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Ventilation for Energy Efficiency and Optimum Indoor Air Quality
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EBES - Energy Efficient Residential Building.

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SYNOPSIS

The new building and HVAC technology was used when an EBES multistorey residential building was built in Helsinki. In the EBES system the building structures are used as an installation space for the heating, piping, ventilation and electrical systems. Building structures are also used as a storage for heating and cooling energy. The main objectives of the overall EBES system are to improve the indoor air quality and energy economy and at the same time to improve the quality of the construction process and reduce costs.

The ventilation system is a mechanical supply and exhaust air system having efficient heat recovery. It is supported by an intelligent programmable controlling system. The ventilation system is designed so that no adjusting and balancing is required after installation. In thr EBES system it is possible to use complex demand-controlled ventilation systems if desired. In this building manual control by residents was used. In each room the indoor temperature is individually controlled and the resident may choose the temperature level desired.

All the HVAC components were tested in the laboratory before installation. All phases of the construction were monitored and filmed by video. The field monitoring of the indoor climate, energy consumption and operation of the system are presently in progress. The project will continue up to the end of 1992.

1. INTRODUCTION

The heating, piping, ventilation and electrical systems and structures of apartment buildings have generally been studied as separate parts independently of each other. A controlled indoor climate, good energy economy, good sound insulation and long service life of the structures can be achieved only through the controlled joint functioning of these parts.

Need for development of an open EBES element building controlling the frame construction in Finnish apartment buildings and the need to develop the indoor climate, energy economy and living standard of apartments without raising the building and operating costs iniated the EBES research project "Energy economic building systems integrated in the heating and ventilation systems of buildings" /1/.

In the EBES system the building structures are used as an installation space for the heating, piping, ventilation and electrical systems. The building structures are also used as a storage for heating and cooling energy (Figure 1).

Advanced EBES building and HVAC technology was used and tested in the experimental building (2-3 storey, building volume 2760 m^3, floor area 842 m^2, eight flats) in Helsinki.

In this paper the results of the field monitoring on the indoor climate, energy consumption and operation of the system are discussed.

