs are well insulated towards the outside, are 0.30 m thick and have 65 mm. diameter air channels as shown in Fig. 2.

The window wall is factory made in one piece and the air from the bottom slab is distributed with a perforated steel channel resting on the floor.

The air rises through slots in the wall and then passes through the window. Above the window the air is collected in a duct and taken to an air-handling unit with fan, damper-complex and a heater.

After passing the air-handling unit the air is drawn into the channels in the concrete slab and again to the window wall. So far in our tests we have not used the circulating air for the ventilation of the room.

In the duct system we have installed a measuring flange and also an automatic volume regulator. The heater is electric and no cooling coil has been installed. The only way of cooling the circulating air is by exchange with outside air in the damper-complex.

The window has 2 + 1 panes and the circulating air passes the inside of the middle pane. In order to capture the heat from the solar radiation, venetian blinds have been installed between the panes where the air passes. They are od the type commonly used in Sweden, 25 mm wide, on the up/out side painted with black and the in/down side is mill-finish aluminum.

In our test room the air duct above the window is placed on the inside of the wall for inspection purpose, but in a real project it might be better to install it on the outside of the wall.

The concrete slab has a heat storage capacity of about 180 kWh/K and m^2 floor area.

TEMPERATURE CONTROL

The amount of solar energy captured is related to the temperature difference permitted in the room. We believe that a temperature difference of three to four degrees centrigrade can be accepted. In order to simplify the automatic temperature control it is convenient to install the principal temperature sensor in the floor slab.

In order to make it possible to store excess heat during cold periods and to chill the slab with cold night air during warm periods we let the control system sense the outside air temperature for a few minutes in the night. During those minutes the set point for the next twentyfour hours is changed according to outside air temperature. If the air temperature is high the concrete slab is chilled, but if the temperature is low the slab is not chilled and the next day the solar energy is captured in the window and deposited in the floor slabs.

To simulate that our test rooms forms part of a multi-story building we have constructed the ceiling slabs in the same manner as the floor slabs. In the air circulation system for the ceiling slabs the temperature of air entering the alabs is controlled to be equal to the temperature of the air entering the floor slabs. This way we get a ceiling surface temperature almost equal to the floor surface temperature.

In a similar manner, to simulate that our test room is one of several office rooms in a row, it has been installed within a outer room.

The outer room has it's own temperature control system and the temperature is controlled to be equal to the temperature in the test room. Fig. 4.

DATA LOGGING EQUIPMENT

To measure and register temperature, energy flows and solar radiation, a 130-channel data log is used. The collected information is then transmitted to and stored in the computer installed in the Department of Building Technology. Integrating devices have been installed where heat flows have to be measured. This permits us to measure and integrate the heat flowing through walls and windows, heat stored in the concrete slabs and also the heat transferred to, carried and deposited by the circulating air.

RESULTS

We have now been running tests since March 1979 with all systems functioning as planned and the data logging system connected. Because of a severe winter with a snow layer of more than two meters outside our test room window; the first period showed erratic values.

However, during the Spring months our tests show an energy need not exceeding 50% of the calculated need for a similar room heated in a conventional way with similar climatological conditions. We will continue the tests this coming winter in order to obtain more exact figures.

The theoretical study showed an even greater energy saving, but those calculations were based on an ideal control system.

The Stockholm City Council has chosen to apply these principles to a wing of the Marsta Nursing home, and this forms a pilot project in the County Counsils effort to save energy in future buildings. The first results from this building will be available in the Spring of 1980.

CONCLUSIONS

1.- Our need to utilize the solar energy during the heating season will increase as the cost of conventional heating increases.

2.- In a well insulated building even the solar radiation falling on the windows is important for the temperature balance.

3.-With the system described in this paper it is possible to distribute the solar heat gain and the internal heat loads over 24 hours, sometimes more.

4.- In order to make this possible the occupants of the building must agree to let the indoor temperature vary a few degrees during the working day.

5.- The system described uses only known and well-tested components.

