VI–5. A Swedish Technique for Conserving Energy

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ABSTRACT

Presentation of a construction system for one family houses, with blocks, bricks and units providing a good thermal insulation and a good air tightness.
The construction system is suitable for detached or semidetached one-family houses.
The system exists of bricks, mineralwool and blocks of cellular concrete together with units of cellular concrete for roofs and floors.
On the basis of the sizes of the blocks the construction system is very easy for using in varying environments.
The walls and roofs can be made very airtight and with a very good thermal insulation.
The airtightness is a pre-requisite for heat recovery from the ventilation air.
Heat recovery in this case is made by the floor units without complicated mechanical apparatus.
For heating of the building you can use either electrical or central heating equipment.
The construction system is based on blocks and units with moderate sizes and very simple connections between e. g. wall and roof.
The system is also a very fireproof construction which means the possibility of a concentrated and more economical building-up area.

This paper presents a construction system for one-family dwellings that is based on bricks and lightweight concrete elements. The system provides a good thermal insulation and minimal heat loss due to ventilation. It can be used for multi-dwelling projects or for individual houses.

The basic components of the system include facade cladding, mineral wool and lightweight concrete elements for walls and floors.

The components are relatively small in size, so that the system can easily be adapted to various environments.

The roof and the exterior walls can be built to provide excellent air-tightness and a low coefficient of thermal transfer.

The fact that the shell of the building is extremely airtight allows for recovery of thermal energy from ventilation air. Heat is recovered through the floor structure of the building without the need for complex mechanical apparatus.

Space heating for the building can be supplied by means of electric elements or hot-water radiators.

The design of the system details facilitates construction work and ensures a reliable structure.

The system is extremely resistant to fire, which allows for greater density of dwelling units and more economical land use, among other things.

The airflow that allows for recovery of thermal energy through the floor structure also constitutes an effective barrier against the possible diffusion of radon gas from foundation rock or fill.

The thermal recovery system is reliable and easy to service, with a minimum of components that require maintenance.

EXPERIMENTAL HOUSE

The experimental house is a two-storey building without a cellar; living area amounts to about 160 m^2, with about 60 m^2 of secondary area.(See Figure 1.)

The foundation is designed as a crawl space that is ventilated by exhaust air, which is forced into the crawl space by a fan. The crawl space functions as a heat exchanger for transfer of the thermal energy in the exhaust air, which is then ventilated out through the roof as in a conventional building. (See Figure 2.)

The crawl space is built of 20-centimeter elements of lightweight concrete on a concrete slab. The floor structure is of a conventional design and consists of 25-centimeter lightweight concrete elements.

The exterior walls are built of 30-centimeter elements with an external layer of grout. All bearing walls and floor structures are built of lightweight concrete. The floor of the second storey is insulated with mineral wool. All windows are fitted with triple glazing. The building can be heated by electric elements or by radiators that are fed with hot water from an electric heater. The floor plan, sections, etc. are illustrated in Figure 3.

The data collected in the experimental house have been used for evaluation of:

- —thermal insulating capacity and thermal resistance of various system components
- —the air-tightness of the building
- —the total energy balance of the building.

These data have also been used to study the crawl space in terms of temperature and conditions.

GENERAL ASPECTS OF THE SYSTEM

The system has been developed for one-family dwellings of one or two storeys, without cellars. (See Figure 4.)

The bearing walls can be built of mortared lightweight concrete elements with a facade of stucco or stone. (See Figure 5).

From an architectural point of view, the system can be used for multi-dwelling projects or for individual houses. The framework of the building is completely resistant to fire, so that density can be increased in the interest of more rational land use and improved economy. (See Figure 6.)

GOALS

The system has been designed to meet the Swedish Building Code's rigorous requirements for energy conservation.

Simplified assembly and appropriately dimensioned components ensure excellent air-tightness throughout the building shell. This allows for increased control of ventilation flow so that energy consumption can be optimized. The crawl space is ventilated by exhaust air, functions as an energy-saving component and is characterized by satisfactory technical properties in general. The design has been approved by Swedish buidling authorities.