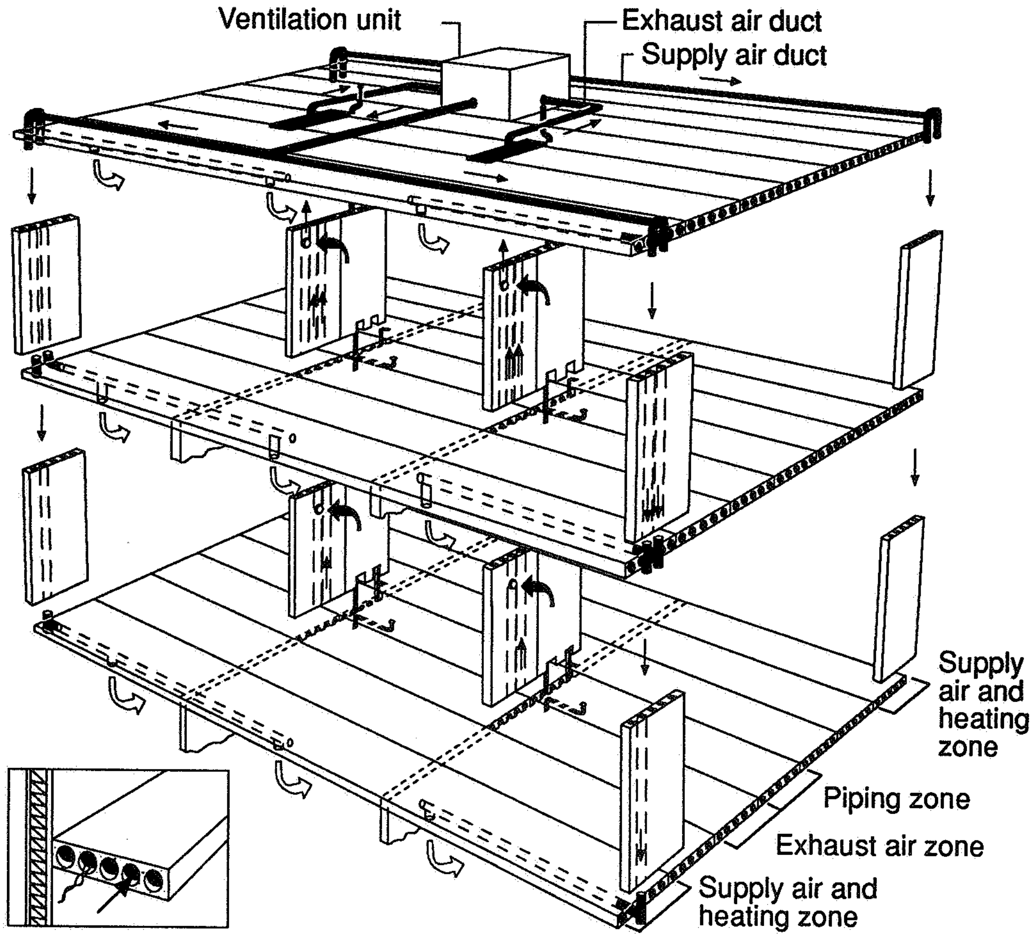

Figure 1. EBES integrated HVAC and building system.

DESCRIPTION OF THE EBES SYSTEM

- **Suitable methods for the distribution of air into the rooms.**
- **A self adjusting air duct system.**
- **Leading of supply and exhaust air into the hollow spaces of the concrete structures in the load-bearing floor and wall structures.**
- **Effective heat recovery.**
- **The use of the building mass as energy storage for cooling and heating.**
- **The installation of water and sewage pipes into the hollow spaces in the frame structures.**
- **The installations of the building's electrical equipment, wiring and accessories in the hollow spaces.**

2. HEATING SYSTEM

The basic heating system is an accumulating type of electrical heating. At night the heat is stored in the floor and ceiling structures by means of electrical heating cables. In the daytime the heat is transferred to the room spaces. The room temperature control is managed by means of a room-based ventilation heating system that incorporates on accurate electronic thermostat.

Combined radiation and warm air heating was found to be a suitable heating system with regard to the stability of the indoor temperature during heating breaks. Radiation heating feels pleasant even when the temperature drops a bit. During reheating, radiation heating is slow. With warm air heating the indoor temperature can rapidly be raised to the desired level if the design heating effect is sufficient. Although the temperature of the structures (Figure 2) may vary considerably, the room temperature is uniform.

When electricity is used as the heating energy, the heating effect of the building can be controlled according to the loading of the power plant without causing abrupt changes in the indoor temperature during heating breaks.

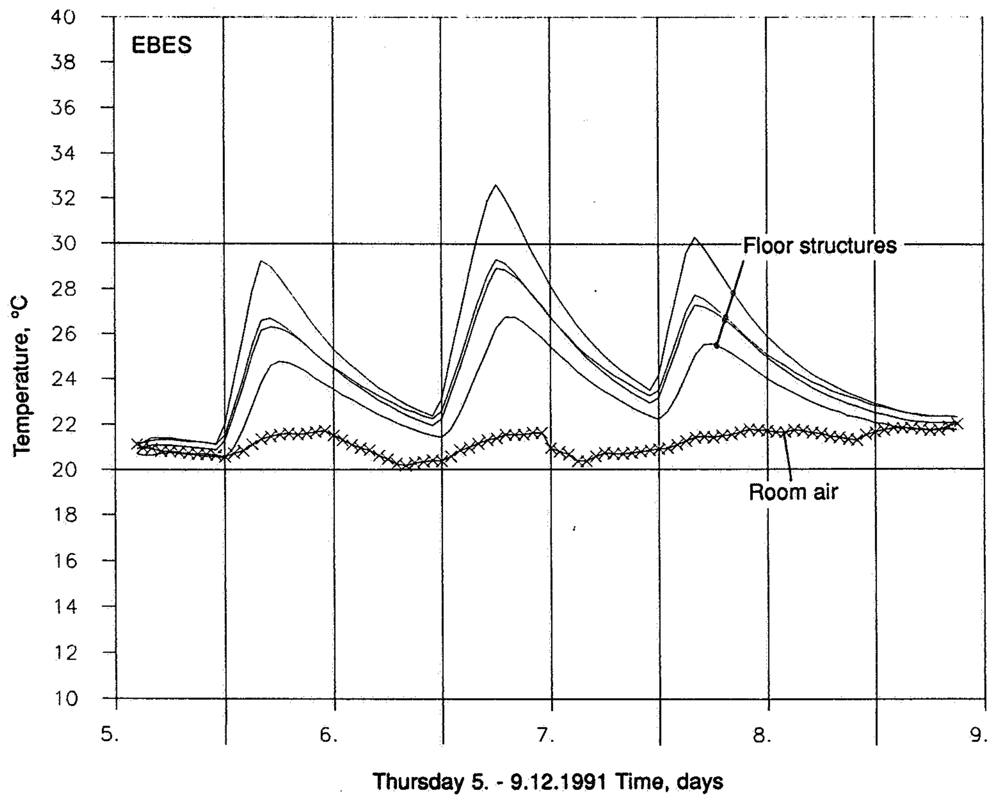

Figure 2. Measured temperatures of floor structures near the heating hollow during heating periods.