6.- Installation cost and maintenance cost is comparable to those of a building with conventional heating and air-handling systems.

7.- We can expect a gain in the cost of heating the building envelope of 60% in comparison to a similar modern and well insulated building of the type now being built in Sweden.

TABLE 1 Comparative climatological information

From ASHRAE 1977 Fundamentals Handbook

Degrees F.

State and station	Winter: Design dry bulb 99%	Winter: Design dry bulb 97,5%	Summer: Design dry bulb 1%	Summer: Design dry bulb 2,5%	Summer: Design dry bulb 5%	Summer: Mean daily range	Summer: Design wet bulb 1%	Summer: Design wet bulb 2,5%	Summer: Design wet bulb 3%
Stockholm, Swe.	5	8	78	74	72	15	64	62	60
New York, NY	11	15	92	89	87	17	76	75	74
Chicago, IL	-3	2	94	91	88	15	79	77	75
San Fran., CA	38	40	74	71	69	14	64	62	61
Houston, TX	28	33	97	95	93	18	80	79	79

TABLE 2 Solar heat gain through a two pane window, kWh per month and m^2. (Stockholm)

Month \ Window facing	East	South	West
January	15.8	53.3	15.8
February	43.9	122.0	43.9
March	121.0	230.4	121.7
April	177.1	227.5	175.3
May 1-14	108.5	98.4	103.7
Sept. 18-30	51.0	84.4	50.1
October	64.1	159.8	63.7
November	19.4	61.6	19.4
December	9.4	32.8	9.4

TABLE 3 Heating requirements and internal heat load for office building in Stockholm, kWh per month.

Month	Requirements[a]	Heat load[b]
January	59.5	31.5
February	54.8	31.5
March	53.8	31.5
April	39.2	31.5
May 1-14	11.6	14.0
Sept. 18-30	7.9	12.5
October	33.5	31.5
November	43.3	31.5
December	51.7	31.5

a) For transmission and leakage per 1.2 m outside wall lenght with 1.0 m^2 three pane window.
b) Internal heat load from lightning and people.

