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LOW ENERGY BUILDINGS AND PASSIVE HOUSE CONSTRUCTIONS

Intended for Budapest University of Technology and Economics, Faculty of Architecture students, as a special addition to the Building Constructions 8 subject material.

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CONTENTS

1. INTRODUCTION

1.1. Grounds

Since the oil crisis of the seventies, we have become energy sensitive. The radical reduction of harmful emissions is justified mainly by environment protection ideas; however, we may understand the necessity for the parallel reduction of the amount of energy used for the heating of buildings. The first energy related requirement was the coordinated with the 38 cm thick small brick wall with both sides plastered. The first so-called B30 wall block was in the end 30 cm thick, however, due to the cavities the heat insulation nature was the same as that of the 38 cm thick solid wall. Later the base materials have become porous, the cavity portion was increased, and however, the insulation qualities could only be improved thru further increasing the thickness of the structure. Current ceramic block walls, when compared to the solid 38 cm thick wall, will provide approximately triple in terms of thermal insulation. Assembled structure thermal insulation thickness values have changed from 4-5 cm values of the seventies – in current international practice - to 20-24 cm and may be expected to further increase, as we aim for the 0,16-0,2 W/m^{2}K heat transmission range in space separation. The later value may be assured only by thermal insulation layers thicker than 30 cm. It is clear, that this kind of requirement will justify the necessity for more effective thermal insulations and – at least in some cases – the need for special materials (e.g.: vacuum panels). The “end product” of energy-conscious design will be the “energy producing house”, the “zero energy house“, or the “passive house”. These ideas, however, do require a minimum of 25-30 cm thick thermal insulation layer positioned on the exterior surface of currently used wall structures, or alternatively, thru the installation of 30-40 thick assembled walls. The end result will be a double or triple improvement in the thermal insulation descriptive “U” value.

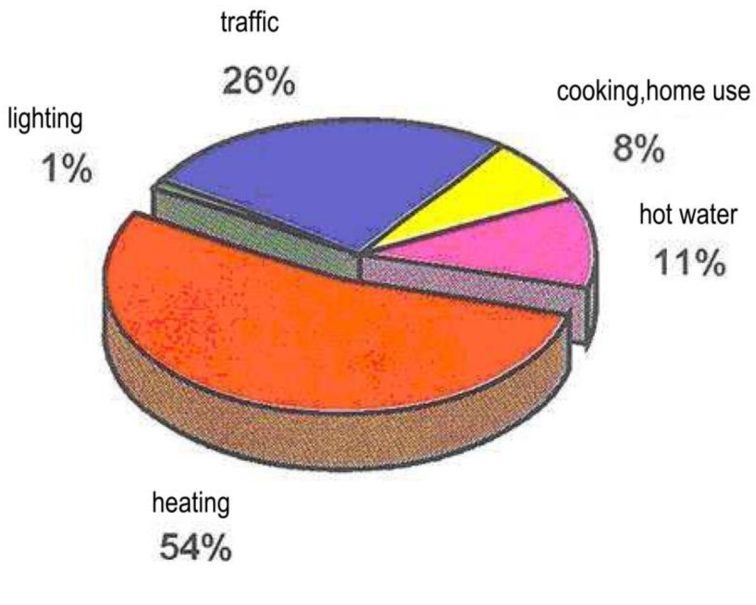


figure 1.: Energy consumption in Hungary

The European Parliament and the Council has, in 2010, declared the 2010/31/EU „Energy Performance of Buildings Directive” (EPBD) which states that by 2021 all new buildings should be built as near-zero energy use and zero CO_2 emission buildings. For public owned buildings, the deadline is 2019. For this to be achieved, first specific requirements are to be set for the given climatic area. Afterwards, these requirements are to be satisfied thru dedicated, life-cycle lasting, optimal, initial cost sensitive structural solutions. The criteria may be satisfied via a great number of different type/quality/class buildings, the issue is the realization of the main goals.

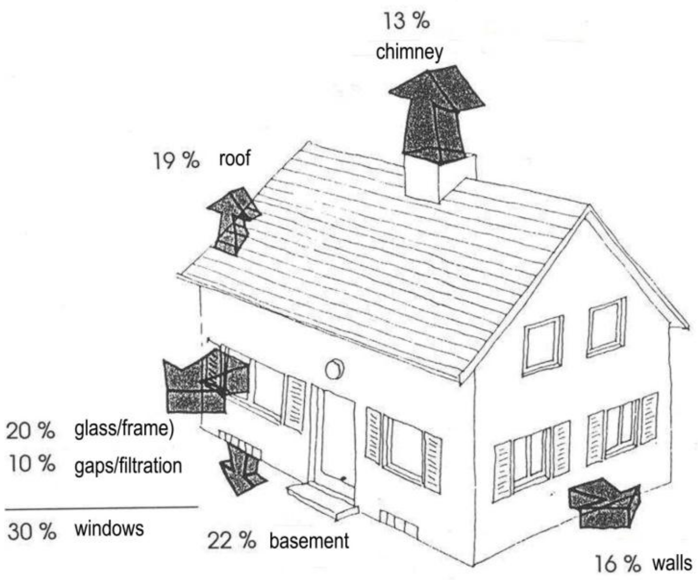


figure 2.: the dispersion of the energy loss of a typical family house

1.2. Low energy buildings and passive houses

On the basis of the operational energy use of buildings, we distinguish the following types/qualities:

- low energy building
- passive house
- near zero energy use building
- zero energy use building
- independent house
- active house

Low-energy buildings are buildings which require less than 50-60 kWh/m^{2}annum for heating (≤ 5 litre houses, or where the heating of the house requires not more than 5 litres of heating oil or 5 m3 of natural gas) and where the total of heating and other energy uses (hot water, cooking, lighting etc.) will not bring the total of the energy used above 90 kWh/m^{2}annum. As a comparison, the current energy standard „C" designation family house in Hungary will require the double of this: about 160-200 kWh/m^{2}annum. In the case of older buildings the value may reach even 600 kWh/m^{2}annum. Low energy buildings are further classified according to energy consumption (e.g.: 3 or 4 "litre" houses).