The supply air that is led into the hollow core slabs must be preheated to such a high temperature that the surface temperature of the hollow core slab is never below +10 °C. The measured temperatures of supply air in a vertical hollow space during the winter period are shown in Figure 3.

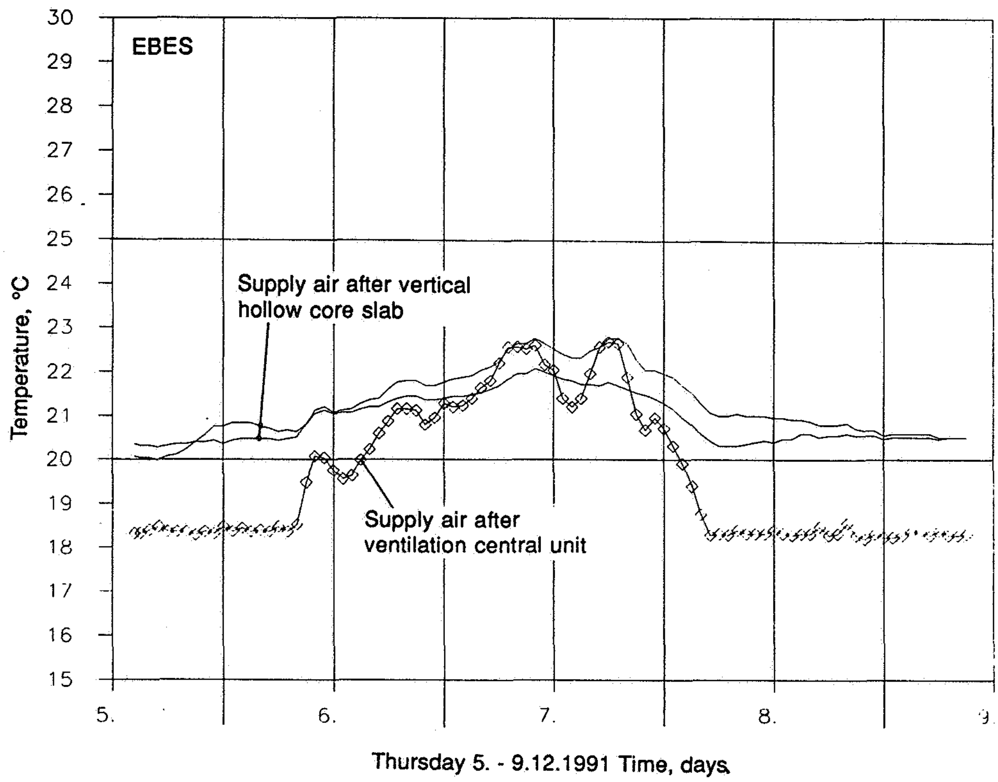

Figure 3. Measured temperatures of supply air after the ventilation central unit and after a vertical hollow (length 6 meters) on the 1st floor.

3. VENTILATION SYSTEM

The ventilation system is a mechanical supply and exhaust air system which embodies heat recovery, efficient filtering and preheating of the supply air. Hollow spaces of hollow core slabs are used as air ducts. Every flat has its own vertical supply and exhaust air hollow spaces. No air flow dampers and no adjusting and balancing of air flows are needed in the EBES system and cleaning of the hollow spaces is easy. Figure 4 shows how the ventilation central unit functions. Total air flows were practically constant.

In each flat the ventilation rates may increased in the kitchen and toilet.

The room-based air flows are preadjusted and measured to the desired values by means of silent and high-quality supply air devices. The resident can control the direction and length of the supply air to accomodate his furnishings so that there is no draught and noise.

