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THE APPLICATION OF BUILDING METHODS FOR SAVING ENERGY IN EXISTING BUILDINGS

THE INDUSTRIAL GROUP FOR
LIGHT CONSTRUCTION ENGINEERING

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INTRODUCTION

Increased energy costs, doubts about the future and imminent oil crises, Government Paper 1977/78:76 reference energy saving loans for existing buildings etc., challenge us to reduce energy consumption in existing buildings. This can be effected by different energy saving methods, e.g. changing patterns of living and savings brought about by improvements in installations and building technology.

In producing this publication, the Industrial Group for Light Construction Engineering illustrates the measures which can be carried out on structural elements in order to save energy. The publication describes different methods and states advantages and disadvantages as well as suitable combinations of measures. Stress has been placed on the measures which are easiest to carry out and consequently which are usually the most economical. However, the economics of different measures should be investigated for each individual case. The publication shows how this should be approached.

It is not the purpose of this publication to describe working instructions for different types of technical measures since it is only intended as a review of current methods. The measures suggested comply in certain cases with current requirements and regulations, for example those in accordance with Swedish Building Regulations - 75 (1).* The reader is referred to the appropriate material manufacturers for detailed instructions. Furthermore, there is a vast amount of literature on different energy saving measures, for example, "Trim, seal, insulate" (2) published by Bygginfo and "Save energy - check your house" (3) by Kjell Andersson.

Among the advantages provided by technical energy saving measures, as opposed to other energy saving measures, is that many have a long service life and require very little maintenance. Furthermore, they produce positive side effects in the way of reduced draughts, warm external walls, etc., which improve the living environment. Changes in facade material and the design of windows can, in combination with carefully selected products, contribute to an improved environment.

This publication discusses only technical measures. From an energy savings point of view, it is however important that these be combined with improvements in building services.

Technical measures should be followed up by an adjustment of the heating system and a reduction in temperature. Otherwise there is a risk that the measures carried out can lead to an increase in temperature and a loss of the intended energy savings.

* The figures within brackets refer to the reference.

1. WINDOWS AND DOORS

1.1 General description of technical measures

Windows and doors (entrance doors, porches, etc.) are energy-sensitive parts of a building. Energy losses are caused by gaps and low thermal resistances of structural elements.

Gaps occur primarily between stiles and frames/door panels. These gaps are easily eliminated by adjusting the opening operation and closing fittings and by fitting new weatherstripping. Weatherstripping is available in many different materials and designs. According to investigations carried out at the Royal University of Technology, Stockholm (4) and Chalmers University of Technology, Gothenburg (5), weatherstripping manufactured from silicone or EPDM-rubber is to be preferred to stripping manufactured from PVC-plastic. Stripping made of textile material, foam, plastic, etc. has an inferior resistance to ageing, does not seal particularly well and should therefore be avoided. Tubular strips provide the best seal. V-strips are preferred for doors since they normally require a lower closing pressure.

In the case of double-glazed windows, where the two layers of glass can be separated and where large gaps between the frames occur, energy savings can be made by fitting a diffusive dust-sealing strip between the frames. The strip reduces the cooling effect of cold air circulation between the frames.

Gaps between frames and walls are best rectified in conjunction with internal or facade renovation since there is a risk that damage can occur around the joint when this is treated. The design of the joint is very important to the result. According to an investigation carried out by the Swedish Forestry Products Research Institute (6), the best material is polyurethane foam or packing strips supplemented with an internal joint seal or jointing compound, a rubber tube or a plastic-coated internal packing strip.

Several measures can be employed to improve a window's thermal resistance. Venetian blinds, thermal insulating window shades, etc. are measures which function well, but whose efficiency is very dependent on how they are managed by the occupant. A certain energy saving can be achieved by applying solar reflective film to the glass or by using sealed panes filled with special thermal insulation gases and by covering the glass with a thin film of heat-reflecting metal. These however affect the transmission of light into the room and have an unknown service life. In certain buildings with a large glazed area, display windows, roof lights, etc., a suitable solution may be to refit them and add additional glazing to certain areas of glass. The commonest solution is however to supplement the glazing or to replace the existing windows with double or triple glazing with better thermal resistance.

1.2 Advantages and disadvantages of different measures

1.2.1 Tightness

The perviousness of windows and doors which causes adventitious ventilation in a building creates both energy losses through unnecessary heat leakage and draughts. Such draughts must be compensated for by higher room temperatures which demand more energy. Draughty windows and doors also diminish the acoustic insulation properties of the facade.

However, buildings must not be made too tight and, in the case of flats, a minimum ventilation rate of 0.5 air changes per hour is required. In buildings with both exhaust and supply ventilation there is little risk that sealing windows and doors will make the house too tight. In houses with heat exchanger systems, the natural ventilation must be low for the system to function. In houses with natural ventilation or exhaust air ventilation, windows and doors often function as supply air devices. In such cases, sealing measures must be carried out with a certain amount of caution and a break may be necessary in the sealing strips, or the use of pervious sealing strips (for example, textile strips) may be necessary in order to provide the necessary supply air.

The energy savings which can be achieved through sealing measures depend to a great extent on the perviousness of the building. Investigations carried out at the University of Technology, Lund (7) indicate that existing windows are often very pervious. Sealing measures on windows and doors between stiles and frames/door panels are however considered the most worthwhile technical measures available for saving energy. If sealing strips of good quality are used, the service life of such measures is currently estimated to be approximately 10 years.

1.2.2 Improving thermal resistance

The thermal resistance of windows and doors is low compared with that of external walls for example. For this reason there is often a greater energy saving/m^2 through supplementary insulation of window areas than of wall surfaces. By changing from double to triple glazing, the thermal transmission (k-value) is improved by approximately 1.0 W/m$^{2\,o}$C. Improved thermal resistance also raises the temperature of the inner surface of the glass and thus reduces cold radiation from the window. This increases comfort conditions, particularly in rooms with large glazed areas and allows the temperature to be reduced without discomfort. The acoustic insulation of the window is also improved and, in certain cases, the tightness as well.

A disadvantage of triple glazing is that the existing window frame construction is subjected to greater loads. The number of window surfaces to be cleaned can also be greater and problems associated with condensation on the surface of glass can arise if fitting is carried out incorrectly. The use of sealed panels increases costs since glass must be changed. By changing from double to triple glazing.

the light transmission through the window is reduced and the amount of solar gain in the building is reduced by approximately 10%.

1.3 Existing building stock

1.3.1 Tightness between stiles and frames/door panels

Older sealing strips in windows and doors are often in very bad condition and incorrectly fitted. The textile strips and pervious foam plastic strips used to date quite often have very inferior sealing qualities and age resistance (4). Often the strips have been painted over and have therefore lost their sealing properties. Such sealing strips on windows and doors should be replaced. Stiles and door panels are often twisted so that windows and doors can only be opened and closed with difficulty. Furthermore, closing devices must be adjusted so that the window and door can be opened and closed easily.

1.3.2 Tightness between stiles and walls

Joints between windows/door stiles and walls are often pervious. Cracks may have arisen through settling or by the frames having shrunk. There may be inferior packing in the joint between the stile and the wall. Elastomeric jointing compound is often used from the outside to seal the joint. In this context there is the risk of moisture on the inside being trapped in the joint causing rot in wooden stiles and adjacent walls.

1.3.3 Windows

The existing window stock is primarily double glazed in wooden frames. Single glazing is usually evident in shop windows and in a number of windows in industrial buildings. Triple glazing with jointed frames is found in a number of buildings from the 1950's. Triple glazing, comprising either a triple glazed insulation frame or a single glazed frame + a double glazed insulation window,is now beginning to be used more and more as a result of modern requirements for energy management (1).

Houses built before 1920 often have un-jointed double glazed wooden framed windows with cross beading. The inner frame is either removable or mounted on a hinge. These windows are usually of good quality but unfortunately are often replaced with modern integral triple glazing in conjunction with building renovation. In houses built after 1930, double glazing is used almost exclusively. Stile and frame profiles were normally in accordance with SIS standards.

Lately, rot has been discovered in wooden windows, particularly those from the 1960's and later. This has meant that many windows have had to be changed, sometimes after only 5-10 years of use. The reasons for damage are many but the parts which are often damaged by rot are stiles and bottom rails. In certain cases such damage has also led to consequent damage to underlying breast work. Damage to the bottom frame is often a result of inferior painting of the glazing joint and that inferior putty has been used. Water has been able to penetrate between the glass and the putty down to the joint and has therefore caused rot damage. The joint between the bottom frame and the side frame is, to a great extent, untreated end-grain timber. As a result of movement in the joint, moisture can penetrate and cause rot. A permeable paint on window timbers on the inside allows the transmission of room moisture through to the cold side. This can give rise to moisture accumulation underneath the layer of paint on the outside if this is tighter than the layer of paint on the inside as a result of several layers of re-painting. Consequently, the moisture causes cracks and the paint flakes creating the right conditions for rot to start.

1.4 Technical solutions

1.4.1 Tightness between stiles and frames/door panels

Gaps between stiles and frames/door panels can often be detected by inspecting the opening and closing action and sealing strips. Gaps can also be detected by using a candle, smoke gun or by applying thermography. This is facilitated if the room is subjected to negative pressure by starting the cooker extractor for example.

Resealing of windows and doors should include the following steps:

a Inspect the windows/door. Do they require repainting or the putty replacing?

b Check that the frame/door can be closed and opened easily and adjust where necessary.

c Check that the closing mechanism and the hinges function and adjust and lubricate where necessary.

d Check that the air gap between the frames of all double windows/doors has not been rendered ineffective as a result of repainting etc. A gap of 1-2 mm is required. If the gap between the frames is greater than 2 mm, a diffusive dust-tight strip can be fitted in order to reduce the air circulation between the layers of glazing thereby achieving a certain savings in energy.

e Always paint exposed wood surfaces (surfaces which lack primer, glazing paint, etc.) before re-applying putty and fitting weatherstripping.

f Select suitable strip dimensions bearing in mind the width of the gap between the frame/door panel and stile. The size of the gap when the window/door is closed can be measured by using plasticine pressed onto a few places on the glazing rebate.

g Select the weatherstripping. When selecting strip for use between the stile and the frame/door panel, the gap width measured in f) must be considered. When selecting sealing strips, textile strips, foam plastic strips (pervious) and cellular strips (impervious) must be avoided. Even strips of PVC-plastic are less suitable. According to tests carried out at KTH (4), strips of silicone rubber and EPDM-rubber have exhibited the best sealing and ageing properties.

Tubular strips provide the best seal but angle strips are also effective. Angle strips are recommended for doors where a low closing pressure is required.

h The way in which sealing strips are fitted is important for their correct function. Special attention should be paid to doors where gaps often occur.

The figures below illustrate how strips should be positioned.

INWARD OPENING WINDOWS

The strip is positioned on the frame

Hinge side (inside)

Hinge side (inside)

OUTWARD OPENING WINDOWS

The sealing strip is positioned on the stile

Hinge side (outside)

Hinge side (outside)

Figure 1.1 Positioning of sealing strips between stiles and frames in inward and outward opening windows respectively.

1.4.2 Tightness between stiles and walls

Cooled surfaces and gaps between stiles and walls can be detected by the appearance of dirt deposits or cracks. Detection can also be carried out with the aid of a candle, a smoke pistol or through thermography. This is facilitated if the room is subjected to negative pressure by turning on the cooker extractor for example. Defects are rectified <u>from the inside</u> and a suitable time is when window painting or wall papering is carried out since damage to adjacent surfaces is easily caused during the work.

In order to function satisfactorily the joint should be built up as illustrated in the figure below.

External rain protection   Air gap   Thermal insulation   Internal air and vapour seal

Figure 1.2 Sealing a joint between stile and wall.

Figures 1.3-1.6 below illustrate some design principles:

Packing with mineral wool, supplemented on the inside with a carefully constructed joint using mastic jointing compound, provides an air and moisture seal which prevents warm, moist air penetrating the joint where it can condense and form water.

Wooden batten Mineral wool packing Elastic jointing compound

≤ 10 mm

Figure 1.3

Where the joint width is greater than 10 mm, a bottoming strip should be positioned as a support for the jointing compound.

Wooden batten Mineral wool packing Bottoming strip Mastic jointing compound

> 10 mm

Figure 1.4

Packing using glass fibre matting +glass fibre matting in thin plastic foil. Where possible the foil should be drawn in an unbroken strip around corners and past adjustment wedges. This provides an air and vapour tight seal which prevents warm, moist air from penetrating the joint and condensing to water.