The expression "passive house" in energetical term means the satisfaction of several different technical requirements, the certification, as of now, may be granted on the basis of a foreign-owned standardized process. The expression in a wider sense covers energy sensitive design and construction of buildings that will use less than 15 kW/m^2 in a calendar year. One of the main passive house concepts is minimal energy loss thru an ideal heated volume – cooling surface ratio. Lately more emphasis is given to energy producing glass surfaces. Other defining aspects are the thermal insulation property of the borderline structures, the prevention of cold bridges and sufficient airtightness. The energy necessary for the climatization of the interior is utilized thru heat exchanging ventilation systems.

The energy loss of the near zero energy use building is kept to the minimum. These buildings will utilize solar heat gain well, are protected against excessive summer heating, have efficient building machinery systems and their supplemental energy need is low. The near zero or zero energy requirement may only be applied to heating/cooling energy, as electrical energy and hot water production requirements will depend to the function and actual use of the house. These buildings will typically satisfy their energy needs from renewable sources.

The independent house is a self sustaining structure which will operate regardless of available utility connections (water, natural gas, electricity, sewage). These buildings have very low energy loss, they utilize energy saving machinery and will replenish the lost energy thru soft technologies. Sewage is treated within the property.

An active house produces, thru renewable (mostly solar based) sources, more energy than it consumes.

1.3. Differentiation

These notes will only deal with low energy buildings and passive houses, since in all of the other building types the ratio of building machinery / energy providing systems is much greater than usual. The aim of these notes is to analyze the optimal energy sensitive construction of the borderline structures of these hoses, mainly thru the analysis of various environmental aspects and technical solutions. We intentionally avoid the creation of a catalog of recommended solutions.

2. THE THERMAL ENVELOPE

2.1. Terminology

The thermal envelope is the collection of all borderline structures that enclose the heated volume of the building and which assure the winter and summer thermal protection of the interior. The thermal envelope is a continuous, airtight, vapour barrier that has – ideally – no cold bridges.

2.2. Components

Based on the above, the components of the thermal envelope are (including all external vertical, tilted and horizontal space separators collectively):

- structure,
- thermal insulation influencing layers (thermal insulation, wind protection),
- thermal energy storage layers (heavy m≥400 kg/m2),
- air and vapour barriers,
- cold bridges,
- glass surfaces and shading.

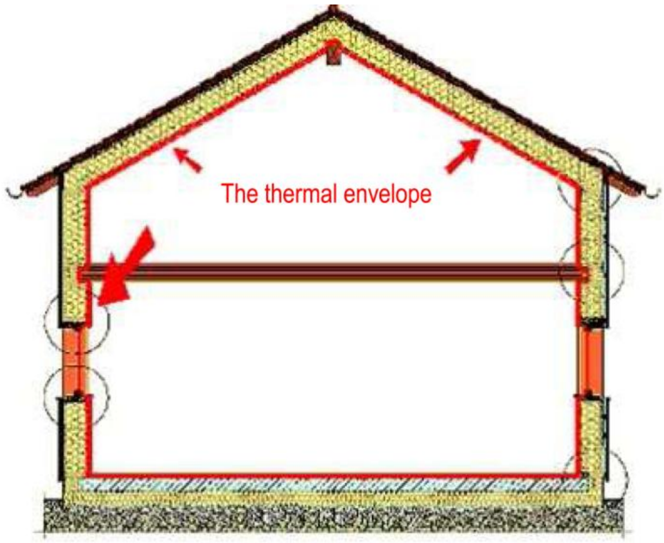


figure 3: The thermal envelope and its components

2.3. Aspects influencing the energetic quality of the thermal envelope

2.3.1. Building construction correlations

The selection of the optimal construction method for a building is a complex process, influenced by a number of factors. During design, all of these factors are to be considered simultaneously. Requirements against the construction are collected in the building CODE, OTÉK (Országos Településrendezési és Építési Követelmények) 50-57. § sections:

- rigidity, mechanical stability,
- fire safety,
- hygienics, health- and environment protection,
- life safety, safeness of use,
- protection against noise and vibration,
- energy conservation and thermal protection.

Building constructions must satisfy all requirements for the specified time and in the specified quality. This is a necessary, but not an acceptable minimum level of satisfaction. The actual level of various requirements will be defined on the basis of effects and loads on the structures.

The energy consumption of buildings is influenced by the complex behaviour of several aspects influencing each other as well as the overall energy quality of the building. These aspects will define the requirements on-, and the construction of- all building components. Some aspects are::

- volume, orientation,
- function and use,
- building machinery systems,
- renewable energy sources,
- boundary structures.

2.3.2. Aspects influencing the energy efficiency of buildings

A. Volume, orientation

The energy conscious design of buildings is an intricate task. The task begins with the building's insertion its natural surroundings, the finding of the proper orientation and the simplification of the volume. Energy use may be reduced with the proper orientation of the spaces (in correlation with the interior temperature and ventilation requirements: north closed, south open spaces) in zones.

100 m^2 area surface:

semi sphere:	310 m^2
flat roof „cube":	380 m^2
flat roof „L-shape":	444 m^2
pitched roof „cube":	450 m^2
pitched roof „L-shape":	508 m^2
complex volume:	620 m^2

table 1. 100 m^2 area surface* according to various building volumes (source: Sopron University)

*Comment: A unified calculation for a two story building. The cubic house is a 10x10x7 m, the „L" shaped house is a 6 m wide house, elevated roof pitch is 45°. The complex volume only includes balconies and recesses.

It is known, that for any given volume, the sphere will give the least possible cooling surface. As a given, the sphere house would be the best shape from an energy conservation perspective. Unfortunately, the sphere is very difficult to fill with function. Surprisingly todays intricately designed buildings will fail to reach the effectiveness of simple volumes, even after the application of a considerable amount of thermal insulation. The "compact" nature will be defined by the cooling surface vs. heated volume ratio (A/V). In case of smaller buildings e.g. family houses, the low ratio as a requirement will be more difficult to adhere to, as there will be a relatively large cooling surface related to the relatively small heated volume. From this aspect, smaller, multi-story buildings are preferable.

