TREES **Training for Renovated Energy Efficient Social housing**

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Section 1 Techniques

1.1 Insulation and Thermal Bridges

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1. Introduction

For some decades past, it has been very natural to us to heat our houses with immense energy quantities. Now, since energy prices have risen more and more counting with an increasing demand and shortage at the same time, we have been realizing that there is an alternative way to provide comfortable room temperatures:

Instead of allowing heat to drain off in huge flows through the building case and escape outwards, and then being „refilled“ by as voluminous heat quantities, we also reach our aim if we reduce the loss of heat to a tolerable minimum by an intelligent design of the construction parts. This does not only lower the energy consumption for (after-) heating to a justificable future-fit standard; it also opens the chance to use renewable energies at a large scale.

The thousands of projects of new building and old building renovation which were successfully realised showed that the target of 80 to 90 percent energy savings will only be reached if the thermal protection will be well dimensioned but also correctly planned and implemented according to the building physics.

2. Insulation Materials and their features

2.1 Thermal Conductivity of Insulation Materials

Insulation materials have a considerably lower thermal conductivity than construction materials. In case of most insulation materials, the low thermal conductivity of stagnant air is utilized. The smaller the air chambers in fibre materials or the pores in foamed materials, the lower the thermal conductivity of the entire insulation material. There are further influences due to the material properties of the substance which forms the air chambers, in a way being the supporting structure for the air chambers: its volume share and thermal conductivity.

The thermal conductivity is indicated by the Greek letter λ (lambda). Its value expresses how much energy flows (in Watt) through a 1 m thick test material, if the difference of temperature between warm and cold side is 1 Kelvin (equal 1°C). Besides this physical value, the specification in thermal conductivity classes has been adopted for daily use (e. g. WLG 040 means 0.040 W/(m·K) respectively 40 mW/(m·K)).

The largest range is found at the wide field of natural insulation materials (40…90 mW/(m·K)); but in the upper range (> 50 mW/(m·K)), materials as mineral bound wood wool should only be used as form boards if needed.

On the other hand, materials like cellulose, wood fibre, flax and hemp are absolutely equivalent to synthetic insulation basic versions referring to their thermal conductivity.

Mineral foam is cellular concrete with a high porosity reaching a thermal conductivity of 45 mW/(m·K) (comparison: „normal“ cellular concrete has not less than a threefold thermal conductivity).

The values of mineral wool (rockwool, glass wool) and polystyrene (35…45 mW/(m·K)) vary corresponding to the fineness of the fibril texture or the foam respectively. In case of polystyrenes, there exists a variant since some years which is optimized by graphite powder, thus reducing the thermal change by radiation and lowering the calculated thermal conductivity to 32 mW/(m·K).

In case of polyurethane foam, even lower values down to 25 mW/(m·K) are achieved by foaming with heavy gases instead of air. Diffusion escaping out of the insulation material is impeded by blocking foil (e. g. aluminium).

The ideal insulation material is vacuum having a thermal conductivity at zero. This is nearly realised in evacuated foil panels which are filled with sheets of pyrogenous silica (as „chamber for the void“). However, there remains a thermal conduction by the carrying structure and the case which is assessed in practice at 8 mW/(m·K) by thermal-bridge influence of (optimised) fixation elements and by aging.

2.2 Features of Synthetic and Natural Insulation Materials

Beside thermal conductivities of insulation materials, their density and their fire-safety classes the tables also indicates their moisture behaviour: While natural insulation materials as wood fibre and cellulose are able to absorb in contrast to mineral wool materials, the damp-blocking behaviour of insulation foams of sealed porosity like XPS and PUR is wanted especially at perimeter and flat roof insulation. Some materials for bulk-commodity insulation like cork shred and perlite sometimes show subsidence, thus their application at walls and step roofs is restricted.

The indications of application areas are generally – however, before taking the deciding in favour of an insulation material, the explicit recommendation of the manufacturer in case of a particular item should be verified.

3. Insulation-systems for (Ultra)Low-Energy-Houses

The presented insulation systems are applied as external insulation. External insulations have some advantages over internal insulations:

- The insulation protects the aged carrying construction, i. e. it saves it from high temperature fluctuations and thus extending its durability considerably.
- Normally, external insulations do not cause any problems at the building physics (moisture or vapour diffusion).
- External insulations contribute to avoid or to reduce thermal bridges.
- External insulations are extremely more efficient than optimised internal insulations.
- External insulations do not diminish the net floor space of the building.

