ENERGY EFFICIENCY IN BUILDINGS AFTER RENOVATION

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Keywords: energy saving actions, dwellings, indoor climate, renovation

Summary

This study focuses on the importance to reduce the energy consumption when buildings are renovated, in order to decrease the environmental impacts. Many dwellings in Sweden were built between 1965 and 1974. These buildings have high energy consumption, and when renovating them it is important that the actions taken result in buildings with both low energy consumption and a good indoor climate. It is also important that all parts involved in the building process are aware of the close relationship between the use of energy in buildings and the indoor climate. The aim of this paper is to describe the actions taken in order to save energy when some buildings from this time period were renovated, and how these actions taken have influenced the indoor climate. The buildings have been investigated both before and after the renovation. The actions taken at the renovation have been evaluated in order to find out if the actions taken were the right ones. Through this renovation the use of energy have decreased with 18.5 %.

1. Introduction

A big part of the existing buildings in Sweden are built during a ten-year period between 1965 and 1974 within the so called Million Programme. Many of these buildings will be renovated in the near future. During this period there were no requirements on low energy consumption in buildings. Oil was the most common fuel used for heating, and was up until the 1970´s inexpensive. Not until 1973, when the oil prices started to go op, did the regulations change in this regard. In order to fulfil the current demands on energy savings, it is necessary to change existing buildings. When renovated the buildings must be adapted to the level of energy consumption of new buildings. Damages and defects in the building envelope have to be investigated during renovation in order to get energy efficient buildings.

Common problems in the building envelope are:

- high transmission of heat through walls and ceilings
- high transmission of heat through the windows
- air leakage

Air leakage through the building envelope influences the energy use of the building. Draught will occur and to compensate for this, the indoor temperature is usually increased. Air leakage can also lead to that parts of the building envelope become cooler, which will be compensated for by increasing the indoor temperature. As a consequence, the heat flow through the wall increases and the ventilation loss will increase.

It is very important that the actions taken result in buildings with both low energy consumption and a good indoor climate. All the actors involved in the renovation process must be aware of how energy saving actions influences the indoor climate in order to find the right solution that will lead to both low energy consumption and a good indoor climate. Experiences from good solutions must be transferred to future building projects as well as from bad ones so that they can be avoided.

There are many examples of how energy savings can be made in a way that leads to an inferior indoor environment. By lowering the air exchange in the ventilation system, energy will be saved, but the indoor air quality may decrease. To air tighten the building without improving the ventilation may also lead to impaired indoor air quality. If a supplementary insulation of the walls not includes all outer walls, the result may be that the indoor climate will not be satisfactory. Some walls may have a lower surface temperature than the other walls which may result in a feeling of draught.

When looking at the indoor climate it is important to have the human body in mind and how people perceive the indoor climate. The temperature to be used is the operative temperature, which is the temperature that people perceive. This temperature is calculated as the mean of the air temperature and the radiant temperature from surrounding surfaces. There are some factors that influence the perceived temperature:

- cold downdraught: when the air in contact with a cooler surface such as a window or an outer wall is cooled and becomes heavier and sinks downwards.
- leakage
- ventilation
- radiation draughts

Complains about draughts are one of the most common one regarding air comfort. Boverket (2000). A human body loses most of its heat indoor through radiation to the surrounding area (37%), and directly to the indoor air (32%). Fanger (1972). This means that the surface temperature and the air velocity are important factors influencing the perception of a comfortable indoor temperature. Even a small air velocity will increase the heat loss from the body and cold downdraught will be perceived as draughts near the floor.

When buildings are heated with a district heating system the measuring of the energy use is often made for one or two buildings, and not for each apartment separated. It is therefore important to study both the change in energy consumption and also the change in the indoor climate in different apartments after a renovation. This is no easily to found out from the measured values.