A unique characteristic of the system which is worthy of special mention today is the barrier against radon gas that is formed by the continuous airflow under the building. This means that the system can be used without further modification for construction of houses on rock with a high uranium content.

TECHNICAL STUDIES

Measurements have been taken at varying frequencies over a period of 13 months. Temperatures have been measured with thermal sensors that have been protected against solar radiation and have been installed so as to record true air temperatures both inside and outside the building.

A sensor of the so-called auxiliary wall type has been used for measurement of thermal flow. The measurement area in the center of the sensor consists of a number of thermo-elements connected in series.

Wind speed has been measured at intervals of 60 seconds by means of a propeller anemometer.

Solar radiation on horizontal surfaces has been measured by means of a solarimeter. Recorded values were registered continuously and the amount of energy supplied was determined twice a day by means of an integrator.

Consumption of electrical energy has been measured by means of a conventional electric meter.

The number of air changes has been determined by the use of the trace gas technique; helium gas is released within the building and the decline in the concentration of the gas is recorded.

A measurement technique developed in Sweden involving pressures of 50 Pa above and below atmospheric has been used to determine air-tightness.

A computerized logging system and a 12-point printer have been used for collection of measurement data.

At several measurement points—9 on the floor structure above the crawl space, 4 on the roof tie beams and 3 on the outer walls—thermal resistance has been determined by recording outside temperature and thermal flow.

Thermal resistance has been calculated as $m = \frac{t_i - t_y}{q}$ m^2 °C/W, where t_i and t_y are the mean values of the inner and outer temperatures and q is the mean value of the thermal flow.

The table below indicates that the measured thermal resistance is continuously higher than the theoretical thermal resistance. (See Table 1.)

Measurements based on the trace gas method indicate an air change rate of 0.03/hour with the ventilation system closed and all openings sealed. The air change rate measured by the pressure method was 1.3/hour.

The wind was southwest at 1.5 m/s (= 3.25 mph) when measurements were taken.

The air change rate generated by controlled ventilation is indicated in Table 2.

The structure thus proved to be extremely air-tight, although the interior surface treatment had not been completed at the time the measurements were taken. (See Figure 7.)

NEW CRAWL SPACE TECHNIQUE

The main design principle of the 60-centimeter-high crawl space has been described previously. This space is ventilated by exhaust air and functions as a heat exchanger. Figure 8 illustrates how exhaust air collected by means of a slotted duct is forced into the craw space and distributed across the entire width of the space. The purpose of the design is to lead the warm exhaust air along the bottom of the floor structure in order to minimize losses due to thermal transmission, and then to ventilate the air out along the bottom of the crawl space, through a duct and above the roof of the building.

Temperature measurements indicate that the average temperature at floor level is only 1.5° C lower than the temperature of the air at a height of 1.3 meters above the floor.

This shows that the floor temperature is higher than can be anticipated with a conventional crawl space insulated according to the standards of the National Swedish Board of Physical Planning and Building. Figure 9 illustrates the mean temperature on the upper and lower surfaces of the floor structure during one week of continuous measurements. Measurements taken during other one-week periods correspond closely to these values.

Thermal loss due to transmission through the floor structure can be described with respect to the crawl space ventilated by exhaust air by determining the effective coefficient of thermal transfer.

Calculation of the effective coefficient of thermal transfer shows that a crawl space ventilated by exhaust air as described above constitutes an energy-saving foundation which can reduce energy losses by 50% in comparison with a foundation consisting of a concrete slab laid directly on the earth, despite the fact that the latter has a considerably lower theoretical coefficient of thermal transfer.

Temperature and moisture conditions in the crawl space were studied more or less continuously throughout the experimental period. The quantity of moisture occuring in the walls and ceiling of the crawl space was measured.

Typical temperature and moisture conditions are illustrated in Figure 10.

ENERGY BALANCE

The total heat loss due to transmission can be computed by normal procedures at 184.6 W/°C. Total heat loss due to ventilation has been computed on the basis of air-change measurements during weeks 8-11 at 20.5 W/°C and during weeks 13-16 at 32.8 W/°C.