Wooden batten Glass wool packing Glass wool in thin plastic foil

10-20 mm

Figure 1.5

Filling the joint with expanded polyurethane foam.

Wooden batten Expanded polyurethane foam

>7 mm

Figure 1.6

1.4.3 Supplementary insulation of doors

Supplementary insulation of external doors is best carried out from the inside by placing insulation between battens on the inside of the door panel after which a plastic foil which provides a vapour barrier and a new internal covering sheet is nailed in position.

Thermal insulation and tightness can also be improved if the external door (porch etc.) is supplemented with an internal door or a wind break.

1.4.4 Supplementary glazing

There are several different technical solutions available today for providing supplementary glazing. Most solutions are based on the principle of increasing the number of glass/air gaps in the window thus improving thermal resistance.

A few examples are:

- Supplementing double glazing with a third pane
- Replacing single glazing with a double glazed sealed pane
- Replacing 2 single glazed windows with a triple glazed insulation window
- Replacing double glazing with triple glazing
- Closing-off the existing glass area with an insulated wall

There are of course several other methods. During an energy crisis or in simpler rooms, a thin plastic foil (figure 1.7) can be taped between the two windows in order to increase the number of air gaps and thus the thermal resistance. Other measures are to use venetian blinds or external, insulating shutters but the effect of these measures depends to a great extent on how they are applied by the occupier.

Plastic foil

Figure 1.7 Plastic foil taped between window frames.

Supplementing double glazing with a third pane

Figure 1.8 shows how an inward opening double glazed window is supplemented with a third pane. A requirement for this design is that the window

Spacer batten

Stile covering

Ventilation hole

Figure 1.8 Supplementing an inward opening double glazed window with a fixed external glazed panel and the covering of external stile wood.

does not need to be opened and is accessible from outside for cleaning The advantages are simple assembly, improved tightness and a certain amount of protection for external woodwork. Even if the external stile wood is covered with factory-painted sheet metal, it is protected against weather and wind and is not expensive where future maintenance painting is concerned.

If it is necessary to open the window, it is possible to fit a single glazed panel mounted in an openable external frame as illustrated in figure 1.9. The frame is fitted with hinges and is locked with locking screws. This design is also easy to fit. Both the methods discussed above should allow for a certain amount of ventilation between the external layers of glazing in order to prevent condensation on their surfaces.

Figure 1.9 Supplementary glazing mounted in an external openable frame.

Supplementary single glazing can also be fitted to the inside of the inner frame. The simplest method is illustrated in figure 1.10

Sealing strip or
silicone compound

Sheet metal clips

Figure 1.10 Supplementary glazing fixed in position on the inside of the inner frame.

where the glass is placed directly against the inner frame. The joint between the glass and the inner frame is sealed with a sealing strip, silicone compound or similar. The pane is fixed with sheet metal clips and must be removed when the intermediate panes are to be cleaned.

Supplementary glazing can also be fixed in an openable frame. The frame is then mounted on the inner frame. Several different systems are available and the principle is illustrated in figure 1.11. When fitting supplementary single glazing on the inside it is important to ensure tightness between the supplementary panel and the inner frame. Moist indoor air can otherwise penetrate between the layers of glazing and cause condensation.

Sealing strip against
the existing inner frame

Figure 1.11 Supplementary glazing fitted in an openable frame on the inside of an existing inner frame.

Replacing single glazing with a double glazed insulation window.

It is also possible to convert a double glazed window to a triple glazed window by replacing one of the single glazed panels with a double glazed insulation window. An insulation window comprises two or more panes which are sealed through adhesion or soldering around a metal strip. There is dust-free, dry air or a special thermal insulating gas between the sheets of glass. The advantage of this type of glazing is that there are only two surfaces to clean.

Several methods are available where the glass in the inner frame is replaced with a double glazed insulation window.

Batten

Sealing tape

Insulation glass

Figure 1.12 Replacing single glazing in the inner frame with a double glazed insulation window.

The principle is illustrated in figure 1.12. The insulation window is fixed between strips of wood, plastic or aluminium. It is important that fitting is carried out in accordance with the instructions issued by the manufacturers of the insulation glass, otherwise the glass guarantee may be invalid. It is also important that the joint between the indoor air and the air between the frames is tight, otherwise air leakage from the room can cause condensation on the glass surfaces between the frames.

Instead of replacing the single glazing in the internal frame, it is possible to replace the whole of the external frame with an aluminium frame having an insulation glass window or an insulation glass panel, i.e. an insulation frame bonded to an aluminium frame. The principle is illustrated in figure 1.13. The advantage of this solution

Frame covering

Insulation glass panel

Figure 1.13 Replacing an external frame with a glass panel having a double glazed insulation panel and the covering of external frame woodwork.

is that the external frame need not be repainted. If the external frame woodwork is covered at the same time, the windows are less expensive to maintain.

Replacing two single glazed panels with a triple glazed insulation window

By removing both glazed panels in an inter-connected double glazed window and then screwing the frames together as illustrated in figure 1.14 it is possible to fit a triple glazed insulation window in the existing frame. An alternative would be to get a new frame manufactured having a triple glazed insulation window and mount this in the existing frame. A further alternative, if it is possible to accept a window which is converted to a fixed window, is to remove the frame and fit the insulation pane directly in the existing stile, figure 1.15. This method produces a tighter window construction. The cost of a triple glazed insulation window is however relatively high and the cost effectiveness of the above-named alternative is low.

o37
o38
o38
o38 Aluminium profile
o39
o39
o39 Existing frames
o4o screwed together
o41
o41
o41 Figure 1.14 Replacing two single glazed panels with a triple glazed insulation
o42 panel.
o43
o43 Replacing double glazing with triple glazing
o44 In addition to improving the thermal resistance, another reason for
o45 replacement is that the window may be in bad
o46 condition. Unconnected windows are often replaced by modern integral windows
o47 in conjunction with modernisation but there is also a case for replacing
o48 windows by those which provide better acoustic insulation if the property
o49 is in a noisy area.
o5o When replacing windows it is also possible to replace the whole window
o51 including the stile, but this often causes extensive damage to the surrounding
o52 plaster work and reveals. The usual practice is to retain the old frame and
o53 fit an insert window into it, i.e. the new window frame is placed in the old
o54 frame as shown in figure 1.16. One can use either a 1+2 glass window,
o55
o55
o55
o55
o55
o55 Insert frame
o56
o56
o56 Existing frame
o57
o57
o57 Figure 1.16 Fitting an insert window in an existing frame.
o58
o58
o58
o58

i.e. a window which has a single panel plus a double glazed insulation panel, or a window with a triple glazed insulation frame fitted either permanently, figure 1.17, or in an openable frame. A permanently fitted window is often tighter than an openable window and also somewhat cheaper to maintain. When choosing replacement windows one should bear in mind future energy and maintenance costs and select a window of high quality. From the point of view of energy, it is also important that the seal between the stile and the wall and between old and new stile be properly fitted.

Covering over existing glass areas with an insulated wall

In offices, shops and industrial buildings there is often an unnecessarily large amount of window area, which is often single-glazed and thus gives rise to considerable energy losses apart from discomfort from cold radiation, heat radiation and the cost of cleaning etc. Where possible, these window areas can be reduced by replacing the window or supplementing with a thermally insulated wall. Supplementary glazing using insulated glazing can be used in certain cases as a possible solution as illustrated in figure 1.18.

Existing single glazing

Display window

Supplementary glazing using a double glazed insulation window

Figure 1.18

2. ROOF JOIST STRUCTURES/ROOFS

2.1 General description of technical measures

Depending on the appearance of the structure, joist structures (loft joist structures, tie beam structures) can be provided with supplementary insulation from above or below. It is best if the insulation can be carried out from above. This is cheaper and does not encroach on the occupied volume.

When carrying out insulation from above where there is no insulation, the work should be commenced by laying a plastic foil as a vapour barrier. It should lie as tight as possible against the sealing panels (or secondary spaced boarding). Insulation can then be carried out. Joints and transitions must be tight. The vapour barrier must always lie towards the warm side.

The following applies to insulation:

Insulation is usually carried out with mineral wool either in the form of sheets, matting/lengths or granules.

The insulation must fill the space between joists completely and shall lie tight against the warm side. Cracks and gaps must be avoided.

A ventilation space shall be provided at the eaves under the roof to the same extent as before insulation. (The National Swedish Board of Physical Planning and Building recommends 0.2 m^2 per 100 m^2 joist structure area and a minimum gap of 20 mm in accordance with SBN-75 (1)).

If there is a floor in the loft, it must be removed and possibly raised. An alternative is to engage a contractor who can inject mineral wool in the form of granules. Then it is only necessary to remove one or two floorboards.

Insulation can also be carried out from inside the room. This is done by building up a new false ceiling using beams which can, for example, be suspended from hangers.

If there is no acceptable vapour barrier or if the supplementary insulation's thermal resistance (m_t) (see Section 6.1.3) is greater than 1/3 of the constructions total thermal resistance (M_{tot}) after insulation, the new false ceiling is provided with a vapour barrier on the warm side nearest to the inside.

In certain buildings (primarily in industry) certain measures can be carried out on the roof instead of on the joist structure. In principle, the three different measures are as follows:

Insulation from the outside by using paper coated mineral wool for example.

From the underside, tight against the roof.

From the underside, suspended from the roof (this also reduces the total heated volume of the building).

2.2 Advantages and disadvantages of different measures

Supplementary insulation on a loft joist structure is always profitable if the optimum method and insulation thickness are selected, see calculation method in section 7.

The reduced transmission losses achieved through supplementary insulation of a joist structure can be calculated in accordance with section 6.1.3.

Apart from reduced transmission losses, the measures carried out mean that the construction is tighter (vapour barrier). This results in fewer draughts and warmer inner areas which in turn mean that the air temperature can be reduced without discomfort.

Furthermore, the measures mean that cold bridges in the construction can be eliminated to a certain extent. This reduces the risk of local cooling which can result in dirt deposition and cold convection currents. This can also allow a possible reduction in the indoor air temperature.

If the loft area is not fitted with a floor it is often quite easy to apply thick layers of supplementary insulation to the joist structure. The reduction in volume does not normally constitute any problem. In many cases the work has a "do it yourself" character. There are exceptions however in areas which are restricted or awkward to get at where the work is difficult to carry out satisfactorily. There are special spray methods for such areas (see section 2.4).

Measures carried out on the outside of the roof disturb building activities to a very minor extent. If the surface layer of the roof (for example paper) requires renovation in any case, the new layer does not detract from energy saving measures. If this is the case, it is preferable to insulating the outside since good profitability is nearly always achievable.

Measures on the roof from the inside have the advantage that the building is provided with a new characteristic, that of noise-absorption. However, when carrying out measures from the underside, moisture and airtightness aspects must be given particular attention.

2.3 Existing building stock

Approximate values of thermal transmission coefficients (k-value) for some common joist and roof constructions are given in table 2.1. It is very difficult to determine the k-value in old houses to any greater degree of accuracy. Methods used are of great significance and material properties may have changed over the years.

The values given in table 2.1 can however be used for preliminary calculations of the savings. (see section 6.1.3).

Problems which may have arisen in existing joist and roof structures are primarily those associated with moisture. i.e. water may have been absorbed in the insulation material by accident (primarily cutter shavings and sawdust). If the existing insulation is completely dry there is no reason for removing it. If, on the other hand, it is moist, it should be changed in conjunction with supplementary insulation and the cause of the dampness rectified. Crushed cellular concrete (blue) should also be removed bearing in mind radiation risks.

JOIST STRUCTURE

Construction	Building year	k-value $W/m^2 {}^oC$
Non-insulated joist structure		1.0
Joist structure with heavy filler, i.e. sand or coke ash	-1920	0.8
Cellular concrete joists	1945-	0.6
Concrete joists with crushed cellular concrete or granulated blast furnace slag	1935-1960	0.6
Joist structures with cutter shavings or coke ash	1935-1960	0.6
Simple timber house joists with approx 150mm sawdust or cutter shavings	1940-1960	0.6
Timber joist structures with floorboards, blind floor and under panel plus 150-200 mm light filler of chalk-blended sawdust or peat mould	1900-1945	0.4
Timber joist structure with fire bottom and 200 mm medium filler (granulated blast furnace slag) and plastered under panel	1910-1945	0.4
Timber joist structure with approx 250 mm sawdust or cutter shavings	1940-1960	0.4
Timber joist structure with mineral wool matting	1955-	0.4
Mineral wool-insulated cellular concrete joist structure	1945-	0.4
Mineral wool-insulated concrete joist structure	1950-	0.4

ROOF

Construction	Building year	k-value $W/m^2 {}^oC$
100 mm cellular concrete 500 quality plus paper cover	1945-	1.0
150 mm cellular concrete 500 quality plus paper cover		0.8
200 mm cellular concrete 500 quality plus paper cover		0.6
160 mm concrete plus 40 mm insulation plus paper cover		0.8
Trapezoidal sheeting plus 50 mm insulation plus paper cover	1965-	0.6
Trapezoidal sheeting plus 70 mm insulation plus paper cover		0.5

Trapezoidal sheeting plus 100 mm insulation plus paper cover		0.4
25 mm timber panel plus 50 mm fully fitted insulation plus paper cover	1940-	0.6
25 mm timber panel plus 95 mm mineral wool insulation between joists 1200 mm plus ventilation air gap plus 25 mm timber panel with paper or corrugated paper		0.4

Table 2.1 Approximate k-values for older joist structures and roof constructions.