The importance to look at both the results of energy saving actions and also to evaluate the indoor climate is shown in a study about energy consumption in new buildings in Malmö, Sweden. For these dwellings a limit of 105 kWh per m^2 gross room area annually has been set for the average energy use. The results show that the houses have not met this energy limit, and it is the energy consumption for heating that has been too high. The consumption has been 186 kWh per m^2 gross room area annually for houses without heat recovery, and with heat recovery 127 kWh per gross room area annually. The results from this evaluation pointed out how important it is that all actors in the building sector know how to design and construct for energy efficiency and gives priority to this issue. To get this knowledge it is necessary to follow up the energy consumption and to evaluate the indoor climate. Nilsson (2003)

Another example is six energy efficient buildings built during the period 1982 to 1987 in Stockholm. The aim of this project was to find out how different technical solutions in buildings and installations could lower the energy consumption of the building. Elmroth (1989). The evaluation shows that all technical details of a building must be designed with great care in order to achieve low energy use.

Because the big amount of old buildings from the Million Programme, it is important to evaluate the consequences of the actions taken to reduce the energy use on the indoor climate when renovation, so that the benefits can be transferred to future project and to avoid drawbacks. This paper describes an initial study regarding energy saving actions during renovation of buildings. The aim of the study was to describe the actions taken and how these influence the energy consumption and the indoor climate.

2. Method

The actions taken during renovation of 441 dwellings built between 1966 and 1970 in Halmstad, Sweden have been studied. The actual block consists of 12 buildings.

The complete study consists of two parts. The first part is an initial study, which describes the renovation of 10 buildings where the purpose was to lower the energy consumption and to renew the exterior of the buildings. The renovation have been analysed to find out if the right actions have been taken with regards to the energy consumption and the indoor climate. This has been done by comparing the measured energy consumption before and after renovation and by measuring the indoor temperatures after renovation. This paper presents the initial study. In the second part the two remaining buildings will be renovated at a larger scale, with more severe requirements on energy consumption and on indoor climate. The results from the initial study will be used in the second part, both in the planning and the design phase.

In the initial study the following measurements were made:

- energy consumption before and after renovation
- indoor temperature after renovation
- operative temperature after renovation
- floor temperature after renovation

3. Description of the renovation

The buildings have 4 storeys and inset balconies. The ventilation system is natural ventilation and since the beginning of 1990 the buildings are heated with district heating.

These buildings had before the renovation a high energy use, 200 kWh per m^2 residential floor area annually. The average energy uses in other old buildings are 180 kWh per m^2 residential floor area annually. The real estate company has in their environment policy stated the importance to aim at low energy consumption and a good indoor climate in all buildings. One of their environmental goals is to lower the energy use in all old buildings by 10% of the energy use in 2001 until the year 2010. Another goal is that the indoor temperature should be 21°C in all apartments.

The real estate company prepared a special programme with the environmental goals for the renovation of the 10 buildings for the design consultants. The programme has no specified limits for energy consumption or any specified demands on the indoor climate. There is just a short text stating that the buildings must have low energy consumption and that the indoor climate must be comfortable.

3.1 Description of the building before renovation

The foundations of the buildings consist of slabs on the ground without any insulation below. The load-bearing structure is made of in situ concrete. The external walls in the ground storey are made up of 250 mm concrete with a 50 mm wood wool slab on the inside of the wall. The external walls on the rest of the house consist of 250 mm light weight concrete, a ventilated air space and sheets of asbestos. A the inset balconies the external walls consist of a 95 mm thick wooden framework with 95 mm mineral wool and double-glazed windows. The inside of the walls are covered with 13 mm plaster board and a vapour barrier, and the outside with impregnated fibreboard, a ventilated air space and sheets of asbestos. The balcony slabs are separated from the concrete floor by of 30 mm insulation, (cellular plastic). The roof slab is of concrete with 150 mm mineral wool on the top. The windows at the façade are also double-glazed.