Figure 11 illustrates the total loss for these periods as straight lines corresponding to the theoretical required energy input as a function of the temperature difference between room air and outside air (curves 1 and 2). The figure also indicates the values of the measured average weekly input (+). Figure 11 shows clearly that there is a considerable difference between the calculated and the measured values.

Calculation of thermal loss due to transmission on the basis of actual measurements generates the following coefficients of thermal transfer:

Roof $k = \frac{1}{6.21 + 0.25} = 0.15\ W/m^{2}°C$

Walls $k = \frac{1}{2.91 + 0.25} = 0.32\ W/m^{2}°C$

Floor above crawl space $k =$ as above $= 0.12\ W/m^{2}°C$

The total loss as calculated above for weeks 8–11 and 13–16 is thus 151.5W/°C and 163.8W/°C, respectively.

These loss are indicated in Figure 11 by curves 3 and 4. These curves show a substantially greater correspondence to the measured consumption of energy.

The complete text of the research report prepared by Professor Bo Adamson and Research Engineer Kurt Källblad of the Lund Institute of Technology in Sweden contains additional analyses and calculations which indicate that the losses due to transmission and ventilation which have been calculated on the basis of measurements can be described as relevant with a relatively high degree of certainty. (See Figure 12.)

Figure 1.

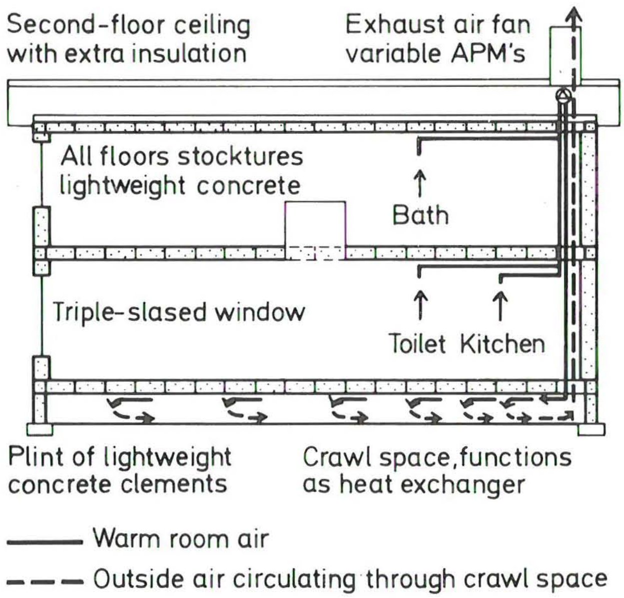

Figure 2.

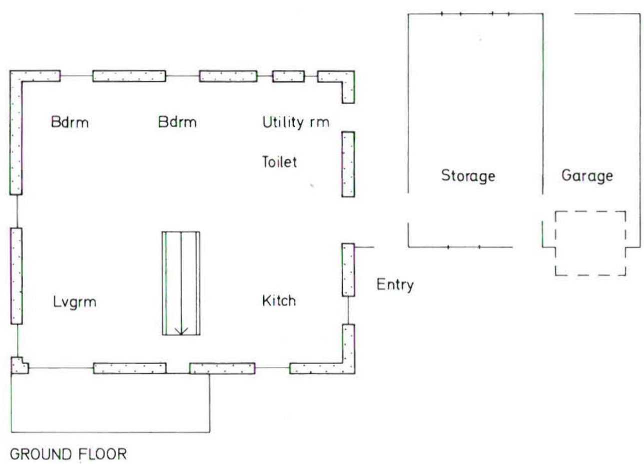

Figure 3.

Figure 4.

