Improving thermal insulation of concrete sandwich panel buildings

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Outline

• A general reduction of CO$_2$-emission requires, among many other initiatives, a reduction of the heat loss from existing buildings

• Good technical solutions are developed for typical Danish building types

• Solutions for concrete sandwich panel buildings will be presented

• A simple but accurate method for estimating the energy saving is described
Thermal bridges often ignored until 2001.

Single glazing formally allowed until 1972.

More severe requirements to lightweight walls until 1995.

All buildings older than 30 years are completely outdated!
EPBD in DK for existing buildings
(EPBD = Energy Performance Building Directive)

The Danish Building Regulations states that:

- When major works are carried out insulation should be improved to today's level for new buildings
- But only if it is profitable to the owner and/or tenants
- And profitability is estimated with quite conservative assumptions regarding service life and interest

Improvement of insulation of existing buildings therefore requires positive engagement of owner and tenants
Concrete sandwich panel buildings

• Main construction type 1960's and 70's in Denmark
• Invented to reduce need for skilled craftsmen
• Similar to many buildings in other European countries
• Insufficient insulation, about 100 mm
• Severe thermal bridges
• Windows worn out
• Roofs needs attention
• Facades not appreciated
• Social problems in neighbourhood
Increased insulation

General problems

• Thicker walls increases depth of window opening reveal and therefore daylight level
• Temporary inconvenience for the tenants

Inside insulation:

• Reduces living space
• Risk of condensation in insulation
• Temperature of original structure decreases, which might cause degradation due to moisture
Outside insulation - advantages

- Eliminates most thermal bridges and thereby risk of mould growth
- Living space not reduced
- No need for evacuating tenants during works
- Installations need no change
- Protects original structure
- For concrete sandwich buildings: Unattractive appearance can be improved
Wall-floor, before, vertical section

- Sandwich wall with 80 – 100 mm insulation
- Reduced insulation along floor
- Water penetration in vertical joints
- Insulation in joints might be missing
Wall-floor, after, vertical section

- Outside insulation with vertical studs, wind breaker and rain screen
- Thermal bridge along floor eliminated
- Penetration of rain can be eliminated
Wall-window, before, horizontal section

- Insulation in wall reduced to 10 mm around window
- Window pane positioned almost ideally
Wall-window, after, horizontal section

- New windows positioned traditionally and ideally near to the outside
- Size is increased
- Simple sealing
- 10 mm insulation at end of outer slab and lining of reveal required
Wall-roof 1, before, vertical section

- Concrete roof slab with roofing felt and 100-150 mm insulation
- Connection to wall insulation can be ideal
- Moisture penetration might cause condensation in roof insulation
Wall-roof 1, after, vertical section

- Outside insulation should be connected to roof insulation, also to avoid condensation
- Original roofing felt acts as water vapour barrier
Wall-roof 2, before, vertical section

- Using standard wall element requires separate roof edge
- Corner not insulated
- Severe risk of condensation and mould growth inside
Wall-roof 2, after, vertical section

- Concrete roof edge element removed
- Ideal connection of insulation
- New water vapour barrier at critical spot
Wall-floor slab 1, before, vertical section

- Floor slab on ground with 50 – 70 mm insulation above (or below) the concrete
- Corner not insulated
- Severe risk of condensation and mould growth inside
- Similar problems if basement
Wall-floor slab 1, after, vertical section

- Insulation of plinth 300 mm below ground surface
- Connects outside and original insulation of wall
- But direct connection to the ground
Wall-floor slab 2, before, vertical section

- Sometimes insulation on outside of plinth, connected to wall insulation
- But direct connection to the ground
Wall-floor slab 2, after, vertical section

- Insulation of plinth connects outside and original insulation of wall
- Increased thickness of no importance due to direct connection to the ground
Estimating supplied energy

A major mean for implementing EPBD in Denmark is a PC-programme (Be06), which calculates the need for supplied energy, taking into account:

- transmission loss through the building envelope
- solar gain including shadows
- heat from people and appliances (based on floor space)
- hot water consumption (based on floor space)
- need for cooling if temperatures above 26 °C
- effectiveness of boilers and installations
- solar panels, heat exchangers, heat pumps
- electricity is multiplied by 2.5
Saving of supplied energy after insulation