3.1 Bonded Thermal Insulation Systems (BTIS)

Also known as Thermoskin or compact facade. Applying BTIS, the insulation material in form of boards will be bonded without gaps onto the external wall. It should be minded that no mortar is to be inserted into the butt joints because of its 20fold thermal conductivity generating a thermal bridge.
In case of old buildings the insulation boards will be dowelled.

Because the new external plaster is exposed to increased temperature fluctuations, a reinforcement tissue is sandwiched into the sublayer of plaster to avoid cracks. As top layer of plaster, several mineral or resin-bonded plasters are offered. A strong shading of the plaster is not recommendable due to high thermic tension.

BTIS are proved and authorized as complete systems in order to guarantee the precise function (e. g. a sufficient adhesion of the glue). Meanwhile, all important manufacturers of insulation systems offer comprehensive informations on application processes which should be already considered ahead of the measures. Particularly to support planners and architects, there are offered partial solutions which serve as basis for further plannings on the own object.

Further, there are different accessories, i. e. mounting elements of high-density PUR facilitating the installation of parts like lamps, railings, porches etc. without thermal bridges. Blocks of impregnated gluelam may also be used.

3.2 (Rear Ventilated) Curtain-Walls

In case of curtain walls an underconstruction will be mounted into which the insulation material in form of web or boards will be jammed (as recommended, slightly oversized). The insulation base will be covered by a plaster-carrying board which itself is covered with reinforced plaster.
As an alternative, insulation materials which are poured or blown into cavities of the underconstruction and plaster-carrying board may be applied (e. g. cellulose fluffs).

If panel material instead of a plaster is to be used as facade surface, rear ventilation will be necessary.

Principally the underconstruction is a thermal bridge at the insulation base. It is absolutely necessary to uncouple it thermically, especially in case of using metal elements in order to avoid a considerable loss of insulating effects. A proper alternative are narrow wooden trusses with considerably reduced thermal-bridge effects.
Compared with the homogeneous insulating layers of the BTIS, thermal-bridge losses of the underconstruction are even higher in case of optimised curtain-walls which can be compensated by 2...4 cm of additional thickness of the insulation material.

Picture on the right: The thermography shows the underconstruction as yellow (=warm) stripes on the blue (=cool) surface of the insulation material. By means of thermal bridges the effective thickness of the insulation material is reduced from 14 to 4 cm! (Such failures discredited high thickness of insulation material as totally unprofitable.)

3.3 Comparison of both systems

The durability of insulation systems can be assessed at 40 years. For decades, initial problems like cracks in the top plaster had been solved constructively; both systems have become mature and proved themselves many thousand times.

BTIS with insulations boards of expanded polystyrene (EPS) form an important share of the market as they are cost-efficient and easy to work. Meanwhile, two negative aspects were eliminated:

- Fire safety or the behaviour in case of fire respectively was improved by insulating the lintels of windows and doors with a stripe of mineral fibre.
- If an improved sound insulation is required, elasticated insulation boards shall be used.

The range of insulating and facing materials is very wide. Therefore, the architectural scope is not impaired. Meanwhile, there are many examples showing the successful integration of high-thickness insulation material into the architecture of a reconstructed building.

3.4 Arguments for High-Insulated Constructions

High-insulated constructions using insulation material of 20 cm thickness (WLG 035) and more are often regarded as exaggeration. But there are several arguments in favour of such solutions:

- The part of insulation material costs is very low (in case of EPS-systems it runs up to approx. one third of the total costs); the main part consists in labour costs and the costs anyway necessary for scaffolding and plaster etc. Also the accurate detail work mounting the insulation is as necessary as in case of „normally“ insulated buildings.
- The economically optimised thickness of the insulation material increases related to energy costs and has been increasing importantly during the last years. A properly mounted insulation endures 40 years and more; therefore, the basis of decision should be the energy costs expected over that duration.
  Besides, the cost optimum runs a very flat curve, i. e. an insulation being „too“ thick only causes little extra costs (due to the above mentioned reasons).
- Vice versa, in case of an insufficient insulation, another (economic) demand of reconstruction will be the result before expiring date. However, later added insulation is not cost-efficient at all.
- In case of high-thickness insulation material, thermal-bridge optimised constructions are easier to realise.
- Even at a high density of inhabitants growing cultures of mould fungus at critical places (e. g. behind garderobes) can only be avoided definitely using a high-thickness insulation material.
- The cooling behaviour of intensively insulated buildings in case of a longer heating blackout is very tempered. The limit of cooling is at approx. 18 to 19 ° C, due to solar and internal thermal gaines, relatively high to the low heat losses.
  Social houses reconstructed in this manner would therefore be well prepared for an extreme case of long-term energy shortages or blackouts.
  That is why this „warmth guarantee“ is more and more a good advertising point!