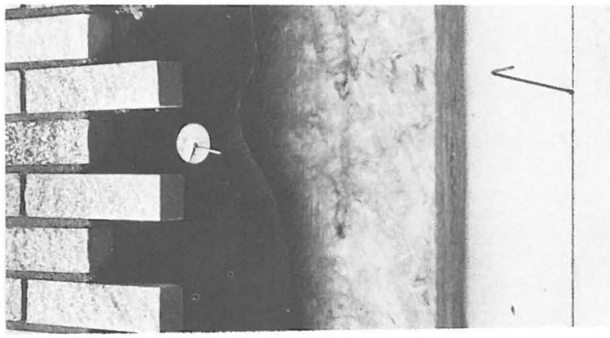

Figure 5.

Figure 6.

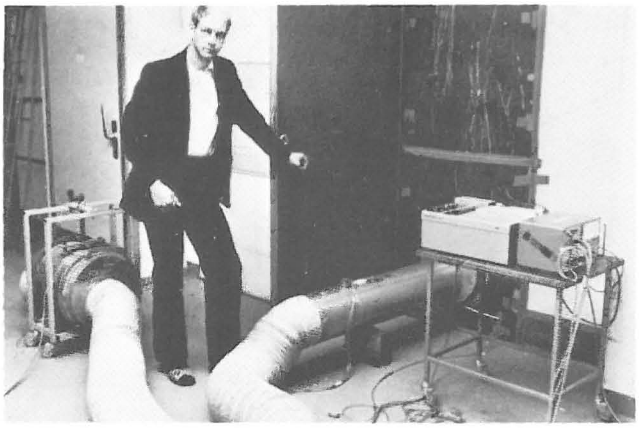

Figure 7.

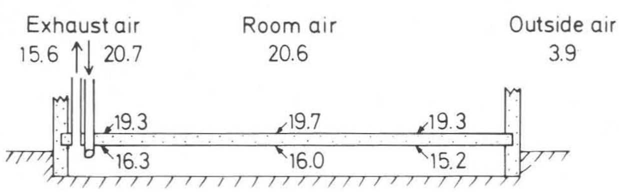

Figure 9.

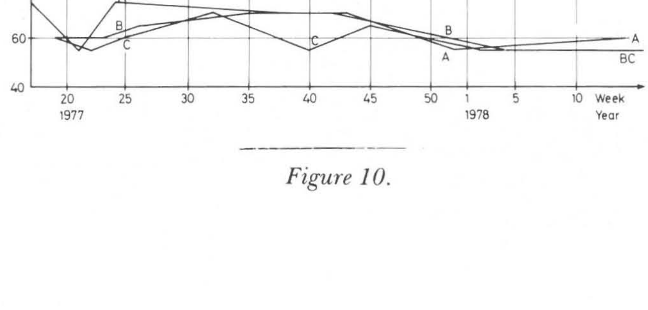

Figure 10.

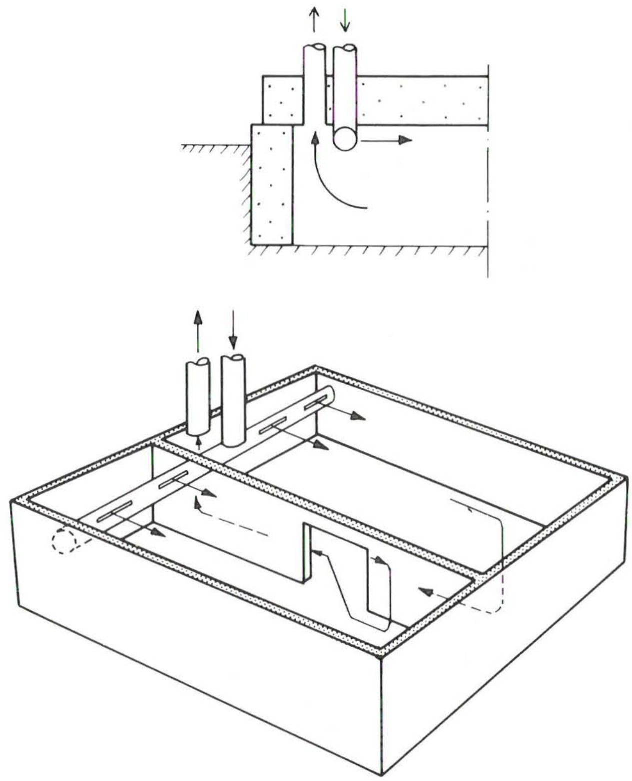

Figure 8.