B. Function, use

During building use, a lot of energy may be saved with the proper definition of internal temperature requirements and air condition attributes. The reduction of the internal space temperature with even 1-2 °C and the reduction of air replacement may result with an up to 30-50 % reduction heating energy use. Alternatively, inappropriate ventilation may lead to an increased internal air vapour content and to unwanted condensations, mildew and structural deterioration. In the summer deliberate nighttime ventilation of several hours may significantly reduce air conditioning costs.

C. Building machinery systems, renewable energy sources

Building machinery energy supply, effectiveness, built-in position will greatly and in many ways influence the energy use and structure of the building. The positioning of the HVAC units (under windows, as surface heating, air heating etc.) will have an effect on how comfortable people feel, thus on energy use and structure as well.

The use of renewable energy sources, on the basis of the origin of the energy, will reduce environment pollution, will increase building energy quality, but, in some cases, necessitates the insertion of special structural elements.

The building machinery systems will relate to parts of the building's construction and its effects, especially in the case of integrated dispositions. The finalization of the structural elements may only be done after the definition of building machinery and other energy related solutions.

Some examples showing the utilization of renewable energy sources:

- solar energy
  - active use
    - solar collectors
    - solar cells (photovoltaic) panels
  - passive use
- geothermal energy – geothermal energy using HVAC systems etc.
- heat exchangers etc.

figure 4. Soil collector, connected to the building's energy system

picture 1. Solar panels adhered to the surface of the roof waterproofing

D. Building boundary structures

With the increase of the thickness of the boundary structures comes increased thermal insulation, however, great structural thicknesses will decrease the useful area inside and will also increase the weight of the built-in materials. High mass heat storing materials, built-in behind transparent surfaces will decrease winter heating costs. In the summer, these heavy boundary structures will decrease the unwanted heating of the interior. At the same time, the primary heating and cooling of the same structures will require more energy. These effects must be considered during calculations aiming for a given comfort zone.

The energy related quality of the thermal envelope will be influenced by the following:

- building form, volume (as described before),
- the thermal insulation of the general surface, heat transmission values,
- cold bridges, linear heat transmission values, surface differentials,
- glass structures (captured heat effect),
- filtration.

Thermal insulation

Current goals, the increasing level of thermal insulation requirements cannot be realized with homogenous structures. For example, the load bearing, thermal insulating, light weight concrete with ceramic pebble additive, or the light adobe wall even when made in a thickness of 70 cm, will still only produce a $U \approx 0{,}20$ W/m^{2}K value. These solutions are non-viable. As a result, generally, only layered constructions are justified. In the layered construction the calculated thickness of the thermal insulation material will provide thermal protection, reduce energy loss, prevent structural or surface condensation and assure the necessary level of internal comfort

Cold bridges

Thermal insulation capacities are greatly influenced by structural cold bridges (locally heightened levels of energy loss). At cold bridges the internal surface temperature of the structures is reduced. This directly results with capillary and then surface condensations. The increase in the thickness of the thermal insulation will in turn increase the relevance of cold bridges.

Cold bridges may form as follows:

- **at material and/or structure changes**

  In case of layered structures, the different internal functional requirements are satisfied by different external layer solutions. Changes in the surface layering are thus indivertible. The most abundant cold bridge develops at the insertion of doors and windows, at the connection of block walls and r.c. structural elements or at the wooden elements of assembled structures. The thermal conduction of wood and that of the thermal insulation materials differs by a magnitude ($\lambda_{\text{thermal insulation}} \approx 0{,}02$-$0{,}04$ W/mK, $\lambda_{\text{wood}} \approx 0{,}13$-$0{,}19$ W/mK) i.e. the difference in thermal insulation property may be in the 4-8 multiple scale. At the rafters of pitched roofs, the increasing of the overall thickness of the thermal insulation has accentuated this previously disregarded problem.

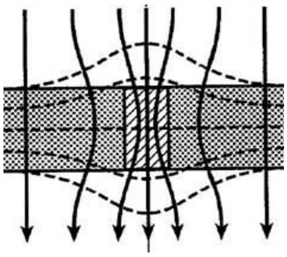


figure 5. a typical example of a structural cold bridge

The laying of the thermal insulation in a wave, the allowing of connection gaps, the folding up of the edges of sheets are also cold bridge sources, in this case related to faulty construction. Graduated connection gaps, multiple layers or the use of poured materials will greatly reduce these problems.

- **at the changes in the geometry**
  The building is a volume in space; therefore the change in its geometry is unavoidable. For example, at the roof, the inclined surfaces will intersect; they will also connect with vertical surfaces as a rule and to horizontal surfaces as an exception: the joining of the roof and the balustrade, the joining to the attic wall, wall edge, rooftop edge line, negative edges etc. The more complex building geometry, the more changes there are, the more cold bridges we will find. The negative effect may be reduced by simple geometries.

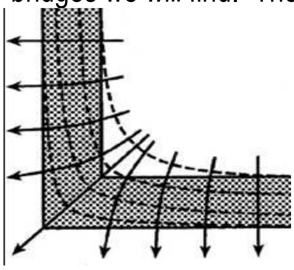


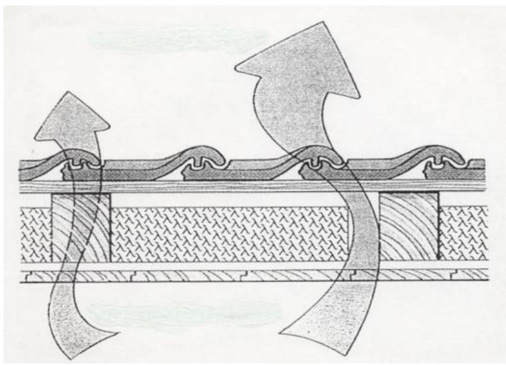
figure 6. the typical example of a geometrical cold bridge

Cold bridges in the boundary structures

These will form as

- **spot-like**: e.g.: at the fixation points of surface finishes and/or thermal insulation layers, at spot-like openings, at recessed structural elements (e.g.: electrical connectors) or
- **linear**: e.g.: at break lines (e.g.: façade edges, wall and slab connections, roofs, covered open areas etc.) and at changes in the underlying structure (at pillars, slabs, etc.)

cold bridges.



picture 2., figure 7. Cold bridges at the rafters

Energy loss thru filtration

Filtration is airflow thru the external boundary structures.