- The excellent summer heat protection of an intensively insulated building was positively mentioned by the dwellers of many projects. This requires beside the insulation an effective sun protection as well as to guide the inhabitants to a correct user behaviour.

3.5 Amortisation of Fabrication-Energy

A frequent argument against high insulating thickness is the pretendedly too high fabrication energy of the insulation material, i. e. the additional energy savings at an insulation thicker than the 10 to 14 cm which are currently usual, is less estimated than the higher fabrication energy.
But calculations have shown that also 30 cm thick insulations will amortise in about two years referring to their fabrication energy compared with a standard insulation.

The table shows some standard insulation materials with their corresponding thermal conductivity and the corresponding required insulating thicknesses for an external wall (with BTIS) at a U-value of 0.15 W/(m²·K). In (nearly) any case, the fabrication energy has amortised within 3 years.

Note 1: the U-value of the uninsulated wall is 1.6 W/(m²·K). The decrease of required insulation thickness at lower initial U-values is relatively small (i. e. U = 1.3 W/(m²·K); BTIS, insulation material with λ = 40 mW/(m·K): required insulation thickness Δ – 6 mm).

Note 2: the relations of magnitude between the insulation materials differ from chapter 3.6 because of using highest (resp. worst) descripted values for fabrication energy.

3.6 Bonded Thermal-Insulation Systems: Ecological Effects and Costs

The picture shows essential magnitudes of environmental influence for different BTIS which are accumulating until realizing an insulation system: Beside the primary energy input there are greenhouse gases (global warming potential), acidifier, particles, and NMVOC etc. which causes summer smog.

Almost all emissions of EPS-systems are lower compared with a rockwool system as reference; in case of conventional EPS („EPS Ecoinvent“) however, the primary energy input is increased. Insulation systems with graphite-modified EPS at a lower density and thermal conductivity („Neopor“, WLG 032) generate obviously lower emissions –except the summer smog potential caused by the expanding agent pentane. Therefore, EPS should be chosen from a fabrication with pentane offtake.

Referring to the costs the EPS systems are most economical.

Insulation systems with mineral foam have the best ecologic attributes. Their additional costs will decrease noticeable with ongoing diffusion in market.

4. Special-purpose solutions: Vacuum-Insulation Panels (VIP) and Transparent Insulation in practice

4.1 Vacuum-Insulation Panels (VIP)

In case of vacuum-insulation panels, the almost completely eliminated thermal conduction of a nearly evacuated cavity is utilized.
Therefore, a core of pyrogenous silica is coated with a protective fleece and shrink-wrapped into a diffusion-sealed foil envelope before the panel is evacuated (similar to a pack of filter coffee).
The thermal conductivity of the panel is „only“ reduced to 2 mW/(m·K) because of the core material and of the envelope and also due to the not entirely perfect vacuum.

Due to the constantly fading vacuum (additional charge for aging) as well as the considerable thermal-bridge effect even of very carefully mounted insulating boards, the effective value for conductivity is however fixed at 8 mW/(m·K).

The panels are only mounted laterally by means of optimized glass fibre dowels to especially prepared identations.
In order to avoid any damage to the foil envelope at all, the actual VI-panel is completed to VIP elements with protection layers at front and backside.
These are available as VIP + EPS elements for a BTIS, and also equipped with protection layers made of recycled PUR.
This sensitive side remains in both cases. Therefore, a very careful handling by trained personell is absolutely necessary. Punctiform pressure has to be absolutely avoided; it is also important for the panel to avoid humidity impacts which would shorten the durability.