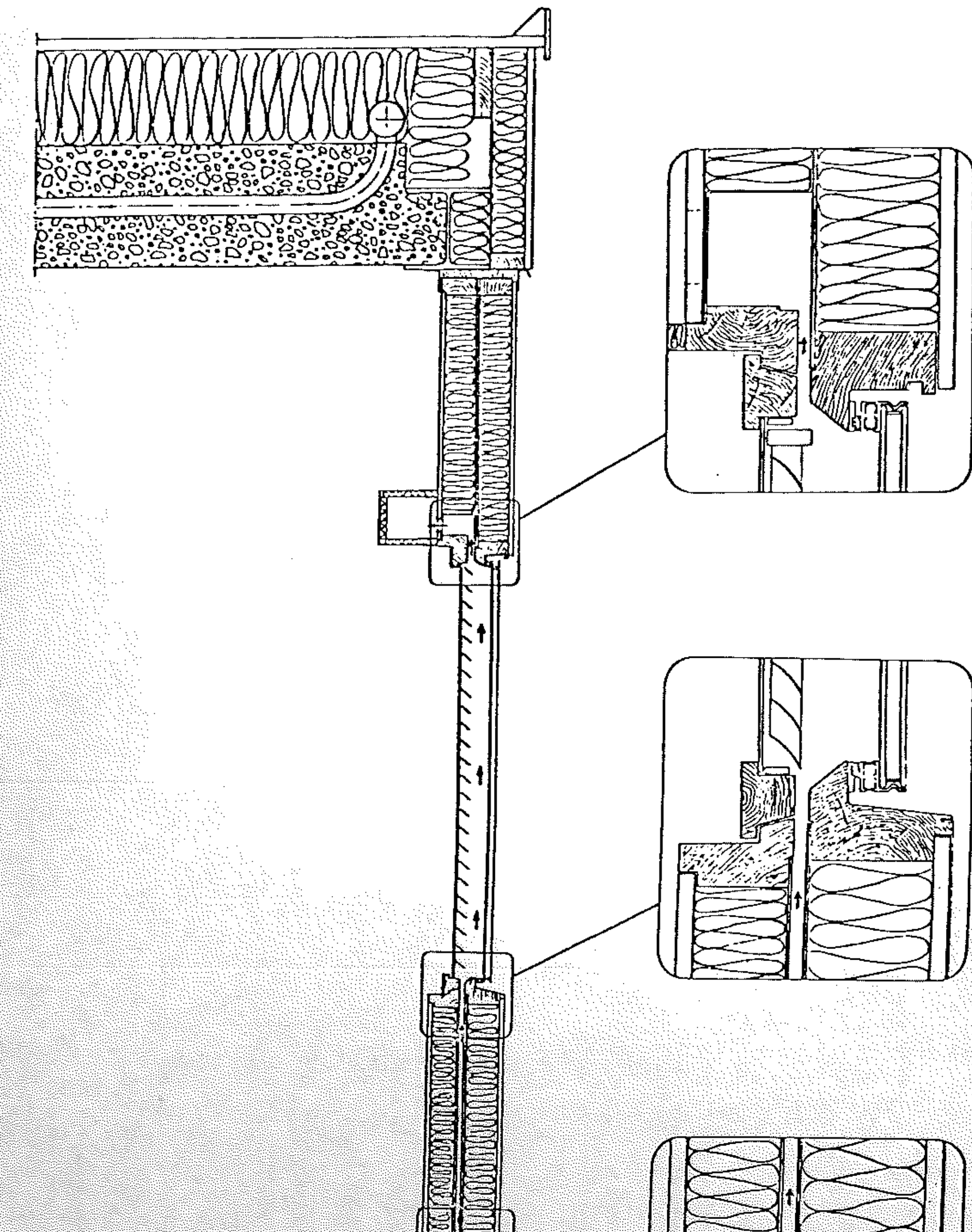

Fig.1
Section through facade wall showing construction and details

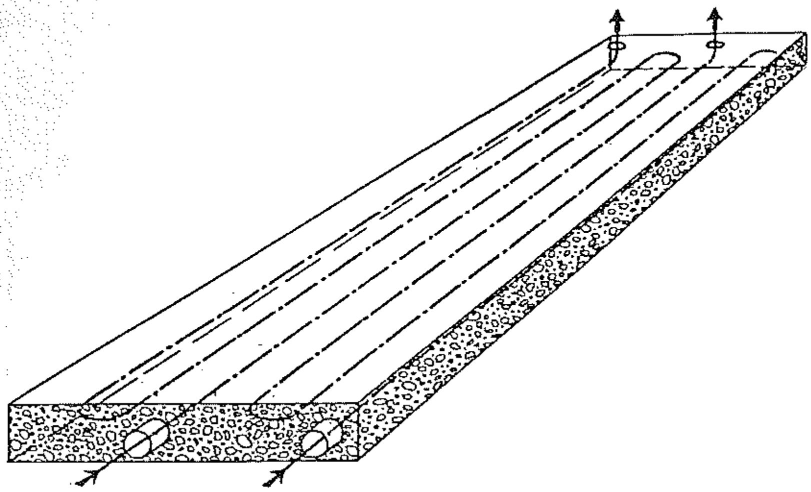

FIG.2
Concrete floor slab showing emedded air ducts