Vapour is produced during the human use of internal spaces partly due to human functions and partly due to human activities. The warm, humid air, because of pressure differences, will migrate towards the exterior in the winter. In the structure, in case of attics, in the thermal insulation, the temperature decreases as the air moves towards the exterior. When the air reaches the mildew point, the humidity will precipitate as water within the structure. This is the reason for the known phenomena, when in dry weather; the roof can be soaked thru, from the inside. As all may know, during exercise the soaked-thru sweater will not keep us warm. Similarly the soaked-thru thermal insulations will not serve their purpose.

On the basis of current investigations, we may state, that – especially in the case of assembled constructions – most of the heat loss occurs not as convection loss, but rather as filtration. Similarly, vapour migration mostly results from filtration, rather than diffusion.

The reduction of these unwanted effects is only possible thru the insertion of a continuous, air and vapour insulating (retardant) layer. The consequent use of the vapour barrier requires a serious change in design attitude.

Summer heat protection: the reduction of air condition energy needs

According to the 2010/31/EU directive, the realized buildings must reach the near zero energy use for the length of the calendar year. Consequentially both winter heating and summer cooling energy use must be considered.

Ventilated façade coverings and ventilated attics are protected from overheating thru the insertion of a ventilation layer between the crust panel/roof and the structure. According to scientific research, due to pressure differences and constant wind pressures, the air in the ventilation gap will stay in motion throughout the year (in various directions). The moving air mass will cool the overheated crust panels. As a result, the surface temperature of the insulation will be a lot less than it would otherwise be in the summer. Thus the interior is also cooler. In the winter, the ventilation will help with the removal of unwanted vapour in the interior of the thermal insulation.

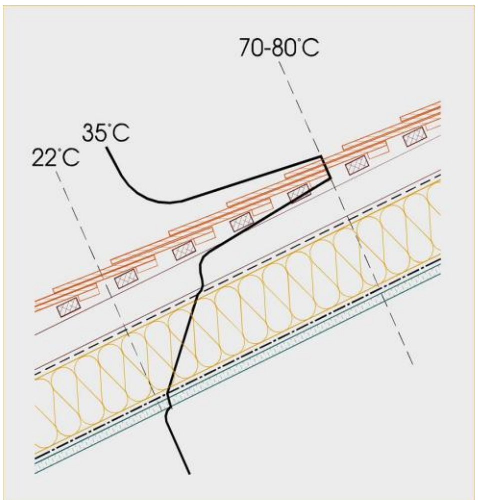


figure 8. the temperature reduction effect of ventilation

The heat storing mass of the building structure plays an important role in the tampering of the internal temperature deviations. When we build lightweight constructions the missing mass is to be provided in another way, if we are to keep cooling costs under control. During the summer the lightweight building will heat up very easily, while the heavy building will absorb heat in a phase offset, typically becoming hot by nighttime. Consequentially, in the first case intensive shading, in the second case, intensive nighttime ventilation is the solution.

If we are to provide effective heat absorption during the winter months, the large, open glass surfaces are to face south. This, however will result with unwanted thermal loads in the summer. Overheating is to be prevented, again, thru intensive shading. Simulation software will help the definition of the proper level of shading for glass surfaces in other areas of the façade. Building automation may be used for the automated setting of the actual shading proper for the given weather condition and desired internal comfort level.

Windproofing

The MSZ 04-140:1991 standard for thermal insulations will give the „κ" correction value for the heat transmission value of the thermal insulation layer in a given, real-life installation. When the insulation is exposed to air, the decrease in the insulation value may reach 10-50%! The MSZ 04-140:1991 standard, however, is based on almost 30 year old scientific theory. The newer MSZ EN ISO 10456 standard, which was published in 2008, considers the materials' air transmission, thickness and the temperatures at the internal and external surfaces. The heat transmission value which is to be used during design is given by a formula. Both calculation methods show that air within the thermal insulation that is in motion will reduce the insulation property. Consequentially, an energy saving "wind" insulation layer is to be inserted at the external surface of the thermal insulation. This wind block layer – in case of ventilated facades – has been proven (both by calculations and research) to significantly influence the necessary thickness of the thermal insulation. Alternatively, with the same thermal insulation thickness, energy loss is reduced by 8-10%.

Wind back pressure may force rainwater underneath the external cover. Residue precipitation on the internal surface of the roof may also saturate the thermal insulation with wetness. The later situation is similar to the effect of outward migrating vapour condensation within the thermal insulation. All of these effects will reduce thermal insulation property of the material.

The ÉMSZ published „Alátéthéjazatok tervezési és kivitelezési irányelvei" design guide recommends the load-related auxiliary waterproofing of crust structures for the improving of their waterproofing quality. Because of thermal insulations thicker than the rafters and also due to technological advancements, nowadays singular ventilated layer structures are abundant. The ventilated structure assures both cooling and the dissipation of vapours. As a result, habitable attics are now made almost without exception with a full surface, vapour transmitting auxiliary waterproofing layer. The layer provides a "wind block" which may be improved thru the closing of the overlaps. The end result will be a "non-ventilating auxiliary waterproofing layer", in other words, an energy saving auxiliary waterproofing.