The elevated handling costs as well as the relatively high price of the elements reduce the application field of VIP to special cases in which the space-saving feature of the very thin elements is the deciding argument (4...5 cm opposite to 20 cm and more): at embrasures, dormers, connections, for indoor-insulation at walls and floors.

4.2 Transparent Insulation (TI)

The variant of Transparent Insulation applied at the housebuilding sector is the passive-solar accumulating wall. It operates as wall heating system with accumulating function: The solar energy passes a transparent capillary insulation material, hits an absorbent layer and is transformed into heat. The temperature of the outside of the wall surpasses the room temperature causing a thermal flow from outside to inside. The wall creates like a thermal accumulator which releases the warmth to the room after 6 to 8 hours. In order to reduce heat losses, the capillary insulation material is covered by a pane or by transparent plaster.

In winter, more solar energy reaches the absorbent layer and the wall at a flat angle of irradiation than in summer when at a steep standing sun and high angle of entry much of the solar light is reflected on top of the TI.

This selecting mode avoids overheating in summer. If inner heat loads should be avoided, the system should necessarily be equipped with adumbration facilities. But in the short-time range, solar benefits are not controllable.

- TI is available as integrated BTIS, as modular curtain wall or as TI-glazing facade.
- TI is only suitable for walls of a density of exceeding 1,200 kg/m³ without any existing insulation.
- The surface share of TI should not exceed 5 to 10 %.
- In this case, energy benefits of 80 to 130 kWh/(m²a) can be achieved at each square meter TI, in contrast to an opaque thermal insulation at U=0.15 W/(m²K) (south surface).
- The compared costs are in case of a TI system five times higher than BTIS.
- At a higher share of TI, the specific energy benefit decreases and the danger of an seasonal overheating in summer increases.
- Conclusion: TI do not replace a highly efficient thermal insulation, it only is to be considered as complement.

5. Thermal Bridges

5.1 Characterisation

Thermal bridges are areas with a higher heat drain than in the standard component area. The result is a cooling-down of the inner surface of the component. If the surface temperature falls below a critical mark, the interior air humidity will condense at this place. On humid, cold surfaces of construcion parts mildew will occur.

Actually, thermal bridges also cause constructional damages by humidity effects and mildew infestation beside their higher energy losses which are absolutely unnecessary. The latter often cause damage to the health of the dwellers. Abatement of rent, compensation claims and finally vacancies are the frequent consequences of a problem which ca be perfectly and constructively solved:

Basically, the temperature of the inner surface is elevated using a thermal-bridge optimized insulation in order to prevent the appearance of mildew and condensate. A reduction of the thermal-bridge effect to zero would be optimal, i. e. also the higher heat drain and the higher heat losses are compensated.

5.2 Examples for Thermal Bridges

Mildew very frequently occur in external corners, particularly if there is furniture at that place. The reason is the outer surface which is more extensive than the inner surface (difference = blue dotted line). Here, the heat flow is higher than at the centre of the wall area (which is the standard surface). At uninsulated corners of exterior walls, the inner surface cools down below the critical value of approx. 13 °C. Therefore, interior air humidity condenses at this place. At cool humid surfaces, there are perfect conditions for the growth of mildew, especially adding nutritives like wallpaper with paste.

Due to the geometrical cause, the proper term is **geometric thermal bridge**.

In case of **material thermal bridges**, the higher heat flow is caused by a construction part of relatively high thermal conductivity which penetrates the standard area. Examples are especially construction parts of (reinforced) concrete connecting with the exterior wall or piercing it respectively: floor ceilings and balcony slabs. There frequently occurs mildew and condensate at the inner edges of floor or ceiling being junctions to the exterior wall.

The problem is aggravated at salient construction parts like balcony slabs or attics which protude into the cold air like gills. Therefore, a reconstruction project often aims at a compact design of rugged structures by integrating pergola ways etc. to the (second) building case.

5.3 Planning

An important condition for a really working high-insulated construction is non-existence of thermal bridges. It should defintitely start at an early phase of planning and it should be an integral part of the complete planning and realising process.
The vision in mind should be a warming coat which covers the heated volume entirely. Thermal bridges and gaps reduce the insulating effects much more than their low surface share propose (similar to a bellybutton-free down-filled winter jacket).