2.4 Technical solutions

1. NB. Ventilation gap
2. Wind barrier
3. Existing joist structure
4. Supplementary insulation
5. Sealing around transitions

Figure 2.2 Supplementary insulation of joist structure from above.

Insulation of the joist structure's upper surface (figure 2.2) is normally carried out with mineral wool sheets or lengths. These products are adapted to normal joist spacing, but can also be supplied in non-standard sizes. It is important that the insulation product fills the insulation space completely (figure 2.3).

1. N.B. Ventilation gap
2. Paper
3. Existing insulation levelled off
4. Supplementary insulation in two layers

Figure 2.3 Supplementary insulation of joist structures from above.

As an alternative, mineral wool insulation can be sprayed over the area. In this case, the material is sprayed via a hose from plant on the ground. This method provides satisfactory filling even where it may be difficult using other methods. This method is also preferable if the transport of insulation material to the loft area is difficult.

Irregularities in the existing layer should be smoothed out using granulated mineral wool or a similar product prior to laying sheet products.

If the insulation is not coated, it should be provided with a wind barrier when insulating joist structures. This can be done by either using paper-coated sheet products, or by laying separate paper-coated building mats on top of the main insulation of uncoated mineral wool sheets. When spraying mineral wool, the wind barrier may be replaced by 20-30 mm extra insulation.

When insulating from the underside of the loft joist structure (figure 2.4) the insulation is placed between laths which are either nailed to or suspended from the existing ceiling. The laths constitute a basis for attaching the new ceiling covering.

Vapour barriers should be fitted on the warm side when insulating from underneath.

The vapour barrier is positioned as illustrated in figure 2.4. It is important that vapour barriers, where fitted, or the underlying sheet material are fitted with tight joints and overlaps. This is primarily to increase the tightness of the construction.

1. Existing joist structure

2. Supplementary insulation

3. Vapour barrier if $m_t > 1/3$ of M_{tot} or if the vapour barrier in the existing joist structure is missing or is inferior

   The joints in the vapour barrier are carefully sealed

Figure 2.4 Supplementary insulation of a loft joist structure from the underside.

Measures carried out from the <u>outside of the roof</u> may be carried out directly on the existing roof if the surface is even. No air gaps, which can reduce the insulation effect, are allowed in either the new or the old insulation. For example, a paper-covered roof can be insulated without the existing paper layer having to be removed.

Alternative solutions:

Fixed, fully-fitted insulation plus paper cover. Figure 2.5.

Mineral wool between beams plus surface layer of sheet metal or similar. Figure 2.6.

The vapour barrier must always be considered. It can be positioned externally (paper cover), internally or between layers of insulation. Its positioning depends on the actual conditions in question.

1. Paper

2. Insulation

3. Paper (existing)

4. Cellular concrete (existing)

Figure 2.5 External supplementary insulation, fixed.

1. Trapezoidal sheet metal
2. Wind barrier
3. Mineral wool between Z beams
4. Existing paper (vapour barrier)
5. Insulation (existing)
6. Sheet metal (existing)

Figure 2.6 External insulation between beams.

When carrying out insulation from the <u>inside of the roof</u>, the insulation can be fitted tightly to the underside of the roof and fixed permanently. The mineral wool comprises sheets with a surface layer intended for exposed fitting.

To avoid moisture problems, the following recommendations apply for tight fitting <u>without</u> vapour barriers adjacent to the new insulation. In figures 2.7 and 2.8, the λn values (see section 6) are given for different fittings.

1. "DRY" vapour pressure $P < 1.15$ kPa)
2. Paper (existing)
3. Insulation (existing)
4. Sheet metal (existing)
5. Mineral wool
6. Max 50% of the total thermal resistance

7. "MOIST" buildings (vapour pressure $P \geq 1.15$ kPa)
8. Paper (existing)
9. Insulation (existing)
10. <u>Vapour barrier (existing)</u>
11. Sheet metal (existing)
12. Mineral wool
13. Max 30% of the total thermal resistance

14.

t mm	λ_n W/m^oC, in accordance with certificate 77030, 36 from SP
50	0.045
80	0.048
100	0.050

Figure 2.7 Maximum insulation thickness and λ n values when using internal supplementary insulation on trapezoidal sheet metal roofing.

1. Paper (existing)
2. Cellular concrete (existing)
3. Mineral wool
4.

Zone (as per SBN)	t_{max} mm	λn W/m^oC
I,II	80	0.040
III,IV	100	0.040

Figure 2.8 Maximum insulation thickness and λ n value when fitting supplementary insulation to breeze block roofs.

In <u>other cases</u> (other material in the roof or other conditions) it may be more suitable to suspend the new construction from a suspension framework to allow more simple fitting of the necessary vapour barrier.

Figure 2.9 shows <u>one</u> example of how the insulation can be suspended.

1. Steel wire
2. Wind barrier
3. Mineral wool
4. Vapour barrier
5. NB. Sealing next to adjacent walls and transitions is important.
6. Mineral wool in supporting profiles of sheet metal.
   Max 1/3 of M_{tot} in this layer

Figure 2.9 Example of suspended internal supplementary insulation.

The most suitable method for insulating from underneath a roof must be decided from case to case since accessibility and the prospect of reducing the volume affect choice.

The manufacturers of insulation material and other material manufacturers concerned can provide further information.

3. EXTERNAL WALLS

3.1 General description of technical measures

In principle, supplementary insulation can be carried out from both the outside and the inside of an external wall. From a technical point of view, external supplementary insulation provides the best solution and does not reduce the internal volume. In the case of cavity wall constructions, supplementary insulation is applied by filling such cavities.

External supplementary insulation is particularly effective since it breaks all cold bridges which exist between intermediate walls and joist structures. Internal supplementary insulation using the same insulation thickness has an inferior effect according to investigations carried out at the Institution for Building Technology at the University of Technology, Lund (8).

1. Outside
2. Outside
3. Inside
4. Inside
5. External supplementary insulation where the cold bridge is eliminated
6. Internal supplementary insulation where the cold bridge remains

Figure 3.1

External supplementary insulation normally comprises mineral wool. In order to qualify for a government grant for energy savings today, the minimum insulation thickness is approximately 100 mm, but attempts should be made to achieve a final result which corresponds to the requirements for new buildings. Even greater thicknesses of insulation can be profitable from the point of energy costs.

External supplementary insulation means that the facade profile is moved outwards and this also affects adjacent structual elements. For example, windows will sit deeper in the wall unless they are moved out. Moving the facade profile as a result of supplementary insulation is partly a question of appearance and this can affect the choice of insulation thickness. There is also the technical aspect. Deep-lying windows in a protected position can stand up to the effects of climate better than windows which are flush with the facade profile.

Supplementary insulation from the inside is advantageous if the work is to be carried out in stages and without being affected by weather and wind. If the external facade is of cultural and historic interest, supplementary insulation should be carried out from the inside. The problem is, however, that cold bridges cannot be insulated and these cause energy losses - such cold bridges exist where inner walls and joist structures meet external walls. Another disadvantage is that the living area is reduced. This is outweighed to a certain extent in that the occupied area can be increased since the external walls become warmer.

3.2 Advantages and disadvantages of different measures

The profitability of supplementary insulation measures on an external wall are not generally self-evident. If the facade is already in need of renovation and the facade coating does not affect energy saving measures, it is always profitable to carry out supplementary insulation on external walls if the optimum insulation thickness (section 7) is selected.

Reduced transmission losses make up the large, relatively simply calculated energy savings from supplementary insulation. An improvement of a wall's k-value from 1.0 to 0.25 $W/m^{2\,o}C$, corresponding to approximately 150 mm supplementary insulation, results in an energy savings of approximately 90 kWh/m^2 per year in Central Sweden. If a detached house has approximately 100 m^2 external wall, excluding windows, this means an energy saving of approximately 9000 kWh/year. The reduced transmission losses which are achieved in theory from supplementary insulation of an external wall can be calculated as shown in section 6.1.3.

Apart from reduced transmission losses, external supplementary insulation of external walls can produce one or more of the following additional advantages:

<u>Tighter facade surfaces</u>

Supplementary insulation carried out in the correct manner makes the construction tighter. This is noticeable through the reduction of number unintentional air changes per hour. Of course the result depends on the original tightness of the wall and the building's volume and insulated area.

Reduced cold bridges

As a result of external supplementary insulation, the sections of the wall structure, such as joist joints, are covered and cold bridges are broken. Cold bridges cause heat losses through the wall and furthermore contribute to keeping down the temperature of internal floor and wall areas. The heat losses can be calculated in accordance with Swedish Building Regulations, Chapter 33:248K (1) if the area of the joist joints in relation to the facade area is known.

Dryer walls

A new facade functions in the same way as a raincoat on walls of brick and cellular concrete The original walls becomes warmer and the moisture equilibrium ratio becomes less. The thermal transmission property is also reduced and the insulation of the old wall increases.

Warmer inner surfaces

Supplementary insulation means that the surface temperature of internal walls becomes higher and the indoor temperature becomes more even. Thus the air temperature can be reduced without discomfort, resulting in significant energy savings.

Acoustic insulation

An external wall with supplementary insulation also has improved acoustic insulation.

Aesthetic aspects

Supplementary external insulation also changes the appearance of the house. As shown in the following, there are cases where environmental and cultural-historical interests must be satisfied. There are methods for preserving plastered environments, timbered structures etc. even after supplementary insulation.

Internal structures with supplementary insulation are subjected to greater temperature variations during the year and during the day than those which are insulated from the outside or not insulated at all. This can mean that temperatures stresses and deformation can increase in the original construction when internal supplementary insulation is applied.

There is also the risk of moisture problems in structural elements when using internal supplementary insulation. A reduced temperature in a material causes an increase in the moisture content. This results in both reduced thermal resistance in the existing construction and that the risk of damage, frost fractures, etc. can increase.

3.3 Existing building stock

The design of the old wall, and the heat transmission coefficient (k-value) and the energy savings, together with practical and aesthetic viewpoints, determine the choice of insulation thickness. The approximate thermal transmission coefficients (k-value) for some common wall constructions in existing buildings are shown in table 3.2 and the k-value after supplementary insulation can be calculated in accordance with the directions given in section 6.1.3.

Measurements must be carried out if the exact k-value for an existing building construction is to be determined. Standard k-value formulae may contain inaccuracies since the working method is significant and the material properties may have deteriorated with age. However, formulae provide sufficient accuracy in most cases and the values stated in table 3.2 can be used for a preliminary calculation of the savings effect (see section 6.1.3).

EXTERNAL WALLS

Construction	Building year	k-value $W/m^2{}^oC$
Planked walls (75 mm plank, 2x25 mm timber panel)	1910-45	1.0
1.1/2 brick plastered brick wall	-1940	1.0
Horizontal timbered wall	-1900	0.8
Single brick wall plus wood wall panels	1930-50	0.8
Cellular concrete wall (250 mm)	1935-	0.8
Cellular concrete insulated concrete shell	1945-65	0.8
Plank wall with insulation matting	1930-40	0.8
Stud wall with light filler (e.g. cutter shavings)	1900-40	0.6
Stud wall with light filler (e.g. cutter shavings)	1930-55	0.6
Cavity wall with insulation	1940-55	0.6
Cellular concrete elements	1965-	0.6
Wood wool wall elements	1940-50	0.6
Stud wall with insulation matting	1930-40	0.4
Stud wall with mineral wool	1950-	0.4
Cavity wall with mineral wool	1955-	0.4
Concrete shell with cast-in mineral wool or cellular plastic	1960-	0.4
Concrete elements with mineral wool or cellular plastic	1960-	0.4

Table 3.2 Approximate k-values for older wall constructions.