roof incline	-	another aspect	two further aspects	three or more aspects
$a \geq a_k$	-	simple laid aux. waterproofing 3.	simple laid aux. waterproofing 3.	simple laid aux. w.p. with overlap 2.2.
$a < a_k$ $a \geq a_k$-6°	simple laid aux. waterproofing 3.	simple laid aux. waterproofing 3.	simple laid aux. w.p. with overlap 2.2.	windproof aux. w.p. 2.1.
$a < a_k$-6° $a \geq a_k$-10°	waterproof aux. w.p. 1.2.	waterproof aux. w.p. 1.2.	waterproof aux. w.p. 1.2.	waterlight aux. w.p. 1.1.
$a < a_k$-10°	waterproof aux. w.p. 1.2.	waterlight aux. w.p. 1.1.	waterlight aux. w.p. 1.1.	waterlight aux. w.p. 1.1.
a<10°	tiled roofs cannot be used			

windproof aux. waterproofing

table 2. Auxiliary waterproofing combinations on the basis of energy saving (tiled roofs) (source: Rita Pataky)

3. REQUIREMENTS

3.1. The requirements of the building

3.1.1. Mass, surface/volume ratio

Generally there is no numeric requirement for the cooling surface vs. heated volume ratio for buildings. The A/V ratio is, however, considered by the “7/2006. (V.24.) TNM rendelet” (national regulation on “the energy use requirements of buildings”) as an influence on the energy use requirements themselves. Low energy buildings have no A/V requirement, in case of passive houses the recommendation is around A/V=0,59–0,84.

3.1.2. Energy use

Architecture and structural decisions aimed at the reduction of energy used will necessarily consider and evaluate the building as a whole, its environment and all other aspects simultaneously. The energy related calibration of buildings is a complex process. During design, all requirements must be satisfied at the same time.

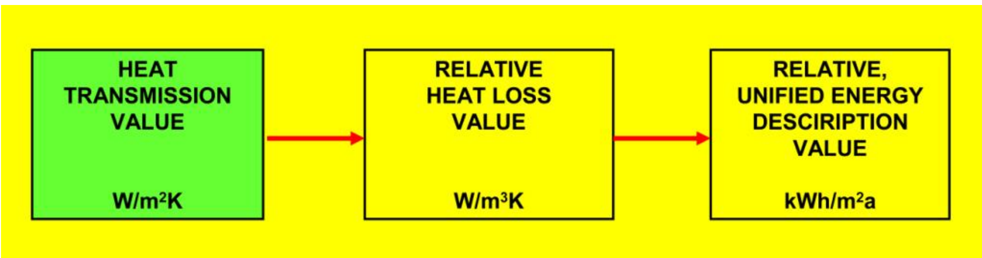


figure 9. Building energy calculation relations

On the basis of the 7/2006. TNM regulation, **the relative, unified energy description value (E_p)** will be calculated for each house. The E_p value will define the total energy (in primary energy) regularly used in a calendar year by the building or building section under investigation. The E_p unit is kWh/m^{2}a(annum). The regulation lists the E_p requirements according to function and on the basis of the cooling surface / heated volume ratio. In case of passive houses, for example, only $E \leq 120$ kWh/m^{2}a may be used for regular yearly operation (energy saving installation may actually achieve E=20-50 kWh/m^{2}a).

3.1.3. Energy used for heating

Both low energy and passive hoses have maximized heating energy values:

- low energy houses: ≤ 50-60 kWh/m^{2}év,
- passive houses: ≤ 15 kWh/m^{2}év.

3.2. Thermal protection

3.2.1. Relative heat loss

The **relative heat loss value (q)** is basically the energy balance of the boundary structures of a given building or building section, in other words, the simple summation of the transmitted heat loss and passive solar energy gain values. The q unit is W/m^{3}K. The q value is given by the following formula:

$$q = \frac{1}{V}\left(\sum AU + \sum l\Psi - \frac{Q_{sd} + Q_{sid}}{72}\right)$$

where:

- V [m^3] is the heated volume,
- U [W/m^{2}K] are surface heat transmission values,
- A [m^2] are cooling surfaces associated to the area heat transmission values,
- Ψ [W/mK] are linear heat transmission values,
- l [m] are the lengths of the linear heat transmitters (cold bridges)
- Q_{sd} are solar gain values.

The relative heat loss value of the building is not use dependent. The definitive elements are architectural, such as mass, orientation and the quality of the borderline materials. The 7/2006. TNM regulation states various q requirements on the basis of building function. Heat transmission and summer overheating related requirements are also given by the regulation these, however, are correlated to the cooling surface / heated volume ratio. When we consider the relative heat loss value, we must also pay attention to protection against summer overheating due to solar gains.

3.2.2. Thermal insulation quality

The **heat transmission value (U)** gives the amount of energy transmitted thru by the boundary structures of a given building or building section. The U value will describe the thermal insulation quality of the boundary structures, given as a generic cross-section value or stated in an official document for the product as a whole. The U unit is W/m^{2}K. The U value is given by the following formula:

$$U = 1/(1/he + \Sigma d/\lambda + 1/hi)\ [\mathrm{W/m^2K}]$$

where:

- U [W/m^{2}K] is the heat transmission value for a given layer structure,
- he [W/m^{2}K] is the heat transmission value of the external surface,

- h_i [W/m²K] is the heat transmission value of the internal surface,
- d [m] are structural thickness values,
- λ [W/mK] are real heat transmission values for the various structures,

The heat transmission value of the boundary structures depends on the materials used and their thicknesses. The definition of a given structural heat transmission value must consider linear cold bridge effects, as well as construction-related changes in the heat transmission value.

All structures with different layer compositions must be individually calculated in terms of their U value and the surface area must be also individually defined (A_i [m²]). The 7/2006. TNM regulation gives U unit requirements for various structure types in tables. The satisfaction of the required U values is, however, only a necessary minimum. It will not directly mean that the structures are satisfactory, nor will it conclude that the building is of low energy use. Complex energy saving requirements must also be met.

For passive houses the layer composite U value of the boundary structures is maximized:

- $U_R \leq 0{,}15$ W/m²K (generally)
- $U \leq 0{,}80$ W/m²K (façade glass surfaces).