In case of refurbishment of old buildings, a completely closed insulation level is economically not practicable at some places: e. g. where the cellar brickwork meets with the basement ceiling at inner and outer walls.
But also in this case, it is possible to reduce the thermal-bridge effects so that the energy standard of a very good new building can be reached at refurbishment, too, in particular referring to multiple family houses at a relatively low surface/volume ratio.

Comparing several approaches to solving the problem, it is helpful to estimate thermal bridge effects by software: on the one hand there are thermal-bridge catalogues with completely calculated standard cases. Besides, the market offers also calculation tools for precise comparison, modulated to the particular project. Meanwhile, these tools can already be applied to small and medium-size architecture firms, also offering the choice to delegate these calculations to planning specialists.

The accurate elaboration of detail drawings is more important than the exact definition of the thermal bridge effects, in case of connections also in 3-dimensional pictures. Referring to this, the feasability of the planned solution under construction-site conditions is important, because:

What is difficult to draw, is even more difficult to be constructed!

Thermal Bridge Conception at first is a job for the planner, cause at the construction site no craftsman can compensate a lacking concept!

5.4 Avoiding new Thermal Bridges: Plinth

In not a few cases, at thermical reconstruction of buildings new thermal bridges are „installed“ which reduce the insulating effect considerably and reduce especially high-insulating constructions to senselessness (an example: the metal underconstruction of a curtain wall, see 3.2)

Concerning BTIS, this is the closing-off profile which often is made of aluminium. At the front area it meets external air and plaster.
Because of high thermal conductivity of aluminium (approx. 4,000 times higher than the thermal conductivity of the insulation material), a higher thermal flow is conducted via the profile. Frequently, the result is reduced temperatures at the inner surface. In any case, the thermal loss by thermal bridge is significantly elevated.

The higher thermal losses per meter of closing-off profile correspond to the thermal losses of 1 to 2 m² insulated exterior wall. You can visualise these thermal-bridge losses as if the surface of the exterior walls has increased by this amount. As the closing-off profile embraces the entire building, this additional loss surface increases correspondingly all around the house. From a thermical point of view, the building has grown by 1 to 2 meters due to the use of aluminium profile.

As alternative, the market offers plastic bars or the presented, thermically completely uncoupled system as an optimum.

6. Airtightness

6.1 Reasons for Airtight Buildings

Especially in case of insulated light constructions like step roofs, the inhabitants frequently complain about inward air draught and uncomfortablenessat windy weather. Additionally, the thermal losses of these rooms are significantly higher than expected from the insulation thickness. After opening the construction part, in many cases there is a heavy humidity penetration and partly a considerable mildew infestation. This often is related to the incorrect use of vapour barriers.

The actual reason however is the deficient airtightness of the construction: If wind passes around a house, there will be a high or low pressure on the external construction parts which attempts to press air into the building or draw room air outwards.

The first is eliminated by wind-sealing on the outside of the insulation level of roofs and curtain walls, especially necessary in case of fibrous insulation material. This protection of the insulation not only provides its effectivity but also increases the durability of the construction, especially when using board material (e.g. bituminised or latexised wood fibre boards).

Additionally, room air cools down at its way outwards, and its humidity (which was still gasiform and without any problem before) condenses in the construction. The humid quantities can amount to more than the 100fold of what penetrates via vapour diffusion into the construction! This explains the noticed considerable humidity damages and mildew infestation.

Thus, the consequences of a construction insufficiently airtight can be even more aggravating than those caused by thermal bridges. Being free from thermal bridges and airtightness are indispensable conditions for an efficient and durable insulating construction and that way already valid for currently prevailing insulation thicknesses (in many countries as common accepted technical standards respectively as norms).

Because ventilation systems are also projected in a modern refurbishment, especially in the multiple dwelling sector, airtightness is necessary for their perfect function, otherwise additional air is supplied by air leakages. Particularly concerning supply/exhaust air ventilation with heat recovery, requirements in airtightness are much higher.

6.2 Respiration-Air via Leakages?

Since in the eighties old leaky windows were replaced by new leak-proof windows, many flats were in consequence infested by mildew. Having learned that the reason for this was a lack of ventilation, the wrong conclusion was now to compensate the eliminated leakages of old windows by leakages at walls and roofs, in order to guarantee a sufficient ventilation.