3.4 Technical solutions

The next section has been divided up into the following technical solutions:

- External supplementary insulation
- Internal supplementary insulation
- Supplementary cavity wall insulation

3.4.1 External supplementary insulation

Prior to supplementary insulation the surface should be as even as possible so that no air gaps are formed behind the new insulation. Cracks and gaps may give rise to disastrous air movement as far as the thermal insulation is concerned. Broken plaster may need to be repaired and loose plaster knocked off. Furthermore, "covers" on timber panels and battens should be removed. Possible air gaps in the old wall should be filled in or carefully sealed. Pervious walls should be fitted with particle board, plasterboard or paper with overlapped joints before supplementary insulation is fitted. Undulations in the old facade can be straightened by using the battens supporting the supplementary insulation and the new facade.

The following gives an account of the methods used for supplementary insulation, divided up according to the surface coating of the facade (sheet metal, timber, brick, plaster). Suggestions are later given regarding detailed solutions for eaves, wind barriers, window frames, skirtings and different types of attachment devices.

Sheet metal facades

Aluminium sheeting and hot dip galvanised steel sheet are tried and tested facade materials which are suitable for covering facades in conjunction with external supplementary insulation. The materials provide a non-flammable facade cladding demanded for houses with more than two floors. They are not heavy and furthermore require very little maintenance. Sheet metal allows many variations with respect to profile and colour and, when coated with PVF_2 Kynar 500, the sheet metal has a surface layer which is very colour stable.

Sheet steel is protected against corrosion either with zinc or paint. Oxygen in the air provides aluminium sheeting with an oxide layer which protects the underlying metal and corrosion-protective treatment is not normally necessary.

Different paint types can be selected depending on the colour stability required.

Supplementary fittings are available as standard or can be made to order from flat sheet metal.

Further information on the use of sheet metal in conjunction with supplementary insulation can be obtained from the respective sheet metal manufacturers, e.g. Ahlsell Profil, Dobel, GavleVerken, Gränges Aluminium Korrugal, Plannja etc. and in the publication issued by the Swedish Institute of Steel Construction, "Facade renovation using sheet metal" (9).

Timbered facades

Timber is a tried and tested facade material which, as a result of its low weight, thickness and simple maintenance, makes it suitable for use as a new facade covering in conjunction with supplementary external insulation.

Timber blends well with the Swedish environment and building tradition. In older housing areas the material seldom gives rise to any aesthetic conflict if the type of facade and surface treatment is selected to blend with other houses. Timber facades can be designed in a number of ways with vertical and horizontal panels, by using different timber dimensions and different designs. Timber facades on modern buildings are often quite rugged in appearance and surface treated with bright colours, varnished in many cases. Older timber facades are often more finely cut and painted in sombre colours. When renovating older houses the result is often best if the new panel is as similar to the original as possible. In cases where the existing timber facade is well preserved, it can often be removed and re-used after supplementary insulation.

Surface treatment for timber panels should be selected so that intervals between maintenance are as long as possible. Timber Information have published booklets on timber facades (10) and the surface treatment of timber facades (11) which provide help when fitting supplementary insulation and new timber facades as well as the choice of surface treatment.

Battens

The insulation and the new sheet metal or timber facade can be attached to the sub-surface using battens. Battens can be of either steel or wood. Steel profiles are made from cold-formed sheet metal profiles, usually Z-profiles or special profiles which reduce thermal transmittance. Steel profiles must be hot dip galvanised.

Battens used for supplementary insulation and facade renovation are normally fitted horizontally since this is advantageous from a fire-protection aspect and furthermore allows simpler fitting.

In houses with more than three floors, it may be necessary to use special flammable battens which are terminated at fire cell limits (Swedish Building Regulations 1975, Chapter 37:34 and Chapter 37 Rebuilding Regulations:34) (1).

Steel profiles mean simpler fitting, particularly when using thick insulation, but on the other hand cause greater cold bridges than wooden battens (see figure 6.2). The old wall constitutes a certain break in the cold bridge but steel profiles normally need further cold bridge insulation on the outside. This is normally mineral wool or particle board.

In order to reduce the length of the attachment device which extends from the wall profile, it may be advantageous to employ one of the following batten combinations when fitting wooden battens in conjunction with thick insulation:

- Cross battens, figure 3.3.
- Double battens laid against each other, figure 3.4.
- Battens with countersunk fasteners, figure 3.5.
- Attachment of battens using building fittings which in turn are attached to the wall using short fasteners, figure 3.6.
- Batten plus fully fitted insulation plus nailing batten, figure 3.7.
- Intermediate fully fitted insulation plus external insulation between battens on spacer blocks, figure 3.8.

The centre-to-centre spacing of the battens should be adapted to the type of facade covering and the size of the insulation sheets. The insulation shall be fitted so that there is a minimum number of joints. The normal centre-to-centre spacing between horizontal battens is

1000-1500 mm	for sheet metal cladding
600 mm	for timber surfaces

Figure 3.3 Crossed battens.

Figure 3.4 Double battens laid next to each other

Figure 3.5 Battens with countersunk fasteners.

Figure 3.6 Attachment of battens to building fittings which in turn are attached to the wall with short fasteners.

Insulation

Fully fitted insulation

Nailing batten

Spacer

Figure 3.7 Batten plus external fully fitted insulation plus nailing batten on spacers.

Fully fitted insulation

Spacer block

Nailing batten

Figure 3.8 Internal fully fitted insulation plus nailing batten on spacer blocks.

Thermal insulation

Mineral wool is the commonest and most suitable material for external supplementary insulation. Mineral wool allows the passage of moisture so that there is no risk of moisture damage caused by condensation. Non-flammable insulation is required for supplementary insulation on buildings of more than three floors. This requirement is fulfilled by mineral wool.

In principle, there are two different ways of fitting the insulation:

1. Wind barrier
2. Timber batten or steel profile
3. Wind barrier
4. Nailing batten
5. INSULATION BETWEEN BATTENS
6. Spacer
7. FULLY FITTED INSULATION WITH NAILING BATTENS ON SPACERS

Wind barrier

COMBINATION OF INSULATION BETWEEN BATTENS AND FULLY FITTED INSULATION

Figure 3.9 Insulation between battens and fully fitted insulation with nailing battens on the outside.

The method using fully fitted insulation creates fewer cold bridges and thus better insulation properties.

Insulation between battens

Insulation is carried out with sheets as illustrated in figures 3.10 and 3.11. The insulation thickness shall be equal to the thickness of the batten.

Existing wall
Nailing batten
Horizontal batten
Insulation
Wind barrier

Facade coating

Pressure impregnated batten

Figure 3.10 Insulation between horizontal wooden battens.

Existing wall
Facade plating
Wind barrier
Insulation
Particle board to break cold bridge
Steel profile

Figure 3.11 Insulation between horizontal steel profiles.

The sheet of insulation must fill the space between the profiles completely. This type of insulation must be provided with an external wind break in order to achieve the intended insulation effect. There must be no air gaps behind the insulation or between the insulation layer and the wind barrier. Gaps must be avoided between the sheets of insulation and adjacent to battens (see figure 3.12). The insulation effect is reduced considerably by large gaps. The insulation sheets must be cut accurately, preferably using a plank as a guide.

WRONG! RIGHT

Figure 3.12 The insulation must fill the space between battens completely. The joints in the wind barrier must be tight.

<u>Fully fitted insulation with nailing battens</u>

The insulation is carried out as illustrated in figure 3.13. The sheets of insulation are fitted carefully edge to edge so that no gaps arise.

Mineral wool insulation

Wind barrier

Existing wall

Nailing batten on spacers

Facade layer

Pressure impregnated batten

Figure 3.13 Fully fitted insulation with external nailing battens mounted on spacers.

The sheets are fitted temporarily to begin with using suitable fasteners and washers. The final fitting is done with external nailing battens nailed to the old facade (figure 3.9).

The nailing battens are mounted on special spacers which are easily pressed into the insulation sheets and which form a foundation for the battens. The fully fitted insulation provides a greater insulation effect compared with the method using insulation between battens since the number of cold bridges is reduced.

Wind barriers

If the existing construction is tight, such as concrete for example, fully fitted insulation with an air perviousness of $1 \leq 0.1\ m^3/hm\ Pa$ can be fitted without the use of a special wind barrier.

Insulation with an air perviousness of $> 0.1\ m^3/hm\ Pa$ between battens must be provided with a wind barrier in order to prevent air movements which can reduce the insulation effect.

In cases where the construction needs tightening and where fully fitted paper-covered insulation ($1 \leq 0.1\ m^3/hm\ Pa$) is used, either directly on existing walls or on top of insulation between battens, the wind barrier paper is fitted so that it faces the wall.

The following can be used as a wind barrier:

- AC 150/200 paper or similar
- Billeruds Tätofol
- Rascos system Vänertät
- Vänerply
- Hard or semi-hard fibre board
- 9 mm Plasterboard
- Asphalt board
- Gullfiber board
- Gullfiber facade sheeting with or without paper-coating (fully fitted insulation)
- Rockwool board with or without paper-coating (fully fitted insulation)

The last four mentioned also break cold bridges; for example, adjacent to steel profiles.

The wind barrier is carefully fitted and with as few joints as possible. Loose paper sheets are fitted with an overlap of at least 100 mm at joints.

A ventilated air gap of at least 20 mm should be provided between facade material and the wind barrier. Nailing battens are necessary to achieve this unless the panel profile allows such ventilation. The air gap must allow penetrating moisture, for example driving rain,to dry out.

In the case of non-flammable facade coatings, insulation material and wind barriers adjacent to air gaps (non-combustible construction), the air gap in the wall need not be broken for fire-cell-limiting walls and joist structures. Such non-combustible wind barriers are plaster and mineral wool intended for fully fitted insulation (the paper is turned inwards when used).

Brick facades

Brick facades have the advantage that they require almost no maintenance. However, the possibilities of using thick insulation is limited when carrying out supplementary insulation. This depends partly on the fact that the brick in itself uses up more room than other facade materials. Furthermore, the facade layer must be built up on angle iron or attached to the existing facade or skirting, see figure 3.14.

However, there is the possibility of being able to use narrower bricks than is traditional.

The following thicknesses are available:

- 60 mm
- 87 mm (known as brick modules)
- 120 mm

Existing wall

Mineral wool insulation

Wind break

Facade brickwork

Angle iron

Skirting insulation

Figure 3.14 Supplementary insulation with brickwork as a surface covering.

The commonest brickwork thickness used for supplementary insulation of small detached houses is 60 mm. Special corner bricks are manufactured to give the impression of having used normal brick thicknesses of 120 mm. Type-approved technical solutions using 60 mm bricks are available for facade heights up to 12 metres.

The design must not lead precipitation into the wall construction. Only where the brickwork envelope is interrupted at skirtings, windows or door openings, etc. is it necessary to ensure that the water can be led away from the facade by using drop strips or paper when carrying out supplementary insulation using facing brickwork.

The stock of bricks to be used for facia brickwork must be dimensioned for the load which bears down on to the brickwork. A certain part of the load is transmitted via cramps to the existing wall but this should not be considered when dimensioning.

As noted above, the new facade is cramped to the sub-surface. This means that the wind load is spread and greater rigidity is achieved.

Tegelindustrins Centralkontor AB in Stockholm can provide further information concerning facia brickwork used in conjunction with supplementary insulation.

Thermal insulation

Insulation in the form of mineral wool sheets, is attached with nails (timber sub-structure) or, for example, TEFAB nails (cellular concrete or concrete sub-structure) and divider plates in the old facade. It is important that the insulation lies tightly against the existing wall and that the sheets are fitted edge to edge so that no gaps can occur.

When dimensioning it is advisable to consider that a gap of approximately 20 mm is necessary between the insulation and the brickwork (when the air perviousness $l \leq 0.1\ m^3/hm\ Pa$).

Wind break

If mineral wool with an air perviousness $l > 0.1\ m^3/hm\ Pa$ is used, it should be supplemented with a wind break. If $l \leq 0.1\ m^3/hm\ Pa$, the wind break can be left out. The wind break is best made from a separate paper placed on the outside of the insulation.

If the house needs to be made airtight, a sealing layer (paper on mineral wool or separate, hard particle board or plasterboard) is used between the new insulation and the existing wall. See figure 3.14.

Plaster facades

Primarily in town environments, there are a number of plaster facades which need supplementary insulation. Approximately 25% of houses built before 1960 are plastered.