For doors and windows this necessarily means that the glass surfaces must be of at least triple plane, thermal insulation glass, typically filled with inert gases and constructed with a Low-E coating. The door and window profile thicknesses must follow suit and we must become familiar with cold bridge gaps in wooden door and window profiles.

Current U value standards cannot be utilized for the design low energy buildings. As this is not likely to change until the implementation of the EU directive, the table below will give a recommendation for various U values, to be used in the layer design process. Overall energy requirement calculations (q and E_p values) – naturally - must also be performed.

	MSZ 04-140 1979	MSZ 04-140 1985	MSZ 04-140 1991	7/2006. TNM regulation 2006	recommended value	passive house recommendation
U wall [W/m²K]	0,85	0,70	requirements for construction average k-value	0,45	0,35	0,15 appr. 20-30 cm thermal insulation
U roof [W/m²K]	0,40 appr. 10 cm thermal insulation	0,40 appr. 10 cm thermal insulation	appr. 12-14 cm thermal insulation	0,25 appr. 16 cm thermal insulation	0,20 appr. 20 cm thermal insulation	0,12 appr. 40 cm thermal insulation

table 3. U value changes in the regulations

	Externally exposed horizontal and inclined border structures	External wall	Basement slab	Doors and windows	Ventilation
U_R [W/m²K]	0,20	0,25	0,30	1,30	0,55 regulated
thermal insulation thickness d [cm]	20	16	12	Dual layer glass, with Low-e coating	

table 4. Low energy building design, recommended U values (source: BME Faculty of Architecture, Department of Building Constructions 2012)

Comments to table 4.:

- „Externally exposed horizontal and inclined border structures" means flat roofs, habitable pitch roofs, attic and alcove slabs.
- „External wall" means façade and footing walls as well as the walls of heated basements.
- Ground floor surface requirements are identical to "Basement slab" to a maximum 15 meter building width, above this, dedicated calculations are to be made.
- The layer recommended maximum U value (U_R) must encompass all effects reducing the thermal insulation quality (grooves, spot-like fixations, rafters, layer changes, structure changes etc.).
- "Thermal insulation thickness" (d [cm]) is defined for thermal insulations with a λ=0,04 W/mK heat transmission value.
- "Thermal insulation thickness" (d [cm]) has been defined, irrespective of the thermal insulation value of all other structures (wall, slab, finishes etc.) and effects reducing the thermal insulation quality (grooves, spot-like fixations, rafters, layer changes, structure changes etc.) – this is an informative value.
- Exact calculations must consider the directional nature of the area heat transmission values as well as the non-linear nature of the thermal insulation's heat transmission resistance.
- The given ventilation value is for a residential building.

A thermal insulation layer may be positioned on the external or internal surface and also within the structure itself. From a building machinery perspective, the external position is to be considered ideal. As a general rule, we are to aim for a layer structure that is "open" to vapour dissipation, i.e. that that has vapour transmission resistance values decreasing, as we advance from the interior to the external surface of the construction. When internal thermal insulation is applied, water vapour condensation is always a risk. In these cases detailed calculations cannot be avoided. When high vapour resistance façade coverings are used, the insertion of a ventilation layer will solve the condensation problem.

The energy calculations, however, will only reflect reality if the thermal insulation material will retain its thermal insulation property, as considered during the design process. The thermal insulation thus must retain its properties both directly after the installation and later, thru the building's life-cycle. The thermal insulation material must be selected so that it should resist all expected loads and the insulation layer must be protected from effects that may increase the thermal transmission value (e.g.: the use of XPS at footings, the insertion of auxiliary waterproofing layers at habitable attic roofs, the insertion of wind block layers at the ventilated external surface of façade thermal insulations etc.). If the material's thermal insulation property is expected to be changing in time, this must be considered during the calculations.

The thermal envelope line is to be as simple as possible. When basements are constructed, the preferred solution is a full, externally insulated basement, instead of internally insulated, partial basements. The later solution enhances cold bridges.

table 10. the thermal envelope without basemen

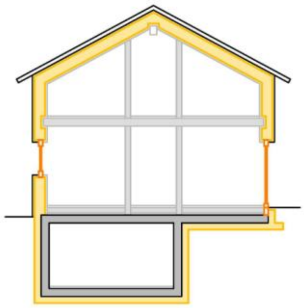


table 11. a basement within the thermal envelope

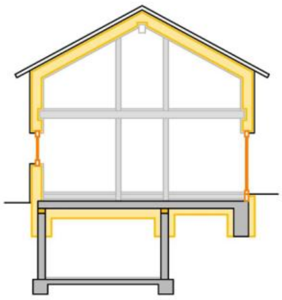


table 12. the cold bridge problems of non-inhabited basements

Research dealing with thermal insulations under the floor layers shows that until about 15m building width, boundary cold bridge effects may be observed. This is more emphasized in the case of smaller buildings. As a result, low energy buildings and passive houses must have full surface under-floor insulation layers. In case of large building widths -.considering the effect of earth heat – partial calculations may prove the justified decreasing or total deletion of this layer.