But a room ventilation via leakages is the wrong way:

- on one hand the leakage average and thus the exchanged air quantity is too small to provide the dwellers with sufficient respiration air and to remove humidity from the rooms. In contrary, uncomfortable cold draughts occur in buildings with adequate big leakages, especially during the heating period. Measurements have shown an 10fold air change per hour – these air quantities are hardly to heat up to 20 °C, apart from losses of energy.
- This is an essential disadvantage of the leakage ventilation: it varies according to the outer conditions of weather and rarely corresponds to the needs of the dwellers. Particularly an oversupply cannot be regulated and reduces the dwelling comfort. Facing the bad quality of ventilation air, the energy consumption is much too high.
- Additionally, spores from mildew growing at the leakages can be carried into the room by the draughting air.
- Actually, this kind of room ventilation is also unhygienic and harmful.

In any case, a ventilation by the provided openings is more favorable:

- During the presence of the inhabitants it is sufficient if they open the windows every one or two hours for a few minutes („block“ ventilation).
- As an alternative, there are special gap ventilation fittings for new windows.
- Special outer air apertures deliver sufficient fresh air at normal wind conditions and limit incoming air at severe wind.
- Optimal air quality is achieved by controlled ventilation via ventilation systems. As an additional benefit considerable energy quantities can be saved with an heat recovery.

6.3 Planning Airtightness: Concept of Airtightness

As described at point 6.1, the consequences of a not sufficiently airtight construction can be even more grave than those caused by thermal bridges.
Being free from thermal bridges as well as airtightness are indispensable conditions for an efficient and durable insulating construction and that way already valid for currently prevailing insulation thicknesses.

Already the thermal-bridge free insulation as well as airtightness requires a careful planning, a concept of airtightness. In this case, for each construction part an airtight layer should be determined which together envelope the complete heated volume without interruption.

At first, the course of the airtight envelope is determined:

- at the construction parts which meet the outer air
- at the construction parts between flats (e. g. at installation ducts)
- at the airtight separation of the flat from the basement (e.g. by a closed basement staircase)

Then the airtight layer for each construction part is defined separately:

- sealing at component area (i. e. interior plastering in case of brickwork)
- linear connections between the different surfaces of construction parts
- punctiform connections at constructional and house-technical (HVACR) penetrations
- construction elements with closing and mounting joints (e. g. windows, doors, hatches, etc.)

Problematic areas like penetrations or joints can be pointedly avoided or reduced by an anticipatory planning (e. g. house-technical penetration by establishing an installation level).

If possible, the positition of the airtight layer should not change, i. e. to leap from the inner side of the supporting structure to outside (like at insulation upside rafters).

The statements concerning the thermal-bridge concept are also valid for the detailed planning:

- to illustrate details, if necessary in 3D
- feasability/realisability of the planned solution under construction-site conditions
- airtightness at first is a job for the planner, and then for the craftsman

7. Exemplary Solutions

7.1 Mounting of Windows

Mounting windows, the position of the window level related to the insulation level should be minded: the perfect position is in the middle of the insulation level. Mounting them from outside the exterior wall comes very close to the ideal (fixing by elbow-mounting or special mounting systems).

The window frame will be airtightly connected by an sealing tape (e. g. fleece cladded butyl adhesive tape) to the airtight level of the exterior wall.
In the shown case this is the external plaster. Before, the subsurface was prepared rodding it smoothly by means of an appropriate mortar or glue: it must be free of cracks and even. Later, when mounting the BTIS, the sealing tape is inserted by plastering together with the insulation glue.

Frequently, the reveal in case of the windows prefixed from outside is not much deeper than before. Anyway it is recomendable to cant insulation at the reveal in order to obtain a wider angle of view and to improve the conditions of incident light. There already are special revealing elements available.

For fire protection, the lintels of windows and doors have to be insulated using a non-combustible material (e. g. mineral wool), see 3.3.

These informations apply correspondingly to external doors.

7.2 Plinth and Basement

At the plinth area, the insulation of BTIS passes over to perimeter insulation by means of a water-resistant insulating material (e. g. XPS) and special plasters at the splash-water area.
The insulation should be done down into the ground in order to reduce the thermal flow via external basement walls or plinth respectively (thermal bridge; critical area room edges floor / exterior wall ground floor).