A certain amount of research has been carried out as far back as 1940 with regard to plaster on insulation. However, it is only of late that interest has been aroused with respect to supplementary insulation of plaster facades. In this context the interest shown in maintaining a plaster finish on houses after supplementary insulation has also grown. This in turn has led to a number of methods being introduced during the last few years. The different methods differ somewhat and can, in principle, be divided according to the method of attachment as follows:

> Rigid attachment in existing walls. This can be done by either using brackets of steel, or battens which go through the wall, for applying plaster and plaster anchorages.

Jointed attachment, which is based on the principle that the plaster layer is attached by using cramps which allow movement in the plane of the plaster layer.

Bonded insulation using light plaster. The plaster contains plastics and has a low specific gravity and is usually applied to cellular plastic insulation.

Insulation plaster which means that cellular plastic granules are mixed with cement plaster in order to achieve a certain degree of insulation.

The following methods can be given as examples of some of the applications:

TM-method (Rigid attachment, Träullsplattfabrikernas Försäljnings AB). Comprises a fully fitted mineral wool sheet +particle board + re-inforcement netting fixed to attachment devices. The grouting and surface plastering is applied to the netting. See figure 3.15.

TM-combination sheeting comprising a mineral wool sheet and a wood wool sheet

Attachment device

Plaster netting

Plaster

Figure 3.15 TM-method (Rigid attachment).

G+R-method (Rigid attachment, Gullfiber AB and Stråbruken AB). Comprises a mineral wool sheet between battens. Skin paper is applied to this on the outside as is re-inforcement netting and Rhodipor plaster followed by surface plaster. See figure 3.16.

Mineral wool sheet between battens

Skin paper

Reinforcement netting

Rhodipor plaster

Surface plaster

Figure 3.16 G+R-method (Rigid attachment).

Serporock method (Flexible attachment,Ernström and Co AB and Rockwool AB). Built up of a fully fitted mineral wool sheet and reinforcement netting fixed to attachments with flexible cramps. Grouting and surface plaster is applied to the netting. See figure 3.17.

Fully fitted mineral wool sheet

Attachments with flexible cramps

Reinforcement netting attached to cramps

Grouting plus surface plaster

Figure 3.17 Serporoc method (flexible attachment).

ISPO-Isolersystem (Bonded attachment, Snöland AB). The system is based on the fact that cellular plastic insulation and plaster are bonded to the existing wall. Glass fibre roving is used as reinforcement. The sheet of cellular plastic is bonded with synthetic resin-based cement adhesive against the existing sub-surface as is the reinforcement to the cellular plastic after which the surface plaster is applied. See figure 3.18.

Fully fitted cellular plastic

Reinforcement (glass fibre roving)

Surface plaster

Figure 3.18 ISPO Insulation system (bonded insulation).

Gyproc method (Flexible attachment, Gyproc AB). This is based on the AJ method where the weight of the plaster layer is taken up at the skirting via brackets across which a suspension line has been laid. The reinforcement and the insulation is attached to eyes which are firmly driven into the existing wall. The facade is plastered with gypsum plaster in this type of construction.

Rhodipor method (Insulation plaster, Stråbruken AB). This is built up of insulation plaster containing polystyrene granules. Surface plaster is applied to this. The thermal insulation of 80 mm Rhodipor plaster corresponds to approximately 50 mm mineral wool. See figure 3.19.

Thermally insulating plaster

Surface plaster

Figure 3.19 Rhodipor method (insulation plaster).

Long-term experience of the different methods is quite limited. A systematic follow-up of the plaster method is being carried out on the initiative of the National Swedish Council for Building Research. Experience gained so far shows that the methods function well from a technical point of view but it should be pointed out that correct working methods and detailed design are important if the risk of crack formation in plaster is to be avoided. Bengt Elmarsson, LTH, has presented and analysed the methods quoted here in "Plaster on supplementary insulation" (12).

Plaster manufacturers and insulation material manufacturers are able to provide further information.

Eaves and loft panels

Aesthetic and practical problems can arise at eaves and with loft panels when the wall profile is moved outwards in conjunction with supplementary external information. An extension of the

Insect netting

Figure 3.20 Extension of the eaves.

416

416

417

417 existing roof projection can be carried out and figures 3.20 and 3.21

418 illustrate suggestions.

419

419

419 Spacer block

42o

Figure 3.21 Extension of loft panel.

421

421 Window frames

422 A well-maintained window frame is important to the appearance of the facade and

423 can, in certain cases, disguise the impression of deep windows. Whether

424 the window frame is to be made wide or narrow depends on the character

425 of the house and must be decided from case to case.

426 The figures below illustrate examples of some solutions.

427

427

427

427 Figure 3.22 Window frame of timber.

428

428

428

428 Figure 3.23 Window frame of sheet metal.

429

429

429

429 Figure 3.24 Window frame of sheet metal.

43o

43o

43o Material manufacturers often have ready-made detailed solutions for

431 different designs of window frames and surrounds.

432

432

Skirting

Supplementary insulation of an external wall's facade can be discontinued where the skirting begins but may also comprise the skirting. An advantage of insulating the skirting as well is that cold bridges which can give rise to cold floors on the ground floor are reduced. Insulation of the skirting is also preferred from an aesthetic point of view. See figure 3.25.

Build up of skirting

Figure 3.25 Supplementary insulation and build up of skirting.

When carrying out supplementary insulation, plaster can be used as a new surface coating on house skirtings. Methods available differ with respect to attachment, type of insulation, type of plaster re-inforcement and types of plaster. Refer to the section on plastered facades. Furthermore, there are pre-fabricated skirting units as an alternative method of supplementary insulation.

Manufacturers of plaster and insulation material can provide further information regarding supplementary insulation on skirting.

Attachment devices

All supplementary insulation requires attaching to existing walls. Attachment to timber facades requires different types of nails and screws but does not constitute any serious problem. However, it may be quite difficult to make attachments in stone and concrete constructions, particularly in the case of cellular concrete. The respective manufacturer should be contacted in order to get the right type of fastener for each individual material. A large number of systems are available on the market and the respective manufacturer can advise on his material's requirements with regard to attachment methods. When fixing to cellular concrete, tensile tests of the attachment device are often required in order to ascertain the attachment device's pulling-out forces in the existing wall. Suppliers of attachment devices sometimes help with such tests. Table 3.26 shows suitable attachment devices bearing in mind the material in the existing wall.

	Cellular concrete	Solid brick	Perforated brick	Concrete	Timber
Expander bolt/screw					
Plastic plug					
Spiral nail					
"Hema" nail					
Wood screw					
Plaster nail					
Cut nail					
Anchor nail					
Kemankare					

Table 3.26 Suitable attachment devices bearing in mind the material in the existing wall.

3.4.2 Internal supplementary insulation

There are different types of supplementary insulation units on the market for internal fitting but the commonest method is to mount a wooden framework on the wall. If thin insulation (50 mm) is used, the battens are applied directly to the old wall surface with a centre-to-centre spacing determined by the internal sheet material which normally comprises chipboard, wood fibre or plasterboard. If greater insulation thicknesses are used, the framework is mounted a little away from the wall and complete sheets of insulation are fitted between the framework and the wall. A vapour barrier which seals the wall should be applied between the covering sheet and the insulation/framework.

Where possible, insulation behind radiators should be considered.

Existing wall

Vapour barrier if m_t is $> 1/3\ M_{tot}$ or if the vapour barrier in the existing wall is lacking or is inferior

Fully-fitted insulation

Insulation between vertical battens

Internal sheet material

Figure 3.27 Internal supplementary insulation.

More details on internal supplementary insulation and its consequences for different constructions can be read in "Internal supplementary insulation" by Ann-Charlotte Andersson (8).

3.4.3 Supplementary insulation by filling cavities

Older houses may have cavities in external walls and joist structures either as a result of sunken insulation or the lack of insulation. These cavities can be filled with insulating material but difficulties in achieving the intended result often arise. This has been indicated in an investigation of urea foam application carried out by Building Technology I at LTH. The material used is required to be non-water absorbing, moisture tight and shall not support the growth of micro-organisms. Materials which fulfil these requirements are mineral wool, polysterene granules, light clinker granules and urea foam. However, the use of urea foam can in certain cases introduce damaging quantities of water into the wall construction.

Cavity insulation is normally carried out by specialist firms. Only well-known companies should be engaged bearing in mind the difficulties in checking the result.

4. OTHER STRUCTURAL ELEMENTS

4.1 General description of technical measures

Apart from the structural elements discussed so far, there are other elements which, in specific cases, may be of interest with regard to supplementary insulation:

Pitched roofs
Brace walls
External basement walls
Floors

However, it may only be possible to carry out work to improve tightness. This applies primarily to buildings of cultural and historic interest or where it may be difficult to carry out extensive measures for other reasons.

4.2 Advantages and disadvantages of different measures

In the case of the insulation measures mentioned above, energy saving can be calculated in the same way as for roof joist structures and external walls (section 6.1.3).

The disadvantage of internal measures carried out on the structural elements discussed is that they encroach on the living area while possible cold bridges are maintained.

External measures on floors and external basement walls respectively are difficult to carry out and seldom profitable. However, these types of measures have little effect on the appearance of the building.

Supplementary insulation of the basic structure reduces heat flow to the ground. This means that frost penetration in the ground around buildings increases. If the subsoil contains a type of earth susceptible to frost the building can be damaged. The insulation thickness must be weighed against this.

Having tighter houses and a reduced air change rate can reduce energy consumption. On a broad basis, a change of 0.1 changes/h, corresponds to approximately 1200 kWh/year in a normal sized detached house.

4.3 Existing building

4.3.1 Pitched roofs

Pitched roofs are normally insulated with the same insulation material as is used in external walls.

A comparison with table 3.2 (referring to external walls) can provide an estimated k-value for existing pitched roofs.

4.3.2 Brace walls

The proportion of brace walls which are insulated is normally quite low. Calculation of the existing k-value (see SBN 75 (1)) should be carried out from case to case.

4.3.3 External basement walls

Table 4.1 gives approximate k-values for some existing floor constructions.

Structural element	Building year	k-value $W/m^2 {}^oC$
External basement walls		
2 course brick wall or brick of natural stone	-1940	1.2
Concrete cavity wall/concrete	1920-	0.9
Concrete cavity wall/concrete plus 50 mm mineral wool external or internal	1965-	0.4
Cellular concrete/lightweight clinker	1950-	0.5
Cellular concrete/lightweight clinker plus 50 mm mineral wool external or internal	1965-	0.4
Access spaces or cellar joist structures		
Filler of sawdust between 6" x 10" joists, 600 mm spacing Dead floor	-1910	0.4
Filling of chalk-sawdust mixture or peat between beams 4" x 9" or 3" x 8", 600 mm spacing	1900-45	0.4
Timber joist structure (2" x 8") plus 150 mm mineral wool	1960-	0.3
Cellular concrete structure, 200 mm	1945-	0.6
Cellular concrete joist structure plus 45 mm mineral wool above and below	1960	0.7

Joist structure above earth or cellar floor		
Concrete slabs with insulation 100 mm concrete plus 70 mm (topside) or 50 mm (underside) mineral wool	1965-	0.3

Table 4.1 Approximate k-values for older external basement walls and floor structures respectively.

4.4 Technical solutions

4.4.1 Pitched roofs

The insulation thickness must be adapted, in this case, to the special conditions dictated by the construction. If this insulation method takes up too much living area, it is possible to apply the corresponding amount of insulation to the tie beams instead. Where sloping roofs lack insulation, ensure there is a ventilation gap adjacent to the roof of approximately 25 mm. Sheets of mineral wool can be used for insulating and it is necessary to make sure that the sheets fill the space completely between battens and the vapour barrier.

NB. Ventilation gap

Existing construction

Supplementary insulation

Vapour barrier if m_t is $> 1/3\ M_{tot}$ or if there is no vapour barrier or if the existing vapour barrier is inferior

Figure 4.2 Supplementary insulation of a sloping roof.

4.4.2 Brace walls

These can be provided with supplementary insulation from the loft side. Insulation can be attached in different ways to the existing wall. Make sure however that a good fit is made against the adjacent insulation. The face between the vapour barrier in brace walls and the intermediate joist structure is normally poor. Make sure that this is satisfactory.

NB. Ventilation gap

Check that the vapour barriers lie tight against each other

Figure 4.3 Supplementary insulation of brace walls.

4.4.3 External basement walls

Insulation of external basement walls can be carried out from the outside or within.

Internal insulation should only be carried out when the wall is dry otherwise there is a risk of mould or fungus forming in the structure.

The construction alternatives which can be used are the same as for internal supplementary insulation of external walls. For safety's sake, timber should be pressure impregnated and the plastic foil should be left out so that drying out can take place towards the inside.

