AIR INFILTRATION REDUCTION IN EXISTING BUILDINGS

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PAPER 10

CASE STUDY OF RETROFITTING A 14-STOREY OFFICE BUILDING IN OSLO

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1. SYNOPSIS

The purpose of an energy conservation project carried out in Norway 1979 - 82 was to demonstrate in practice how energy consumption may be reduced both significantly and cost-effectively in existing buildings. The project included 28 commercial and institutional buildings.

One of this buildings was a 14-storey office-block in Oslo, built in 1971. The main reduction in energy consumption in the building was achieved by thightening air leaks between concrete wall elements and windows. The thightening was done by applying sealing compound in two critical type of joints in the facades.

The energy consumption has been measured one year before and after the retrofitting. Thermography was used to find the air leaks and to verify the tightening afterwards. In addition pressure tests were carried out by using the buildings ventilation system, in order to obtain an estimate of the total infiltration. The leakage at 50 Pa was reduced from about 6,3 ach to about 3,0 ach.

The retrofitting including some changes in the ventilation systems and running time resulted in a reduction in the energy consumption with 705.500 kWh/year or 95 kWh/m^2 year. The payback period (including all project costs) was 1,2 years.

2. THE MAIN PROJECT

This energy conservation project was a co-operation project between research organisations, HVAC-contractors and -consultans and building owners. The purpose was to demonstrate in practice how energy consumption may be reduced both significantly and cost-effectively in existing commercial and institutional buildings.

The project was co-ordinated by NVEF (the Norwegian assosiation for HVAC-contractors and -producers) and included 28 buildings spread all over Norway. Each building got a project team consisting of HVAC-contractor, -consultant, -control contractor and -user. The Norwegian Building Research Institute assisted the project teams with measurements and computer calculations.

The project was carried out in 1979-82. In this period the project teams suggested a total of 327 energy saving measures with less than 3,5 years payback period. Because some building owners did not manage to finance all suggested measures only 170 measures were carried out in the project period. This reduced the energy consumption in 27 of the buildings with 12,5 mill kWh/year = 74,4 kWh/m^2, year which corresponds to 23% reduction.

The project is documented in a main report and a short version report[1] in Norwegian covering all 28 buildings.

2.1 The building in this case study

Construction. 14 storeys, tot. floor area = 7400 m^2.
Tot. heated volume = 24.200 m^3 = 1729 m^3/storey.
Concrete wall-elements of sandwich-type.
Concrete floors and columns. Double glazed windows. Built in 1971.

Heating. All electric. Electric room units (induction units) under all windows. Outdoor design temperature = -20 ^{0}C.

Ventilation. 2 main systems with rotary heat exchangers, 70% efficiency. Electric main batteries. Separate system for floor no. 14 with recirculating air at night. Induction units under all windows, diffusers in inner zones. Ectraction = control valves in all rooms.

Fig. 1. The case building. Herslebs gate 19, Oslo

3. RETROFITTING MEASURES

3.1 Reducing air infiltration

The first site visit revealed high air infiltration rates through slots between the wall elements. This was later documented with thermography and pressure tests. Because of the infiltration it was impossible to keep the rooms sufficient warm in the winter time with the electric room units. Therefore the ventilation had to run all night at outdoor temperatures below 0°C. Even with rotary heat exchangers this costed a lot of energy for heating the supply air.