Even if digging up the ground at the plinth is not absolutely necessary (e. g. for damp-protection measures, the perimeter insulation should reach to 25 cm below ground top level at least.
The wall insulation is supported by an additional frost apron which elevates the temperature of the ground in front of the perimeter wall and protects against frost.

The under-side insulation of the cellar ceiling is conducted from inside around the external basement wall by means of an additional insulating stripe.

Both measures together elevate the temperature of the inner surface at the thermal bridge of the plinth exceeding the critical value and avoid mildew.
The higher thermal losses (approx. 0.9 m² of additional exterior wall per meter plinth) can be reduced by a perimeter insulation going even deeper into ground. For that, an insulation material thickness of 10 cm is sufficient at the bottom. The frost apron, however, stay at a level of –25 cm below ground top level.
The additional insulating stripe at the insulation of the cellar ceiling does not only make sense at the external basement walls but also at any places where basement brickwork pierces the cellar insulation and therefor interrupts it.

Note: the effect of a missing basement insulation is noticeable in the thermography on the slide „Insulation-Systems: (rear ventilated) Curtain Wall“ as a bright (= warm) bar.

7.3 Attics or sills

A thermically not separated attic has the effect of a gill. This thermal bridge can be reduced considerably by carrying the insulation of the exterior wall on to the roof insulation. The gapless insulation of the coping of the wall is also important. Metal parapet elements should not penetrate the insulation layer completely, but they should be fixed by means of thermically uncoupled mounting elements (see 3.1).

The situation is analogue at the sill of a roof without finishes. If in this case the foot purlin interrupts the insulation, it should be integrated into the insulation system.

7.4 Salient Ferroconcrete Balcony Slab

The effectivity of different insulation measures are pointed out considering a salient balcony slab as example:

1. In case of an uninsulated building, the critical area is at the upper edge between exterior wall and storey-ceiling. There frequently occurs condensate and also growth of mildew. The higher thermal losses in this area correspond to additional 3.5 m² of insulated exterior wall per meter of balcony connection; therefore it amounts to 14 m² in case of a 4-m wide balcony.

2. Using an insulation thickness of 20 cm, the thermal-bridge effect will be considerably reduced, because the first 20 cms of the linked ferroconcrete slab are also insulated. The temperature at the upper edge of the room increases correspondingly and surpasses significantly the critical value for condensate and growth of mildew.
   The higher thermal losses in this area now correspond to additional 0.5 m² of insulated exterior wall per meter of balcony connection; therfore, it amounts to 2 m² in case of a 4-m wide balcony (also conceivable as a 50 cm high additional strip of wall above the balcony connection).

3. If the balcony slab is additionally insulated all around, the higher thermal losses will decrease only a little: the additional surface of exterior wall due to the thermal bridge decreases from 0.5 to 0.15 m² per meter of balcony connection (correspondingly 0.6 m² at the example balcony).
   This additional measure is little economical, but because of preservation orders of buildings this can be reasonable.

4. The optimum in terms of thermal-bridge improvement is to remove the old balcony slab and to erect a thermically uncoupled balcony in front of the insulated building. The remaining thermal-bridge losses are neglectably low.
   This measure is not necessary because of moist protection; for that reason, a highly insulated construction is sufficient (2.). Moreover it is to keep in mind that a new balcony construction requires energy for its fabrication (especially steel constructions).

8. Quality Assurance

In the past, the quality of energetic refurbishment was not considered adequately. Therefore, the expected energy saving was frequently not achieved which in consequence caused the assumption that highly insulated constructions do not make sense.

Often, construction damages and mildew infestation occurred due to failures in construction physics which discredited insulation itself in some circles.

Thousands of successfully realised projects prove however the functional capability of a high-insulation construction when accurately planned and implemented.

The targeted standard can be reached if the following points are regarded:

- developing concepts of insulation and airtightness already during the draft-planning time,
- elaborating graphics of the connection details while planning the execution minding the practicability a the construction site,
- pointing to particularities in execution at tender and allocation/contracting
- defining interfaces to other crafts and performances,
- to specify the particular quality criteria of the construction parts,
- introducing craftsmen early while executing and monitoring the construction,
- to coordinate the responsabilities and competences of the crafts,
- to adjust immediately mounting faults or wrong decisions at material choice,
- result checking by means of Blower-Door + Thermography
- using check lists