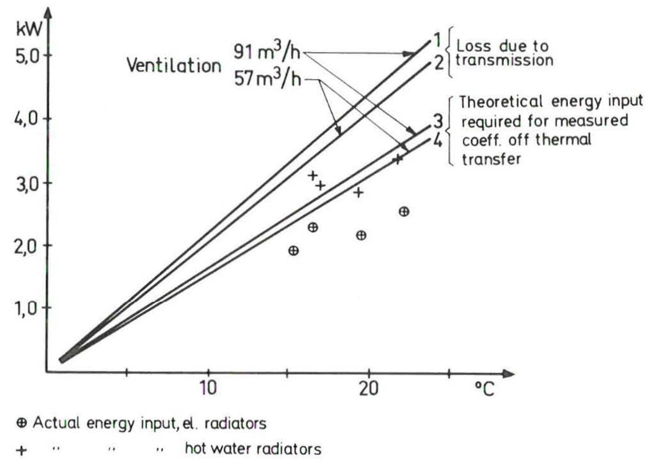

Figure 11.

Table 1

Part of building	Lightweight concrete quality itc.	Thickness m m	Coefficient of thermal transfer W	Theoretical thermal resistance x) $m^2{}^\circ C/W$	Average value of measured thermal resistance $m^2{}^\circ C/W$
Floor over crawl space	500	250	0,15	1,67	1,85
Second-floor ceiling	500	200	0,14		
	mineral wool	150	0,035	5,71	6,20
Exterior wall	400	300	0,12		
	rendering	10	0,9	2,51	2,90

x) Exclusive of transition resistance

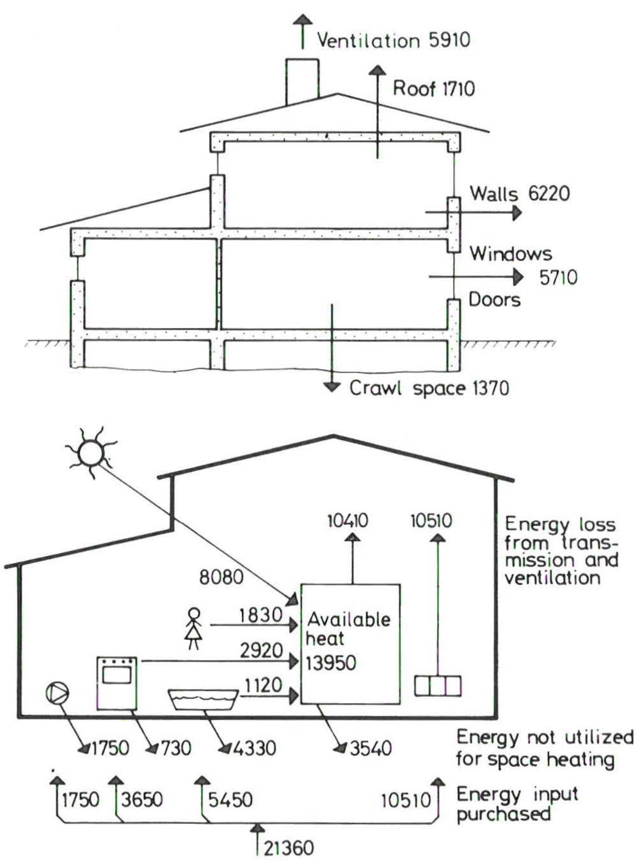

Figure 12.

Table 2

	Exhaust duct closed			
	Via crawl space		Direct to outside	
	Air change/h	m^3/h	Air change/h	m^3/h
Fan closed sealed ventilation openings	0,04	15	0,03	11
Fan closed open ventilation openings	0,04	15	0,12	46
Fan at min. RPM	0,15	57	0,24	91
Fan at max. RPM	0,39	148	0,45	171