External insulation is normally quite difficult to carry out. A trench is dug along the cellar wall and hard mineral wool sheets are fitted against the cellar wall. In this way a thermally insulated layer is formed preventing capillary action thus making the existing cellar wall dry. Above ground it is possible to either plaster the mineral wool according to one of the plastering methods or use skirting elements (see section 3.4.1).

Existing wall

Supplementary
insulated facade

Plastered skirting

Asphalt coating

Ground sheets

Refill using drainage
material

Figure 4.4 External supplementary insulation of external basement walls.

4.4.4 Floors

The insulation of floors must be adapted to the existing construction. The choice of method depends on whether there is a timber or concrete joist structure. In the case of timber structures, the insulation can be applied either in, above or below the existing floor structure. In the case of concrete structures, the insulation must be laid above the concrete. However, the concrete must be covered first with a plastic foil in order to avoid moisture problems.

Floor units comprise a surface layer next to the insulation of mineral wool or cellular plastic. The elements are laid out on smoothed surfaces. The manufacturers' recommendations should be followed since the design of elements can vary.

170
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171
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171 Chipboard

Supplementary insulation

Existing timber structure

172
172 Figure 4.5 Insulation using floor elements.
173
173
173 Insulation using separate surface layers is another construction where the
174 insulation is made up either of cellular plastic or
175
175
175 Chipboard

Supplementary insulation

Plastic foil

176 Existing concrete floor
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177 Figure 4.6 Insulation using a separate surface layer.
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hard mineral wool. Chipboard is normally used as a surface layer. Figure 4.6.

Built-up timber floors are a common construction but careful attention should be paid so that moisture problems do not arise. The space between wooden beams, existing floor and upper floor layer is filled completely with insulation.

Chipboard

Wooden beam

Supplementary insulation

Existing floor

Figure 4.7 Insulation under built-up timber floor.

Insulation under joist structures can be carried out if there is access space under the joist structure. Insulation must fill the space between beams and the underside of the existing joist structure completely. Thicker insulation is possible if the insulation is applied directly to the joist structure. A secondary spaced board is nailed to the spacer device and keeps the insulation in place.

Existing insulation

Supplementary insulation

Secondary spaced board

Figure 4.8 Insulation under joist structures.

Existing insulation

Supplementary insulation

Secondary spaced boarding
on spacers

Figure 4.9 Insulation under joist structures.

Insulation in joist structures can be carried out by injecting insulation material. Mineral wool, polystyrene granules or urea foam can be injected through drilled holes. However, in certain cases, urea foam can introduce dangerous amounts of water into the structure. The work is normally carried out by specialist firms.

Only well-known companies should be engaged bearing in mind the difficulty in checking the results.

Drilled hole   Cavity filled with insulation

Existing insulation

Figure 4.10 Insulation of joist structures by the injection of insulation material.

4.4.5 Tightness

There are a number of joints in buildings. It is extremely important for these to be tight. A tight joint can be made by adapting the vapour barrier so that it can overlap joints between structural elements or by using different sealing systems and materials. The different systems currently available and which are either insulating or air and vapour sealing or both, are the following:

Jointing compounds are air and vapour sealing. These can be supplemented at the bottom with a mineral wool strip or a tubular strip.

Sealing strips of EPDM rubber which when folded double are pressed into the joint and are air and vapour sealing products.

Mineral wool strips of glass fibre or mineral wool which are pressed into the joint. They only insulate and must normally be supplemented with a sealant. Mineral wool strips baked in plastic foil also function as air and vapour seals.

Jointing foam, normally polyurethene foam, is available as a single component type and fills, seals and insulates the joint satisfactorily.

5. COMBINING DIFFERENT METHODS

The way in which the energy saving measures are combined and the order in which they are carried out is of great importance to the final result. Viewpoints are given below on both the combination of technical measures as well as technical and other energy saving measures.

5.1 Combination of technical measures

The most profitable technical energy saving measures are to eliminate natural air leakage in windows and doors and, where possible, around windows and doors. Other energy saving measures should therefore always be preceded or combined with sealing measures. An easily accessible and badly insulated roof joist structure is profitable to insulate but even here the risk of gaps and passages for air must be eliminated when the existing insulation is supplemented. When carrying out supplementary insulation on external walls, the building's tightness must also be improved. Joints in walls and between walls and frames must be sealed and the risk of air passing through the insulation at eaves and skirtings must be eliminated in order to achieve the required result from supplementary insulation.

Even the building's other facade details should be maintained in conjunction with external supplementary insulation and the fitting of new facade coverings. Examples of suitable measures are the maintenance painting of gutters, drain-pipes, wind barriers, windows, etc.

5.2 Combination of technical and other measures

When combining technical and installation measures it is important that the measures be carried out in the right order. A good rule is to begin by carrying out sealing and/or insulation measures and then to carry out adjustments of the heat supply and ventilation in the building. Note that adjusting of the heat supply (and thus the room temperature) to a building's different sections is important in order to achieve the desired effect from technical measures. If adjustment is not carried out the result will only be a few degrees rise in the room temperature (this encourages opening windows more often) and the energy consumption remains unchanged. The reduction of the air temperature indoors results in an energy savings of approximately 5-7% per degree.

6. CALCULATION OF, AND EXPERIENCE FROM, SAVINGS THROUGH TECHNICAL MEASURES

6.1 Calculation

Calculating the true effect of different energy saving measures is complicated. Several factors affect the result. An example of such factors is the estimation of the existing building section's thermal resistance and tightness, the way in which different energy saving measures are carried out and side effects which often result from different measures and combinations of measures.

6.1.1 Tightness measures

The effect of tightness measures between frames/door panels and stiles on windows and doors depends to a great extent on the perviousness of the existing doors and windows. An investigation of windows carried out at LTH (7) indicated that only approximately 15% of the windows investigated were suitably airtight. Windows and doors where closing devices are badly adjusted and where weather-stripping comprised textile strips or foam plastic strips are very pervious.

Rectifying such windows and doors and thus reducing the natural ventilation can reduce the number of air changes in a flat or house by an estimated 0.1 - 0.3 changes per hour. What this means in terms of energy saved can be calculated using the formula:

$$W = n \times V \times c \times \varphi \times Q$$

W = energy saved in kWh per year
n = reduction in air change rate per hour
V = flat/house volume in m^3
c = specific heat of air (Wh/^{o}C kg)
φ = density of air (kg/m^3)
$c \times \varphi = 0.36$
Q = number of degree hours per year, i.e. the integrated product of the number of hours and the difference between indoor and outdoor temperatures when heat must be supplied, divided by 1,000. See figure 6.1

An example shows that for every reduction of the changes/h by 0.1 in a 125 m^2 house in the Stockholm area (zone III) there is a saving of:

$$0.1 \times 125 \times 2.4 \times 0.36 \times 110 \approx 1200 \text{ kWh/year}$$

Using an energy cost of 15 öre/kWh, this gives a saving of 180 Crowns/year which exceeds the cost of good quality weatherstripping for a house of this size.

It is difficult to assess the potential savings as a result of other sealing measures between stiles and walls, around floors, roofs, etc.

6.1.2 Supplementary glazing

By fitting an existing double-glazed window with a third pane, the thermal transmission (k-value) is improved at the glazed section from approximately $k = 3.0$ to $k = 2.0\ W/m^2\,^oC$. The annual saving is thus the improvement in k-value times the number of degree hours for the area as shown in figure 6.1. For example, in Stockholm where Q is approximately 110, the saving is:

$$(3.0-2.0) \times 110 = 110 \text{ kWh/year } m^2 \text{ glass area}$$

It must be remembered that glass is a transparent building material which allows the transmission of solar energy during the day. Thus the resulting energy losses are dependent on the radiation and thus the position of the window. Calculations carried out by Professor Bo Adamson at LTH (13) give the following approximate values for energy savings as a result of the third pane:

Town	North facing wall	East/West facing wall	South facing wall
Malmö	90 kWh/m^2, year	75	55
Stockholm	105	90	75
Luleå	145	125	110

This table assumes that the "free heat" from solar radiation is used for heating the house and that room thermostats are fitted. If the free heat is not wanted or if the windows are shaded by thick curtains, the energy savings will approximate to the values for north facing walls.

Energy savings in excess of these can also be achieved because the cold radiation from windows is reduced as a result of the improved k-value and the temperature on the inside of the windows is increased. When the cold radiation from the windows is reduced, the temperature can be reduced without the room feeling colder.

6.1.3 Supplementary insulation of joist structures, external walls, etc.

The energy savings in the form of reduced transmission losses which can be achieved by supplementary insulation can be calculated by the following relationship

$$W = \Delta k \times Q \times A$$

W = energy savings in kWh per year

$\Delta k = k_{before} - k_{after}$, i.e. the difference in thermal transmission coefficient before and after supplementary insulation, $W/m^2\,^oC$

(63)

Q = number of degree hours per year divided by 1000

A = the area provided with supplementary insulation in m^2 excluding windows, doors, etc..

The difference in thermal transmission co-efficient, Δk, is an expression of the improvement of the wall's thermal insulation as a result of supplementary insulation. Approximate thermal transmission co-efficients before supplementary insulation, k_{before}, can be extracted from tables 2.1, 3.2 and 4.1 for some common structures. The thermal transmission co-efficient after supplementary insulation, k_{after}, can be calculated from figure 6.2.

The number of degree hours depends on the outdoor and indoor temperatures and the duration of the heating season. By dividing the country into four zones, as shown in figure 6.1, (division in accordance with SBN -75) and assuming that the indoor temperature is 20°C, it is possible to assume the following approximate values for the number of degree hours.

Zone	Q at an indoor temperature of 20°C
I	163
II	130
III	110
IV	98

Figure 6.1 Degree hours (in thousands)/year for zones I-IV with an indoor temperature of 20°C.

More accurate Q values for different indoor temperatures and areas can be extracted from Klimatdatabok för Sverige (14) or VVS-handboken (15).

<u>k-values after supplementary insulation:</u>

The structure's k-value after supplementary insulation can be calculated from the following relationship:

$$k_{after} = \frac{1}{M_{tot}}$$

$$M_{tot} = \frac{1}{k_{before}} + m_t$$

M_{tot} = total thermal resistance in m^2°C/W

M_t = thermal resistance of supplementary insulation in m^2°C/W

The thermal resistance of supplementary insulation varies according to design and insulation thickness.

In the case of fully-fitted insulation, m_t is obtained from:

$$m_t = \frac{d}{\lambda n}$$

d = thickness of supplementary insulation in metres
λn = material's thermal transmittance in W/m°C for practical purposes

In the case of sheet metal profiles, the following is used:

$$k_{after} = \frac{1}{M_{tot}} + \Delta k$$

$$M_{tot} = \frac{1}{k_{before}} + \frac{d}{\lambda n}$$

Δk = addition resulting from the cold bridge caused by the metal profile in W/m²°C

The following applies for mineral wool between wood battens

$$m_t = \frac{1}{\frac{P\alpha}{m\alpha} + \frac{P\beta}{m\beta}}$$

$P\alpha$ $P\beta$ = percentage of insulation and percentage of timber frames respectively in relation to the whole area.
$m\alpha$ $m\beta$ = thermal resistance (d/λ) in m² °C/W for the insulation and timber frames respectively

The k-value of the structure depends on the thermal transmittance factor λ of the material used. The material's λ value can vary quite considerably. The λ values which can be used for calculations are indicated in Swedish Building Standard 75, Chapter 33:5K.

An approximate k-value for supplementary insulated walls can be obtained from figure 6.2 in the case of fully-fitted mineral wool insulation and for mineral wool insulation between metal profiles and timber frames respectively with c = 600 and 1200 mm respectively. Interpolation and extrapolation for other spacing is possible. In the case of normal metal profiles, it is assumed that the cold bridge between the profiles and the facing material is broken by a strip of wood fibre board or similar material. The diagram in figure 6.2 provides sufficient accuracy for most cases for practical calculations, bearing in mind the difficulty in obtaining a correct initial k-value.

Fully-fitted insulation
One square = 10 mm insulation

Example:
95 mm supplementary insulation

0.1 0.2 0.3 0.4 0.5 0.6 0.6 0.8 0.9 1.0 k-value

Figure 6.2 Diagram of k-values as a function of supplementary insulation thickness.