- Key information for estimating profitability
- Can be calculated with the programme Be06 if the building is modelled before and after the insulation
- Programme required because of influence of eg. solar gain
- Easy general estimation of the saving connected with improvement of each building component wanted, like $Q_{\text{roof}} = Q_{\text{roof, original}} - Q_{\text{roof, improved}}$
- (eg. should the insulation on the roof be increased by 100 or 200 mm)
Building components
Method for general estimation

- "Typical" building is modelled by the programme before and after insulation
- Sensitivity to change of properties of one building component at a time gives effective heat loss $Q$
  - Increase and decrease gives almost same $Q$
  - Sum of individual changes equals all changes at ones
  - $\Delta Q = Q_{\text{original}} - Q_{\text{improved}}$

<table>
<thead>
<tr>
<th></th>
<th>Total supplied energy S kWh</th>
<th>Change $\Delta S$, kWh</th>
<th>Effective heat loss $Q = \frac{\Delta S}{\Delta A}$ kWh/m$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical building</td>
<td>170 000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wall area + 200 m$^2$</td>
<td>175 167</td>
<td>+ 4833</td>
<td>24,2</td>
</tr>
<tr>
<td>Wall area – 200 m$^2$</td>
<td>165 037</td>
<td>– 4963</td>
<td>24,8</td>
</tr>
</tbody>
</table>
Typical concrete sandwich building

- 3 floors
- 12 m x 50 m
- Floor height 2.8 m
- 120 windows 1,5 m x 1,5 m
- 40% North and 60% South
- Ventilation rate 0,7 times per hour
- Details like previous, type 1 where two types
- Effective heat loss can be presented as tables for different constructions before and after insulation
## Example of savings

<table>
<thead>
<tr>
<th>Component</th>
<th>Area or length</th>
<th>Insulation thickness</th>
<th>Effective heat loss, Q kWh/m² or kWh/m²</th>
<th>Total saving kWh/year</th>
<th>Saving per m² floor space kWh/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Original</td>
<td>Improved</td>
<td>Original</td>
<td>Improved</td>
</tr>
<tr>
<td>Wall</td>
<td>790 m²</td>
<td>80 mm</td>
<td>80+145 mm</td>
<td>42,0</td>
<td>12,6</td>
</tr>
<tr>
<td>Floor edge</td>
<td>248 m</td>
<td>80–40 mm</td>
<td>40+145 mm</td>
<td>16,0</td>
<td>2,2</td>
</tr>
<tr>
<td>Windows</td>
<td>270 m²</td>
<td>U= 2.7 W/m²K</td>
<td>U=1.5 W/m²K</td>
<td>104,9</td>
<td>20,7</td>
</tr>
<tr>
<td>Win. reveal</td>
<td>720 m</td>
<td>-</td>
<td>10 mm</td>
<td>25,3</td>
<td>1,1</td>
</tr>
<tr>
<td>Roof</td>
<td>600 m²</td>
<td>100 mm</td>
<td>100+200 mm</td>
<td>34,5</td>
<td>9,8</td>
</tr>
<tr>
<td>Roof edge 1</td>
<td>124 m</td>
<td>-</td>
<td>-</td>
<td>-9,0</td>
<td>0,8</td>
</tr>
<tr>
<td>Ground floor</td>
<td>563 m²</td>
<td>50 mm</td>
<td>50 mm</td>
<td>33,4</td>
<td>29,5</td>
</tr>
<tr>
<td>Plinth 1</td>
<td>124 m</td>
<td>0</td>
<td>145 mm</td>
<td>65,2</td>
<td>34,0</td>
</tr>
<tr>
<td>Sum</td>
<td>1800 m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- \( Q_{\text{window}} \)'s represent difference between larger numbers
- Negative Q due to Danish rules for attribution loss to components
- 48 kWh/m² = 72 before – 24 after
Conclusions

• Outside insulation of concrete sandwich buildings from 1960's and 70's can be efficient both regarding durability and energy performance

• The insulation standard can become close to today's requirements by reasonable means

• The concept of "Effective heat loss" enables
  1. To break down the total energy saving into saving related to each building component
  2. To estimate values valid for quite different geometries of buildings based on the same construction technique
Saving of supplied energy after insulation

- Key information for estimating profitability
- Transmission loss and ventilation loss is determined from U-values, degree-days and ventilation rate
- Supplied energy for heating
  = transmission loss + ventilation loss
  – efficiency factor x "free energy"
  ("free energy" = solar gain + heat form people + appliances)
- Usable "free energy" covers a larger part of the loss after insulation =>
  Supplied energy is reduced more than transmission loss