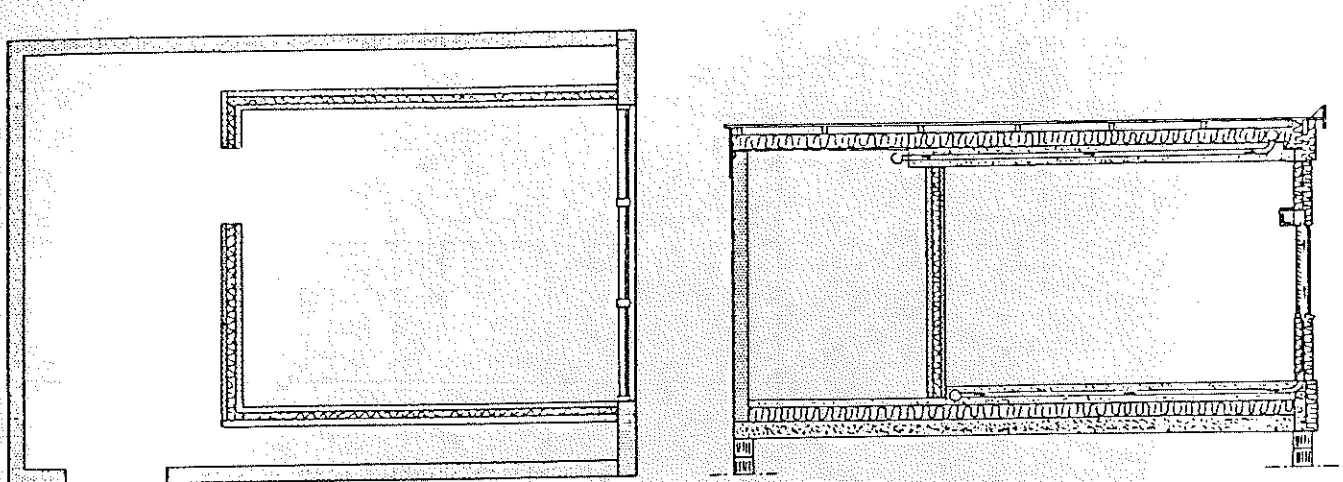

Fig.3 Test room and surrounding room

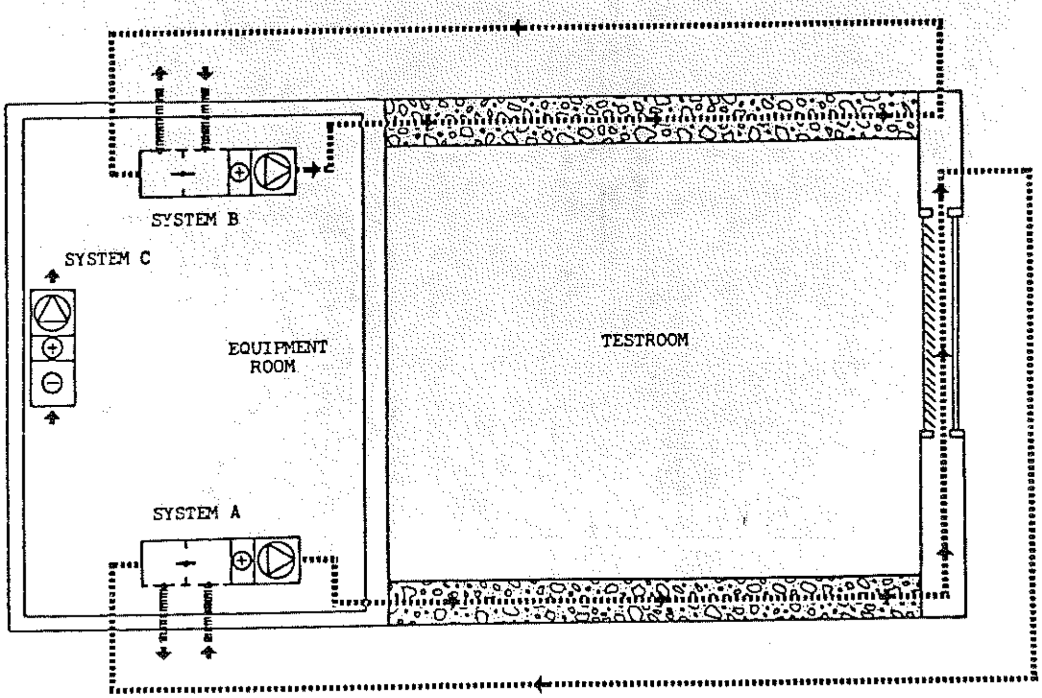

Fig.4 Air circulating systems in test building