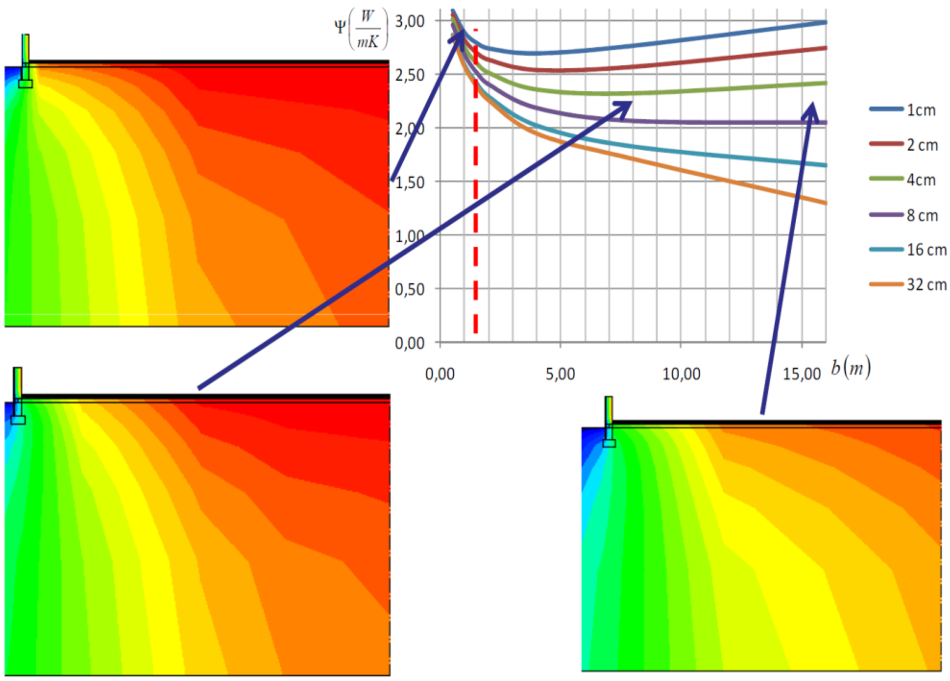
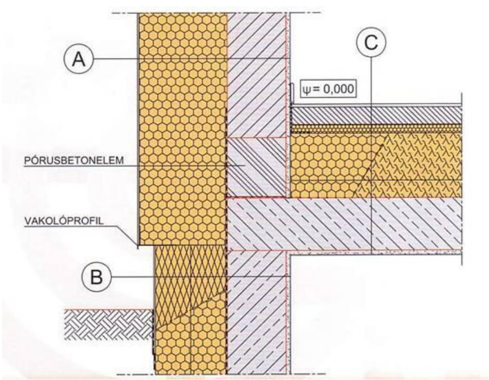
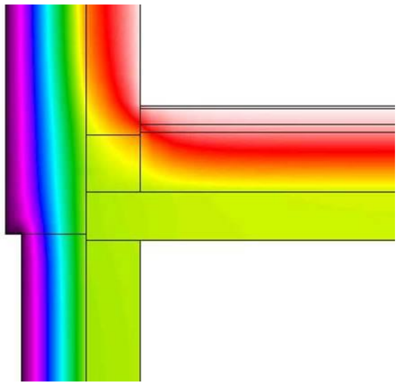


table 13. Under floor thermal insulation effect on the linear heat loss value (source: Szikra 2011)

The thermal insulation of floors directly at the ground or at uninhabited basements will influence the foundation. Due to the tendency towards a continuous line of thermal insulation the otherwise non-feasible surface foundation becomes an alternative. The linear foundation, or the basement wall is a considerable linear cold bridge which may only be reduced by the insertion of load bearing thermally insulating materials (light weight concrete, glass foam, compressed PUR etc.)





tables 14-15. Tempered basement walls pose a serious cold bridge problem. A solution may be the insertion of light weight concrete or glass foam

3.2.3. Cold bridges

In the case of low energy and passive houses, the intended reduction of geometrical cold bridges dictates that compact, unbroken architectural models are to be selected. Spot-like cold bridges are considered during simplified layer heat transmission calculations (U_R), while linear cold bridges are considered both at the U_R as well as at the relative heat loss value (q) analysis.

The cold bridge effect on layer heat transmission must be thought of, as early as the layer design phase. Exact calculations are helped by cold bridge calibration software, cold bridge catalogs and the MSZ EN ISO 10211 standard. A more down-to-earth solution is the use of the 7/2006. TNM regulation's cold bridge describing „χ" correction value. In case of passive houses $\Psi<0{,}01$ W/mK is justified. The overall effect of cold bridges is the compulsory insertion of thicker or better thermal insulations.

Careful design and construction will reduce cold bridge effects. The prevention of cold bridges is closely related to the solving of detail issues such as:

- in case of roof structures: the use of rafter-thick, single layer thermal insulations is to be avoided. Instead use, cross hatched multiple layers or elements with thin cross-sections:
  - multi-layering, i.e. inserting thermal insulations both between and above/below the rafters (the external thermal insulation is better, as this also protects the wooden structure against internal vapour condensations)
  - above rafter thermal insulations
    - multiple batten grid inserted thermal insulations or
    - "walkable" thermal insulations, without a batten grid;
- thru the reduction of the wooden cross-section area;

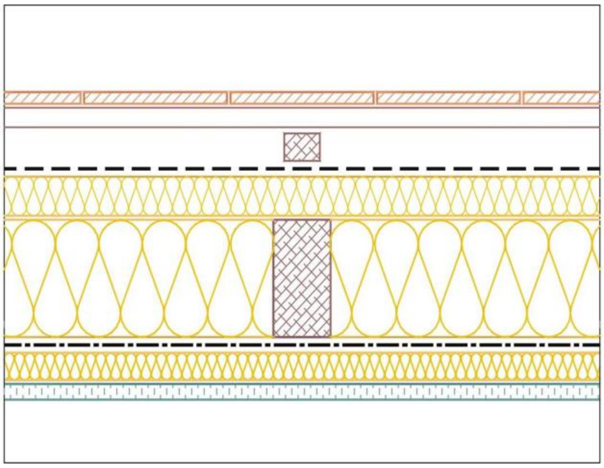


figure 16. the reduction of cold bridges thru multi-layer, thorough thermal insulation

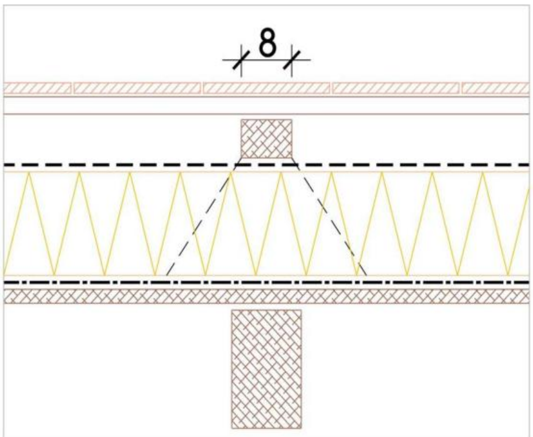


figure 17. the reduction of cold bridges thru above-rafter thermal insulation

- in case of fixations going thru the thermal insulation, use cold bridge gap hard plastic inserts;
- for the fixing of the thermal insulation itself, use recessed, hidden thermally insulating fixation elements;

figure 3. recessed, low cold bridge effect fixation element

- the plane coordination of windows: windows are ideally inserted at the middle of the isotherm lines of both silicate and thermally insulated wall structures (this, however typically falls into the middle of the thermal insulation layer, or at the most near its inner surface). In case of assembled, fully thermal-insulated wall structures the position is almost always in the middle of the wall line;