Figure 1 Façade before renovation

3.2 Description of the building after renovation

The actions taken at renovation are:

- 250 mm supplementary loose wool insulation on roof slab
- the sheets of asbestos have been replaced with 50 mm insulation (mineral wool) and 108 mm brick wall
- the windows in the façade have been replaced by triple-glazed windows
- adjustment of the heating system

- sealing of balcony doors
- new inlet are placed over the window at the insert balcony

Figure 2 Façade after renovation

4. Results of the measurements

The results of the action taken have lowered the U-value of the outer walls and the roof, see table 1 below.

Table 1 U-value before and after renovation

Part of the building	U-value before renovation, W/m^2°C	U-value after renovation, W/m^2°C
Roof	0.23	0.12
Outer wall	0.49	0.28
Window in the facade	3.0	1.4

Through the actions taken at renovation the energy consumption decreased from 200 kWh per m^2 residential floor area annually to 163 kWh per m^2 residential floor area annually.

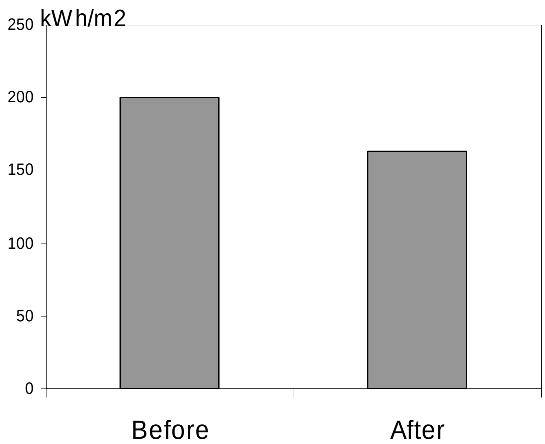

Figure 3 The energy use before and after the renovation

No actions were taken to neither the external wall nor the windows at the insert balcony. Thus, this part of the building still has high U-values.

When analysing the indoor climate it is of interest to look at both those parts where actions have been taken and those parts where nothing was changed. The part of the building that is of special interest is the walls and the windows at the inset balcony. At this part the walls still have a U-value of 0.46 w/ ^{2}°C and the windows U=2.7 w/ ^{2}°C.

Measurements have been made of the indoor temperature close to this part of the building. The temperature was measured 1 meter from the balcony door at four different levels on a vertical line above the floor at 0.1 m, 0.6 m, 1.1 m and 1.8 m height. The temperature on the floor and the operative temperature 0.6 m above the floor were also measured. The outdoor temperature was +2 °C when the measurements were made. The results of the measurements are shown in table 2.

Table 2 Measured indoor temperatures after renovation

Measurement points	Temperature after renovation °C
Air +0.1 m	21.7
Air +0.6 m	22.3
Air +1.1 m	22.6
Air +1.8 m	23.0
Floor	22.0
Operative temp. +0.6m	23.1

The indoor temperature has also been measured during a period of 2.5 weeks in the same apartment, and these measurements gave a temperature of 22 °C with small fluctuations.

5. Conclusions

The results from the initial study:

- The energy consumption was decreased with 18.5%, and the energy goal set by the real estate company has been fulfilled for these apartments.
- The indoor temperature, the operative temperature and floor temperature close to the balconies have acceptable values even thought no actions on these parts of the walls were taken. They are protected behind the balcony.
- By using supplementary insulation on the façade the walls have become more airtight, and the air leakage has been lowered and the energy consumption has decreased. The walls made of blocks of lightweight concrete had before the renovation some settlement cracks.
- It is important that measurable values on the energy consumption and on the indoor temperature are given in the construction documents, so that all partners in the building process will aim at low energy consumption and comfortable indoor climate. And it is also important to evaluate the outcome of the actions taken at renovation.
- It is important to aim at a good indoor climate in the planning and design phase even at renovation.
- It is important to have the knowledge about the close relationship between the use of energy in buildings and the indoor climate.

6. Further research

The results from this first part will be used in the renovation of the two remaining buildings in the block. The results will be used in the planning and design phase. A deeper evaluation of the indoor climate in the buildings subjected to at the first renovation will be carried out, which involves the use of questionnaires to the tenants.

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