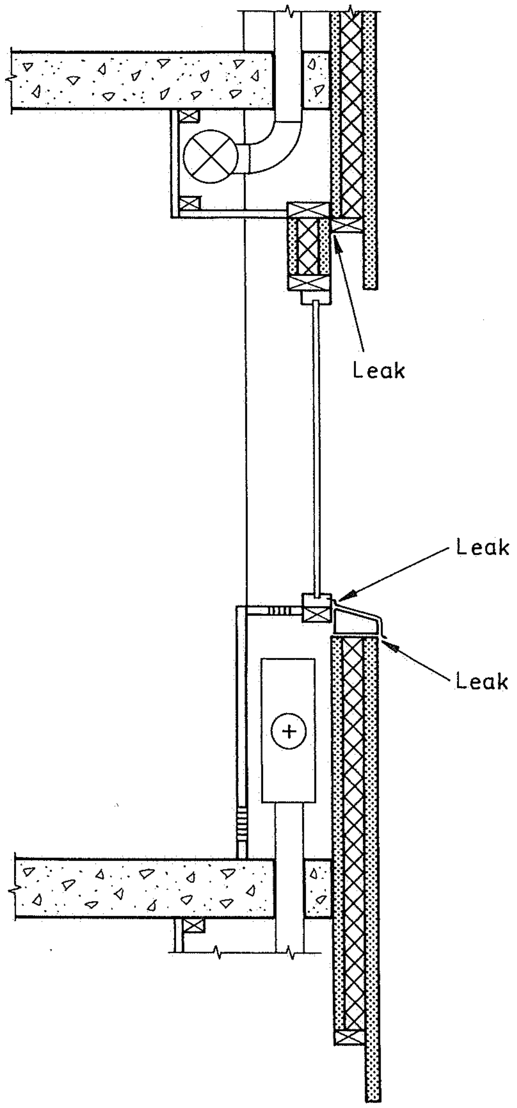

Fig. 2
Wall construction and leak points

The two leak points (slots) under all windows was tightened by applying sealing compound from inside. Easy access was made by removing the front panels of the induction units.

The leak point over the windows was very difficult to reach and was therefore left untightend.

The cost for the tightening including removing and replacing of front panels was kr. 85.000,- for the whole building.

After the tightening the indoor temperature was over 20 °C all the winter with the ventilation turned off in the nights and weekends.

The reduction in infiltration and ventilation energy was approximately 340.000 kWh/year.

3.2 Other measures

Humidification stopped. Before the project started the humidifiers in the ventilation systems was set to give 60% R.H. The measure was here simply to turn the humidifiers completely off without telling the office workers. This saved approximately 200.000 kWh/year without any costs and with very few complains. Because of hygroscopic heat exchangers the humidity never got under 30% R.H.

Rebuilding top floor ventilation systems, recirculation. The top floor contained canteen, kitchen and meeting room with separate ventilation systems for outdoor air only without heat exchangers. These systems was running all the time. The measure here was: Rebuilding one of the systems to allow recirculation in nights and week-ends controlled by a time switch. The two other systems was simply turned off when not in use by mounting time switches. These measures costed kr. 16.400,- and saved approximately 165.500 kWh/year.

3.3 Payback time

The total energy reduction was 705.500 kWh/year corresponding to 28,6% reduction. The measured energy consumption for heating and ventilation the second heating season is here corrected to the same outdoor temperature-time as the first heating season.

With a price for electric energy of kr. 0,21/kWh (1980) this gives a net payback time of 0,7 years. Including project costs the payback time is 1,2 years.

4. AIR INFILTRATION ENERGY LOSS

The yearly energy consumption for ventilation and heating was measured together. Lack of information of running time for the ventilation makes it difficult to separate the different heat losses. Measuring the building leakage at 50 Pa before and after tightening allows however an approximate calculation of the infiltration loss. This was done with the computer program ENCORE[2], together with the cauculation of the transmission loss.

4.1 Measured pressure difference inside/outside

The measurements of pressure distribution was done in connection with the thermography before and after retrofitting, see fig. 3.