The following applies for timber frames and steel profiles: $k_{after} = k_{fully-fitted} + \Delta k$

Δk_{timber}

Insulation thickness	C 600	C 1200
t_2=0	0.04	0.02
t_2=0.5t	0.02	0.01

Δk_{steel}

Insulation thickness	C 600	C 1200
t_2=0	0.20	0.10
t_2=10-15 mm	0.16	0.08
t_2=0.25t	0.08	0.04
t_2=0.5t	0.04	0.02

Linear interpolation is applied for other frame spacings and insulation thicknesses.

Example. Supplementary insulation using 95 mm mineral wool between timber frames c 1200, k_{before}=0.8 W/m^{2o}C.

Follow the 0.8 line up from the horizontal axis. Draw a line up to the curve and then across to the vertical axis. Count 9.5 squares up on the vertical axis (=95 mm supplementary insulation). Then go back to the curve and where this meets, go down to the horizontal axis.

Read off k=0.29=$k_{fully-fitted}$

Addition for frames Δ k according to table above = 0.02

k_{after}= 0.29 + 0.02 = 0.31 W/m^{2o}C.

6.2 Experience

Monitoring of supplementary insulation is documented only to a limited extent. There are many difficulties in carrying out this type of evaluation. The problems include the difficulty in elucidating initial data, the k-value of the existing structure, energy consumption over a long period prior to measures carried out etc. Furthermore, ther are difficulties in carrying out measurements and uncertainties occurring during the actual measurement. Furthermore, different energy saving measures are frequently combined. For example a boiler may be adjusted in conjunction with supplementary insulation of a joist structure. This means that it may be difficult to ascertain the true effect of a specific savings measure.

Inferior results to those expected as a result of different technical measures may be due to the fact that the heating system was not adjusted after the application of technical measures. This means that the room temperature has simply increased so that the expected savings have not been achieved. Other reasons may be badly carried out work, for example draughts between supplementary insulation and the old wall.

The Industrial Group for Construction Engineering (16) carried out monitoring in 1977. This showed that the savings effect, calculated in accordance with 6.1.3, were exceeded by 0-50%. Reasons for the variation depended on the state of the initial structure and the life styles of the occupants.

A technical explanation of the additional effects can be attributed to the following related factors discussed in section 3.2:

- Tighter facade coverings
- Fewer cold bridges
- Dryer walls
- Warmer inner surfaces
- Reduced air temperature indoors (as a result of the others)

A thesis presented to CTH in 1978 - External supplementary insulation to facades of small detached houses (17) gave evidence of the same tendency, i.e. the effects of supplementary insulation were often greater than expected. To quote an example, 20 detached houses achieved energy savings of 168,000 kWh/year instead of the expected 87,500.

Another thesis presented to KTH in 1978 - The effects of energy saving measures (18)-noted certain additional savings as a result of supplementary insulation in multi-family houses. Combinations of different measures were common in the buildings studied in this investigation.

Evaluations carried out on a more official basis indicate the same tendencies.

The calculated energy savings as a result of improved k-values, constitute, with few exceptions, the lower limit of the true effect.

Work concerned with the monitoring of energy saving measures is going on all the time since it is important for the country's economy and energy supplies to invest in the most profitable energy saving measures in the future.

7. COST EFFECTIVENESS AND PAYBACK PERIODS

Different methods can be used to determine the most economic supplementary insulation thickness.

The optimum economic insulation thickness can be determined according to the cost effectiveness and payback period method, originally proposed by Professor Bo Adamson. The optimum economic insulation thickness is normally greater than the building standard's minimum requirements. The cost effectiveness and payback period method is based on comparison of the investment cost,and possibly the capital maintenance cost,with the total energy saved during the lifetime of the building. Cost effectiveness is defined as:

$$\text{Cost effectivness} = \frac{\text{investment cost}}{\text{total energy savings}}$$

Cost effectiveness must be compared with the price of energy, i.e. the cost of consuming a unit of energy. Future energy cost development and interest (net interest after tax) must be considered in this context. Energy cost development and net interest determine a relation factor which is also dependent on the life of the building. This relation factor is tabulated in table 7.1. The energy cost to be compared is today's energy cost multiplied by this relation factor.

An energy saving measure is cost effective as long as the cost of saving energy is lower than the corrected cost of energy, i.e.

$$\frac{\text{Investment cost + maintenance cost}}{\text{Annual energy savings x life of building}}$$

$$\leqslant \text{relation factor x current energy cost.}$$

If the remaining life of the house is 30 years, the net interest 5% and the annual energy cost increase is assumed to be 7%, the relative value of a future energy savings is 1.358 x today's energy cost. Using an energy cost of 15 öre/kWh, the cost of energy savings must not exceed 15 x 1.358 = 20.37 öre kWh.

Life of building 30 years

Annual energy cost increase in %	Interest					
	3	4	5	7	10	15
3	1.000	0.864	0.752	0.585	0.422	0.276
4	1.166	1.000	0.865	0.663	0.470	0.300
5	1.366	1.164	1.000	0.758	0.527	0.327
7	1.905	1.601	1.358	1.000	0.670	0.395
10	3.242	2.677	2.227	1.579	1.000	0.540
15	8.394	6.766	5.489	3.687	2.142	1.000

Life of building 20 years

Annual energy cost increase in %	Interest					
	3	4	5	7	10	15
3	1.000	0.905	0.822	0.687	0.538	0.382
4	1.108	1.000	0.906	0.752	0.584	0.409
5	1.231	1.107	1.000	0.825	0.638	0.440
7	1.528	1.386	1.226	1.000	0.758	0.511
10	2.141	1.898	1.689	1.354	1.000	0.548
15	3.862	3.381	2.972	2.321	1.548	1.000

Figure 7.1 Relation factor for building life of 20 and 30 years for varying net interest rates and energy cost increases.

Average and marginal cost of saving energy

The effect of each centimetre of insulation decreases with thickness. It is most economic to increase the insulation thickness so that the last centimetre fulfils the interest requirement precisely.

(71)

The marginal costs of saving energy can be obtained by calculating the cost of saving energy stage by stage. From a practical point of view it is best if 20-30 mm insulation is added for each stage. For maximum profit, the marginal cost of saving energy must be the same as the current energy price. This determines the economic optimum thickness. When the optimum insulation thickness has been determined, the total profitability of the measures is checked by calculating the average cost of saving energy. In the case of profitable measures, this is always lower than the marginal cost of saving energy. The following applies in general:

> The marginal cost of saving energy determines the insulation thickness.
>
> The average cost of saving energy determines the profitability.

The method for calculating the cost of energy savings is described in more detail in Swedisols publication "Det lönar sig att isolera mera" (19).

8. Calculation examples

8.1 Specification of examples

The object being considered is a three storey apartment building built in the 1950's. The house is situated in zone III. The building's dimensions are length = 34.5 m, width = 9.0 m, height = 8.0 m. It comprises 12 flats.

The walls comprise 250 mm cellular concrete + plaster with a calculated k-value of 0.8 W/m^2 ^{o}C. The total external wall area provided with supplementary insulation is 530 m^2.

The roof joist structure comprises 200 mm cellular concrete and 30 mm mineral wool. The structure's k-value is calculated as 0.5 W/m^2 ^{o}C. The total area accessible from the outside is 280 m^2.

The windows comprise 84 inward-opening double-glazed windows. The total frame area is 130 m^2, the glazed area is 105 m^2. The k-value is calculated as 3.0 W/m^2 ^{o}C. Weatherstripping is made up of textile strips. Twelve doors have glazed panels.

8.2 Tightness of windows and doors

Weatherstripping comprises older textile strips with inferior sealing qualities. Replacing weatherstripping and adjusting all windows and glazed doors is expected to reduce the air change rate by 0.2 changes/h. According to 6.1.1 this gives an annual energy savings of

0.2 x 34.0 x 8.5 x 2.4 x 3. x 0.36 x 110 = 16,480 kWh/year.

Based on an energy cost of 15 öre/kWh, this gives savings of 2,470 Crowns/year. The cost per flat is assessed as 450 Crowns, or 5,400 Crowns in total. Energy saving grants amount to 150 Crowns/flat, or 1800 Crowns. The service life of the measures is assessed as 10 years.

8.3 Supplementary glazing

Windows not only constitute a source of energy losses but also require a considerable amount of maintenance. External maintenance painting of windows currently costs approximately 275 Crowns and must be repeated every 5-10 years.

In the building in question, the external frames of a double-glazed window were replaced by a double-glazed insulation panel discussed in 1.4.4 and at the same time the external frame woodwork was covered with a factory-painted sheet metal profile. Using 6.1.2, the energy gains per year are

$$(3.0 - 2.0) \times 105 \times 110 = 11{,}550 \text{ kWh/year}$$

Applying an energy cost of 15 öre, this corresponds to 1,730 Crowns/year. The cost of fitting is 350 Crowns/m^2 or 45,500 Crowns. The energy savings grant (approved cost) amounts to 250 Crowns/m^2 or 32,500 Crowns. The reduced costs for painting are 275 Crowns/window based on 0.7 x 15 and 22 years if we assume a 30 year period. This means 23,100 Crowns each time or a total of 92,400 Crowns over a 30 year period.

8.4 Supplementary facade insulation

The building was provided with supplementary external insulation and was covered with facade cladding on timber frames with a spacing of c = 1200 mm (framework approximately 5% of area).

In order to arrive at an optimum insulation thickness, thicknesses of 45, 95, 145 and 195 were studied (95 mm is currently the minimum approved thickness for loans and grants). In the case of 145 and 195 mm, the insulation was applied in two thicknesses with an external fully-fitted layer of 50 and 100 mm respectively.

The remaining life of the building was assumed to be 30 years. Q = 1110 (see figure 6.1). The total building cost is assumed to be 220, 240, 260 and 290 Crowns/m^2 for the insulation thicknesses studied (assumes an approximate cost for supplementary insulation including facade cladding).

The k-values after the measures are carried out are extracted from figure 6.2. The k-value for 95 mm insulation is already described in the diagram, the others are shown in table 8.1. The table also shows the energy consumption for the different thicknesses. In the case of 95 mm insulation this is:

$$W = k \times Q \times A \text{ kWh/year}$$

$$W = 0.31 \times 110 \times 530 = 18{,}000 \text{ kWh/year}$$

	Supplementary insulation mm				
	-	45	95	145	195
k-value $W/m^2\ {}^oC$	0.80	0.45	0.31	0.22	0.19
$m_t\ m^2/W^oC$	0	0.98	1.98	3.30	4.00
Building cost Crowns/m^2	-	220	240	260	290
Energy consumption kWh/year	46,600	26,200	18,000	12,800	11,100

Table 8.1

The cost of saving energy (see section 7) is calculated for 95 mm insulation as:

$$\frac{\text{Investment}}{\text{Savings}} = (\text{öre/kWh})$$

$$\frac{240 \times 10^2 \times 530}{(46{,}600-18{,}000) \times 30} = \frac{1272 \times 10^4}{85.8 \times 10^4} = 14.8 \text{ öre/kWh}$$

The marginal cost of saving energy for the step between 95 and 145 mm is:

$$\frac{(260-240) \times 10^2 \times 530}{(18{,}000-12{,}800) \times 30} = \frac{106 \times 10^4}{15.6 \times 10^4} = 6.8 \text{ öre/kWh}$$

The average and marginal costs of saving energy respectively are illustrated in table 8.2.

Cost of saving energy öre/kWh	Supplementary insulation mm 0	45	95	145	195
Average		19.0	14.8	13.6	14.4
Marginal		19.0	4.3	6.8	31.0

Table 8.2

The current energy price can be assumed to be 15 öre/kWh, the interest 8% and the increase in energy costs 8%. Thus using table 7.1 in section 7, the relative value of future energy savings is 1.0 greater than the current cost of energy. Therefore the cost of saving energy must be compared with:

$$15 \times 1.0 = 15 \text{ öre/kWh}$$

145 mm insulation is therefore the optimum thickness in this case since the step between 95 and 145 is the "last which is profitable" i.e. this is less than the comparison price of 15.0 öre/kWh.

The average cost of saving energy is of the same magnitude as the "comparison costs", despite the fact that the whole of the building cost is taken up by the insulation. This is not always correct since the effect of new cladding, better acoustic insulation, etc. should also be included in the calculation. If facade renovation is necessary, irrespective of supplementary insulation, only the cost of insulation should be included in the cost of saving energy. This then becomes considerably less than that calculated above.

Using 145 mm supplementary insulation saves 33,800 kWh/year. This corresponds to 4.8 m^2 oil (1 m^2 oil corresponds to approximately 10,000 kWh) if efficiency is assumed to be 70%.