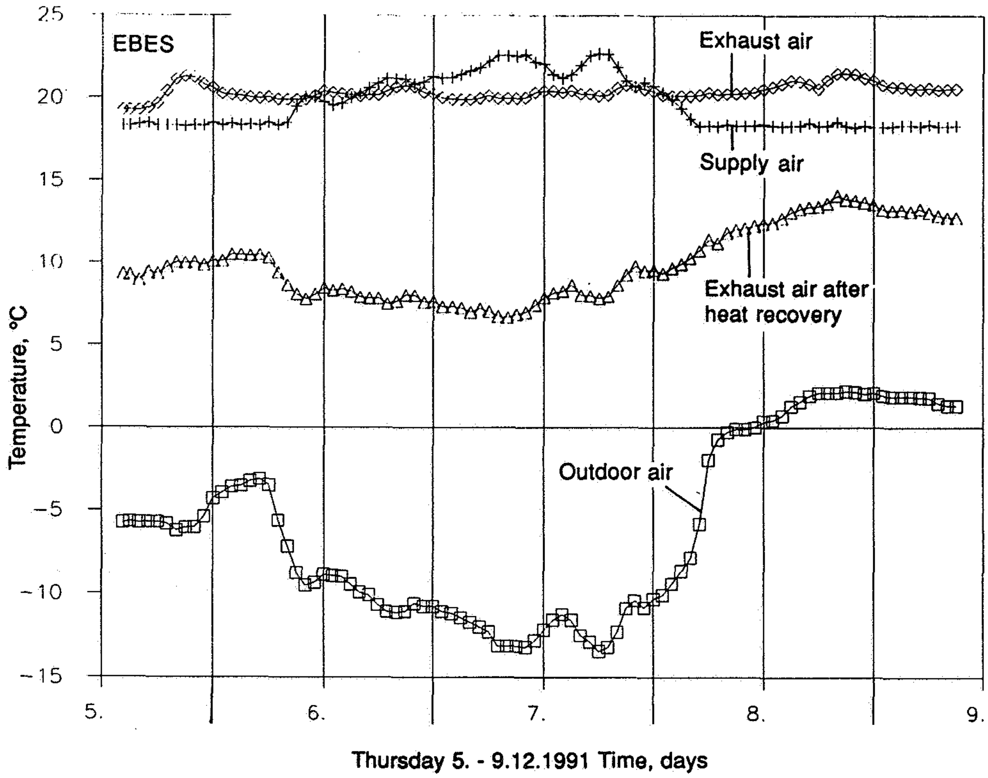

Figure 4. Measured temperatures of air flows in the ventilation central unit.

4. OBJECTIVE VALUES FOR INDOOR CLIMATE AND VENTILATION

The basis of both the heating and ventilation systems of an energy economic EBES block of flats is that the final goals of the indoor climate standard are clearly stated. In addition to thermal comfort and air quality, the noise of the equipment and the sound insulation of the structures must be taken into account.

For residents, the key flexibility requirements of the techniques of controlling the indoor climate in apartment buildings are /4/, /5/, /6/, /7/:

- an ideal and even temperature for each room
- silent demand-controlled ventilation that eliminates draughts
- the prevention of spreading of odours
- good sound insulation.

The objective values of the indoor climate of the EBES block of flats meet the recommended values in the compiled Finnish Building Code. The following values are higher: the indoor air temperature can be controlled to 21 ± 2 °C, the air change is 0.65 - 1.0 l/h and the highest permissible sound level is 25 - 30 dB(A).

5. TECHNICAL PROPERTIES OF THE EBES-BUILDINGS

The functional requirements of a mechanical supply and exhaust air ventilation system that provides sound attenuation and heat recovery - such as that used in the EBES block of flats - is that the outer building envelope (n_{50} < 0.5 1/h) and the floors (n_{50} < 0.1 dm^3/sm^2) in particular, are sufficiently airtight. At a test pressure of 200 Pa, the leakage air flow rate of the air ductwork may be a maximum of 0.1 dm^3/s per square meter of the envelope surface of the air ductwork. To avoid the disturbances that change the air flows in the ducts and are caused by the thermal forces due to the temperature difference between the outdoor and indoor air as well as by the wind, the static pressure of the duct work must be at least 100 Pa when the building does not have more than seven storeys. The mechanical supply air flow is about 80 % of the exhaust air flow. Air change is continuous.

Air ductwork according to the EBES system is simple to design and easy to adjust. Its features furthermore include technically stable air flow, sound control and the possibility of making changes in the air flows when the flow rates in the main ducts of sheet metal are a maximum of 4 m/s. The air flows in the mutual ducts (vertical hollows) are 3 m/s and those in the room ducts (vertical or horizontal hollows) are 2 m/s /2/, /3/.