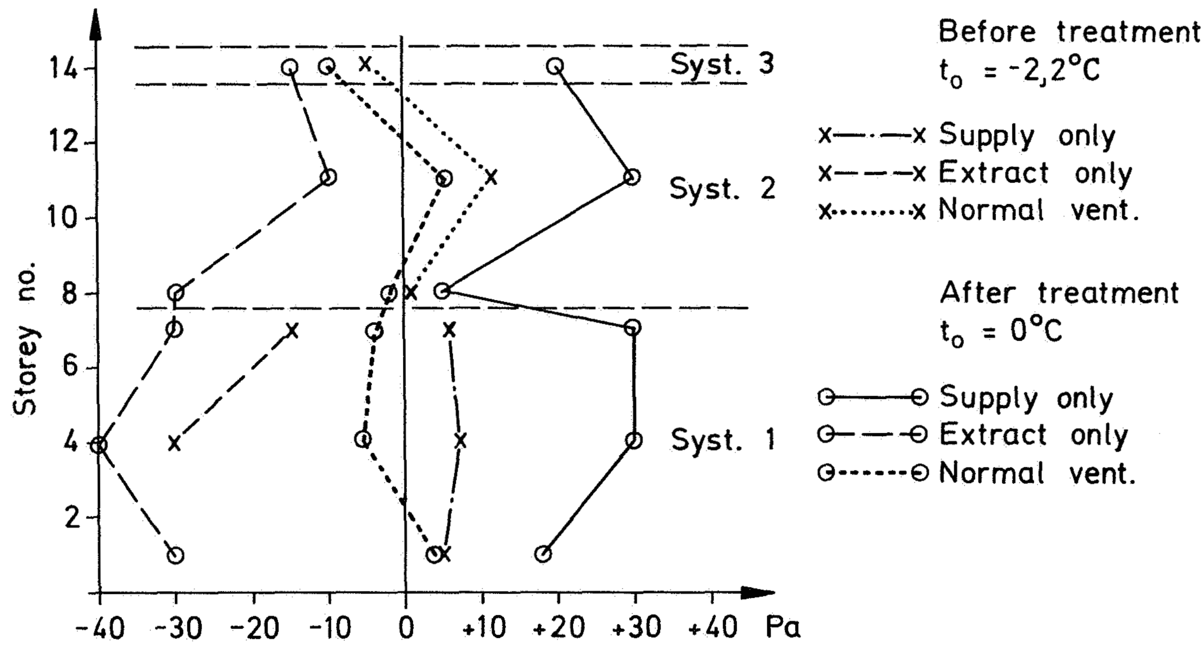

Fig. 3. Pressure distribution, inside/outside

4.2 Measured air flow

Syst. 1:	Supply, normal and extract fan stopped	=	25.900 m^3/h
	Supply, only extract fan running	=	800 "
	Extract, normal	=	28.200 "
Syst. 2:	Supply, normal	=	24.300 "
	Supply, only extract fan running	=	1.200 "
	Extract, normal	=	22.500 "
	Extract, only supply fan running	=	200 "
Syst. 3:	Supply and extract, design values	=	11.400 "

The air flow was measured the same day as the pressure distribution after treatment was measured. Method: Ducttraversing with calibrated hotwireanemometer, type TSI 1650, according to Nordic guidelines[3].

The air flow before treatment was measured by the project team in March 1979. These measurements correspond within ± 10% to our measurements in Dec. 1980.

4.3 Calculation of building tightness

Measurements of pressure differences inside/outside were carried out only as a control for the thermography and are therefore complete only in 4. - 7. storey. Using this data and measured air flow in system 1 it is possible to calculate approximate values of building tightness before and after treatment.
The formula used has been tested by Railio[4].

$$n_{50} = n_m \left(\frac{50\ Pa}{\Delta p_m}\right)^{0,7}$$

1. Before treatment:

   a) Supply - extract (fan stopped) = 25.900-800 = 25.100 m^3/h

   Air changes: n_m = 25.100/ (7 • 1729) = 2,07 h^{-1}

   Measured over-pressure = (7 + 6)/2 = 6,5 Pa

   Air changes at 50 P_a: n_{50} = 2,07 $(50/6,5)^{0,7}$ = 8,63 h^{-1}

   b) Extract - supply (fan stopped) = 28.000 m^3/h (approx.)