The building cost in the example is:

$$260 \times 530 = 137{,}800 \text{ Crowns}$$

Loans and grants are provided for supplementary insulation. Using the regulations applicable in July 1979, we get:

Using 145 mm supplementary insulation, the approved cost for a Government energy saving loan and grant is:

Insulation:	$m_t \times 20 + 70$	136 Crowns/m^2	(grant base)
Cladding, sheet metal:	80 Crowns/m^2	80 Crowns/m^2	(not applicable to grant)
	Total	216 Crowns/m^2	

Total approved cost 530 x 216 - 114,480 Crowns.

8.5 Supplementary insulation of roof joist structures

Roof joist structures are accessible from above. The optimum thickness is calculated in the same way as for external walls. Here we have chosen to study 100, 200, 300 and 400 mm at costs of 30, 45, 60 and 75 Crowns/m^2 respectively.

The k-values for the different alternatives are given in table 8.3. The average and marginal costs of saving energy are shown in table 8.4.

		Supplementary insulation mm				
		0	100	200	300	400
k-value	W/m^2 ^oC	0.50	0.24	0.15	0.11	0.09
m_t	m^2 ^oC/W		2.20	4.70	7.10	9.10
Building cost	Crowns/m^2		30	45	60	75
Energy consumption	kWh/year	16,520	7,930	4,960	3,640	2,975

Table 8.3

Cost of saving energy öre/kWh	Supplementary insulation mm 0	100	200	300	400
Average		3.3	3.6	4.4	5.2
Marginal		3.3	4.8	10.6	21.0

Table 8.4

15 öre/kWh is the comparison cost as in the case of the walls, which means that 300 mm is the optimum insulation thickness.

The energy savings are (16,520 - 3,640) = 12,880 kWh/year.

The building cost is 60 x 280 = 16,800 Crowns.

For 300 mm supplementary insulation the approved cost for Government energy saving loans and grants is:

$$m_t \times 10 + 20 = 91 \text{ Crowns/m}^2$$

Total approved cost: 280 x 91 = 25,480 Crowns

8.6 Finance

Alternative 1

We will assume that the facade is in very good condition and that the windows are not in direct need of renovation. The building owner chooses to insulate the roof joist structure and carry out "general sealing" of windows and doors.

Measure	Cost Crowns	Approved cost Crowns	Savings kWh/year	Savings Crowns/year*)
Sealing windows, doors	5,400	1800	16,480	2,470
Roof joist structure	16,800	25,480	12,880	1,930
Total	22,200	27,280	29,360	4,400

*) energy cost of 15 öre/kWh

Table 8.5

Government grant: 35% of approved cost = 9550 Crowns
(Maximum 3000 Crowns/flat).

Government loan: Approved cost - grant = 17,730 Crowns

Alternative 2

We will assume that the facade is in immediate need of renovation and that the windows need repairing. The building owner has decided to carry out supplementary insulation of the facade and windows and to cover the outside of window frames with sheet metal as well as the proposed measures for roof joist structures windows and doors indicated in alternative 1.

Measure	Cost Crowns	Approved cost Crowns	Savings kWh/year	Savings Crowns/year[1)]
Sealing windows, doors	5,400	1,800	16,480	2,470
Roof joist structure	16,800	25,480	12,880	1,930
Supplementary insulation of windows	45,500	32,500	11,550	1,730[2)]
Supplementary insulation of facade 3)	137,800	114,480	33,800	5,070
Total	205,500	174,260	74,710	11,200

1) Energy cost of 15 öre/kWh.
2) Savings through reduced maintenance painting of windows, resulting from the covering of external timber frames, is assumed to be 3,000 Crowns/year
3) Including new facade cladding.

Table 8.6

Government grant: 35% of approved cost
Maximum 3,000 Crowns/flat = 36,000 Crowns
Government loan: Approved cost - grant = 138,260 Crowns.

All the measures indicate profitability. The savings effects for the measures illustrated here can be costed. Despite this, the example in alternative 2 indicates that the Government loan and grant regulations do not cover the whole of the cost whereas this was the intention of the measures for supporting energy savings.

It should however be pointed out that the costs in the example are very approximate and refer to work and materials. Some of the costs could be kept down by carrying out "do-it-yourself" work.

9. Loans and grants for energy savings

The Code of Statutes issued by the Ministry of Housing and Local Government, BOFS 1979:30 EN4,details loans and grants available for different energy saving measures in dwellings, etc. The following amendments were introduced as of July 1, 1979:

The requirements for an existing wall's k-value are more stringent with regard to thermal insulation. Support is only given for supplementary insulation of such external walls where $k \geq 0.7$ W/m^2 ^{o}C in southern Sweden (zones III and IV) and $k \geq 0.6$ W/m^2 ^{o}C in northern Sweden (zones I and II).

In order to get a grant or a loan it is necessary to apply supplementary insulation which corresponds to at least 100 mm mineral wool (A quality) or corresponding.

The standard allowance for supplementary insulation of walls has been increased according to $m_t \times 20 + 70$ Crowns/m^2.

Loans for facade cladding are normally only granted if the k-value requirements for external walls according to SBN 75 are satisfied. Energy saving grants are not made.

Support in conjunction with other measurements, approved for support, is given at the rate of 150 Crowns/flat for sealing windows and doors with approved weatherstripping in multi-family houses.

For fitting triple glazing or similar improvements, the approved cost is 250 Crowns/m^2 (window area, external frame measurements).

Energy saving support is given in the form of loans and grants. Grants amount to 35% of the approved cost and are limited to 300 Crowns/flat. The rest of the approved cost can be borrowed. The interest on these loans is subsidised in the case of multi-family houses if the approved cost is 25,000 Crowns or greater. The Government has discontinued the earlier interest subsidy for small detached houses.

The Ministry of Housing and Local Government's information on energy saving loans and grants for houses and certain areas is attached as appendix 9.1.

Further information on energy saving loans and grants can be obtained from Local Authorities or County Housing Authorities.

SUPPLEMENT 9:1

Information from the Ministry of Housing and Local Government regarding energy saving loans and grants for houses and certain other buildings.

Valid from 1980-01-01

You can get a grant of up to 3000 Crowns/flat if you improve the energy economy of your house. Furthermore, you can apply for a Government loan. In order to be able to get a loan and a grant, the approved cost must be a minimum of 1500 Crowns.

Information and application forms are available from the Council. Applications are also made to the Council.

Holiday homes excluded

Loans and grants are available for small detached houses and multi-family houses. In certain cases it is also possible to get support for buildings connected with dwelling houses. Buildings which do not need any considerable amount of heating are not eligible for support. A housing association can, in certain cases, get support for a communal building. Permanent dwellings are eligible for support but this does not apply to holiday homes.

Real energy savings

Another condition is that the measures do result in real energy savings. External supplementary insulation of external walls and roof joist structures must correspond to at least 10 cm mineral wool A quality or 10 cm foam plastic.

Houses which already have acceptable insulation are not eligible for grants or loans for further supplementary insulation and improvements.

Apply in good time!

Work must not be commenced before the County Housing Department has reached a decision or given dispensation to commence the work. It is therefore necessary to apply in good time.

Approved cost

Loans and grants are calculated on the cost approved by the County Housing Department. Basic amounts have already been calculated for most measures. This means that you only get support according to the basic amount even if the work costs more. If there is no basic amount calculated, the County Housing Department will calculate the approved cost.

An example for a small detached house

This is the approved amount which was applicable 1/1 1980. This might have changed if you apply later.

Central heating

Fitting central heating	maximum 15,000 Crowns

Electric heating

Control equipment for direct electrical heating	1,000 Crowns
Night storage of hot water	500 Crowns

Heating controls etc.

Motor shunt valve for external sensors and time control	2,500 Crowns
Type-approved thermostatic radiator valves	125 Crowns
Circulation pump (in conjunction with heat control)	500 Crowns

Wood-fired heating

In order to get support it is normally necessary for free fuel to be available.

A boiler which requires refilling no more than 2 - 3 times/day	maximum 10,000 Crowns

Heat pump, type-approved/or corresponding approval

Heat pump for year-round operation	maximum 24,000 Crowns
Heat pump for at least half year's operation	maximum 14,000 Crowns

Solar heating

System for hot water	maximum 8,000 Crowns

Heat recovery

For example ventilation heat exchanger	7,000 Crowns

Wood chip firing

Stoking device with thermostatic controls	maximum 8,500 Crowns
Pre-heater with a reservoir of at least 300 litres	maximum 4,000 Crowns

Supplementary insulation

The amount depends on the amount of supplementary insulation, for example:	10 cm mineral wool (A quality)
Roof joist structure	40 Crowns/m^2
Floor joist structure	75 Crowns/m^2
External walls	110 Crowns/m^2

Facade covering

Facade covering is only eligible for loans and not grants. Facade coverings are normally only eligible if the supplementary insulation is such that the new building requirements in Swedish Building Standard 1975 are fulfilled.

Sheet metal cladding, facade sheets	80 Crowns/m^2
Timber panels	100 Crowns/m^2
Thick plaster	120 Crowns/m^2
Brick work facade	140 Crowns/m^2

Sealing with injected foam plastic

Joist structure edge	25 Crowns/meter
Joist structures above access spaces or external walls	30 Crowns/m^2

Triple glazing

or similar improvements	250 Crowns/m^2

(m^2 = window area, external frame measurements)

Energy saving grants

Energy saving grants amount to 35% of the approved cost. The maximum grant is 3,000 Crowns/flat. You can get either grants or grants together with energy saving loans.

Those who get improvement loans for energy savings can get a greater interest and mortgage-free proportion of the loan instead of energy saving grants. See improvement loans.

Energy saving loans

Energy saving loans can be given for that part of the approved cost which is not covered by an energy saving grant. No collateral is required for loans up to 20,000 Crowns. A Council guarantee or a mortgage is required for higher loans.

The maximum mortgage period for loans is 20 years. This is an annuity loan: i.e. the sum of the interest and the mortgage payments is approximately the same each year over the period of the loan. In this way the annual mortgage repayment is small in the beginning and increases over the years. If the energy saving loan is combined with the Government Housing loan for any other type of rebuilding, the energy saving loan has the same mortgage period as the housing loan.

The interest is determined each year (11%, 1980).

In the case of multi-family housing, an interest grant is made if the cost exceeds 25,000 Crowns or if the total cost is over 25,000 Crowns for the energy saving loan in combination with the Government housing loan.

Interest is not deductible for energy saving loans applicable to small detached houses but is applicable for Government loans for new or renovation building (see Government Housing loans).

In certain cases it is possible to get an advance on a loan.

Government housing loans

Government housing loans are given for new and rebuilding. If you plan to extend the building and improve the house's heating economy, you can combine the energy saving loan with the building loan when rebuilding.

A mortgage is required as collateral for a Government housing loan. In certain cases a guarantee from the Council is acceptable. The approved rebuilding cost must be at least 10,000 Crowns in the case of small detached houses and 25,000 Crowns for multi-family houses.

The housing loan plus mortgage loan, or in certain cases only the housing loan, can cover up to 100% of the approved cost of rebuilding. * If the mortgage loan is insufficient, the Government loan can be increased/extended. The approved cost is determined by the County Housing Department.

The maximum period for the housing loan is 30 years (a maximum of 20 years for small detached houses in certain cases). The loan is a mortgage loan (see explanation under energy savings loan). The interest is determined each year (11% 1980). If the approved rebuilding cost is more than 25,000 Crowns, an interest grant is given which covers part of the interest costs (applies also to the 25,000 Crowns). The housing loan is paid out when the work is finished. It is however possible to get an advance on the loan in certain cases.

Home improvement loans

Government improvement loans are granted after a means test to people who have reached the age of 60 years, those who have pre-retirement pensions, handicapped people etc. The loan can be used to improve the dwelling and for energy saving measures. Only those with low incomes are eligible for home improvement loans. The net assets of the person concerned must not exceed 100,000 Crowns.

The cost of interest and payments are low or non-existent. A person granted a home improvement loan is not eligible for an energy savings grant. Instead the proportion of the loan which is not subject to interest or mortgage repayments amounts to a maximum of 6,000 Crowns. More information regarding home improvement loans can be read in the publication issued by the Ministry of Housing and Local Government, "Förbättringslån till småhus", available from the Council or the County Housing Department.

It is also possible to get support for energy saving measures in

General community buildings (application is made to the Housing Department's Communal Building Delegation).

Communal and County Council Buildings (application is made to the Housing Committee).

NB. Different regulations apply to these buildings.

* In certain cases, the housing loan plus mortgage loan can cover more than the rebuilding cost in multi-family houses. More information is given in "Lån och bidrag till ombyggnad av bostäder" available from the Council or the County Housing Department.