MEASURED TECHNICAL PROPERTIES OF EBES BUILDING	
- **Leakage air flow rate of the building envelope (test pressure 50 Pa)**	**0.7 l/h**
- **Normal ventilation rates of the flats**	**0.77-0.87 l/h**
- **Temperature efficiency of the heat recovery**	**60 %**
- **Accuracy of the preadjusted air flows**	**5 %**
- **Leakage air flow rate of the air ductwork (test pressure 250 Pa)**	**1.0 dm^3/sm^2**
- **Average sound levels**	
bedrooms	**24 dB(A)**
living rooms	**21 dB(A)**
kitchens	**24 dB(A)**
normal ventilation	**24 dB(A)**
increased ventilation	**29 dB(A)**
toilet	
normal ventilation	**29 dB(A)**
increased ventilation	**35 dB(A)**
bathrooms	**31 dB(A)**
saunas	**28 dB(A)**
- **Sound insulation between flats**	**55-62 dB**

NEW PRODUCTS OF THE EBES SYSTEM
- Sound attenuated, draughtless and air heating supply air devices. - A silent cooker hood capable of effective vapour collection and able to increase the air flow. - An exhaust air device capable of increasing the air flow. - A new type of ventilation central unit equipped with heat recovery. - A connection piece system for the hollow spaces of the hollow core slabs that are used as air ducts. - A control technique for the room-based heating effects of the heat accumulating building frame.

The measured energy consumption of the EBES building is in Figure 5. Supply air heating energy is very small because the heat recovery is efficient (60 %). About 70 - 85 % of the electricity was low cost night electricity.

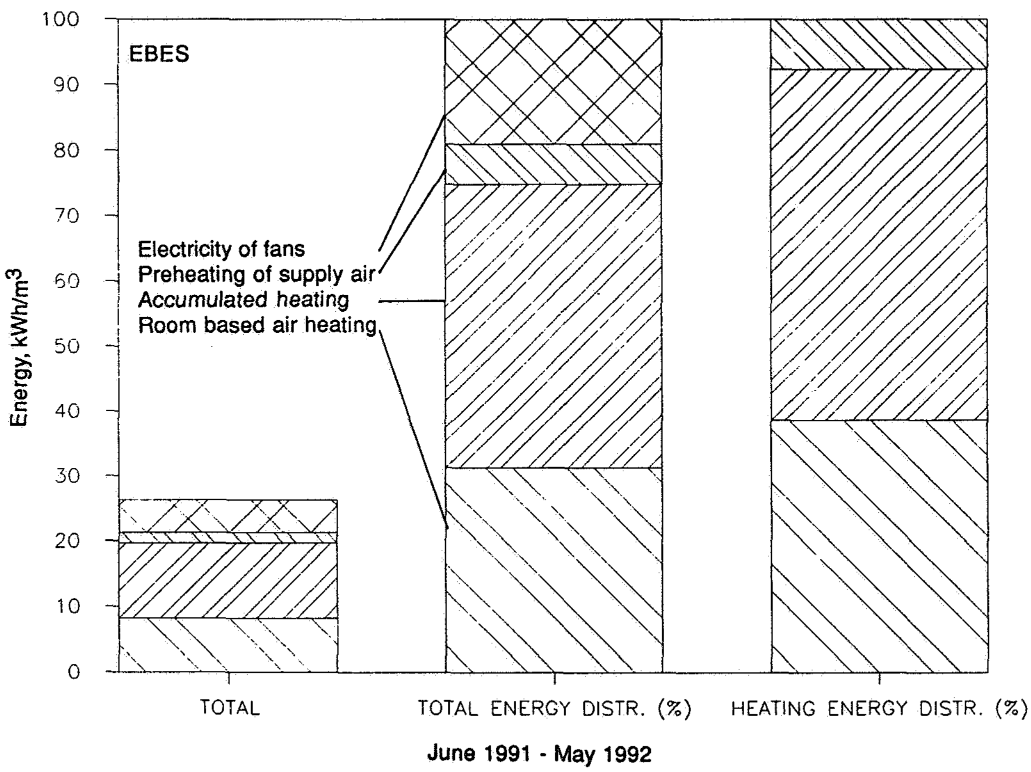

Figure 5. Energy consumption of the EBES building (1 year). Energy: kWh per building volume m^3. The mean outdoor temperature was 6.5 °C, which was 2 °C higher than the normal level in Helsinki.

6. CONCLUSIONS

The development of a heating, piping, ventilation, electrical and building system within the EBES research project has increased the possibilities of using an open EBES element building system to improve the standard of living and form a bases for the development of new integrated element building systems that offer all-round economy.

In the EBES building the residents were very satisfied with the thermal indoor climate, the freshness of the indoor air and the controlled ventilation. All technical systems functioned well. Thanks to heat recovery and the use of hollow core slabs, the energy consumption of the supply air heating was only 5 % of the total energy.

ACKNOWLEDGEMENTS

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