   Air changes: n_m = 28.000 (7 • 1729) = 2,31 h^{-1}

   Measured under-pressure = (30 + 15)/2 = 22,5 Pa

   Air changes at 50 Pa: n_{50} = 2,31 $(50/22,5)^{0,7}$ = 4,04 h^{-1}

   c) Mean leakage number: n_{50} = (8,63 + 4,04)/2 = 6,3 h^{-1}

2. After treatment:

   a) Measured over-pressure = (30 + 30)/2 = 30 Pa

   n_{50} = 2,07 $(50/30)^{0,7}$ = 2,96 h^{-1}

   b) Measured under-pressure = (40 + 30)/2 = 35 Pa

   n_{50} = 2,31 $(50/35)^{0,7}$ = 2,97 h^{-1}

   c) Mean leakage number: n_{50} = 3,0 h^{-1}

4.4 Energy consumption separated on the users

All the measured and calculated energy consumption for different use together with the measured (temperature-corrected) total comsumption before and after retrofitting is shown in fig. 4.

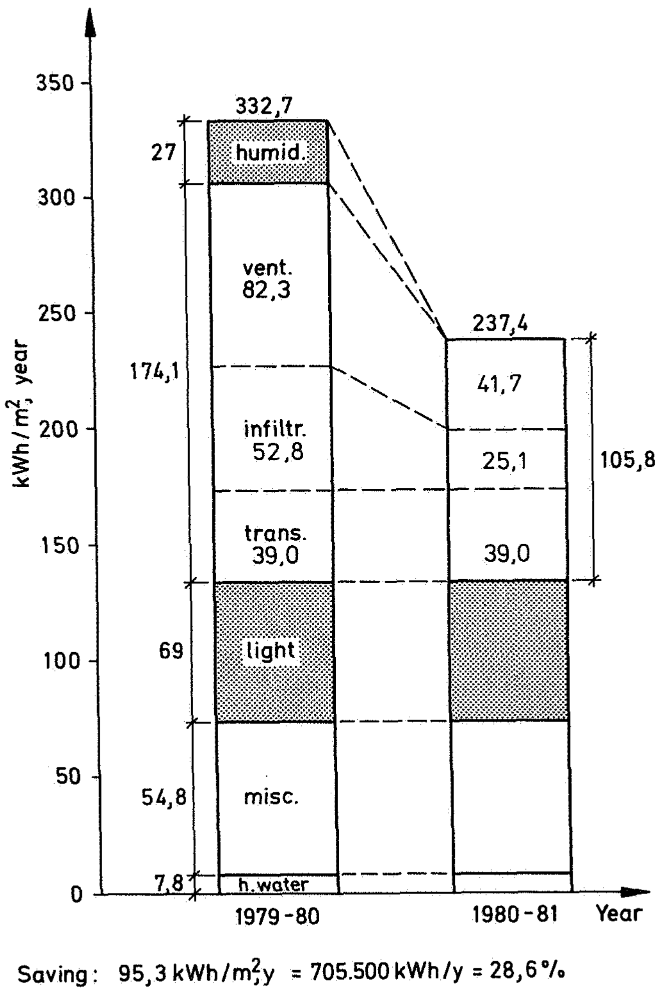

Fig. 4. Energy consumption before and after retrofitting

5. ACKNOWLEDGEMENT

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6. REFERENCES

1. Norwegian Ventilation and Energy technical Association, (NVEF) "Energy savings in 28 commercial buildings" (Energisparing i 28 yrkesbygg), NVEF, Oslo 1982, 160 p.

2. LARSEN, B.T. "The Computer program ENCORE, Part 1, User's Manual." Norwegian Building Research Institute. 1977.

3. SVENSSON, A. The Nordic Ventilation Group, "Methods for measurement of airflow rates in ventilation systems". Bulletin M83:11, The National Swedish Institute for Building Research, 1983, 100 p.

4. RAILIO, J. VTT, Finland. "Measurement of the tightness of a building with its own ventilation system." LVI-3-1982, pp 33-35.