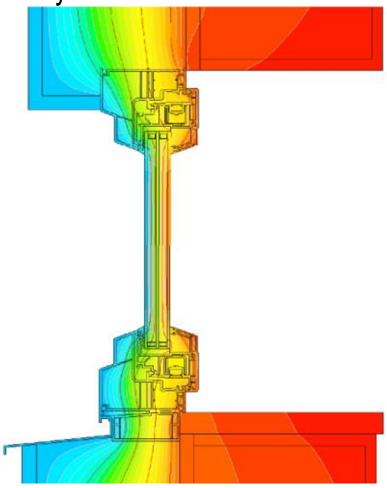


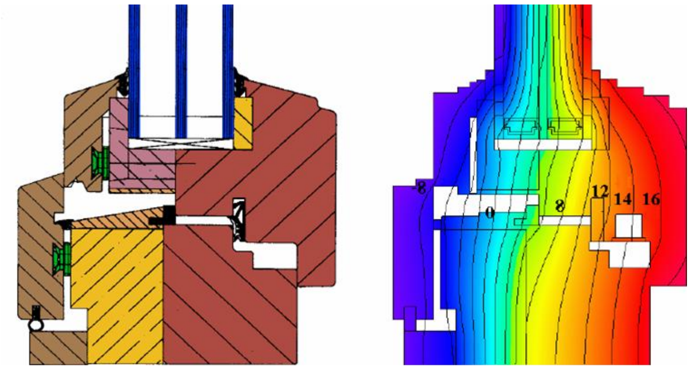
figure 18. the ideal location of windows from an energy saving perspective is at the inner surface of the thermal insulation.

- external, hidden shading devices are to be installed in the thermal insulation layer, these, however, will reduce the effectiveness of the thermal insulation. To lessen the unwanted effect, a negative cavity is constructed. The cavity must not influence the performance of the load bearing structure.
- doors must also be positioned in the middle of the isotherm lines, here the covering of the footing insulation is the main issue. This is usually done with stainless steel curb profiles;
- the insertion of the roof window is a sensitive area in all low energy buildings. This is due to the fact that, at the roof, the glass panel is elevated from the thermal insulation layer. The effect is reduced by the insertion of gradually laid, compressed PUR frame sheets etc.

picture 4. roof window insertion with thermal insulation frame inserts

3.2.4. Glassed structures

Glassed structures usually satisfy natural lighting requirements. At the same time, transparent structure winter solar gains are to be aimed for, in other words, as much heat is to be captured as possible. In order to achieve the above, it is recommended that in case of both low energy and passive houses, most (around 70%) of the glassed surfaces are to be oriented towards the south. As an addition, passive solar collector spaces are to be created (solar areas).



figures 19-20. a cold bridge gapped, triple layered wooden window

Internal space summer overheating is to be avoided thru the shading of southern and western oriented glazed windows. In other cases simulation will help the determination of the necessity of shading.

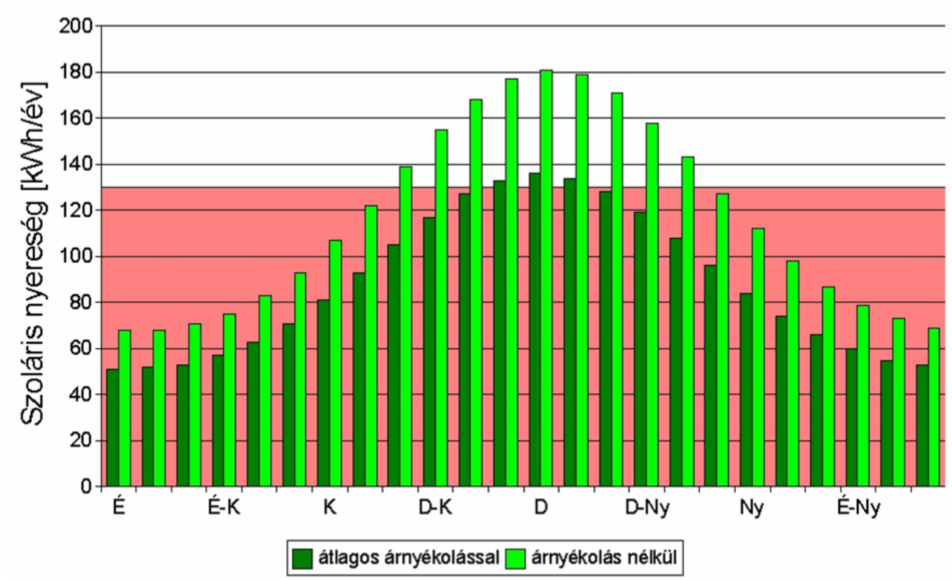


figure 21. Solar gains in relation to window orientation (Solar gains / Orientation N, N-E, E, S-E, S, S-W, W, N-W)

In case of low energy buildings, it is recommended that the appropriate window type - for the given orientation - is to be determined thru calculations. Naturally, for example, a southern double glazed window may produce more heat gain than heat loss.

3.3. Air tightness, ventilation

In any room, the necessary minimum of ventilation is defined by the amount of fresh air needed for the given function and by the protection related ventilation needs of the structures (the prevention of condensations and saturated freezing). Energy may be conserved thru the reduction of unnecessarily high ventilation habits and thru the re-using of the energy escaping with the ventilated air (using heat-exchangers in ventilators).

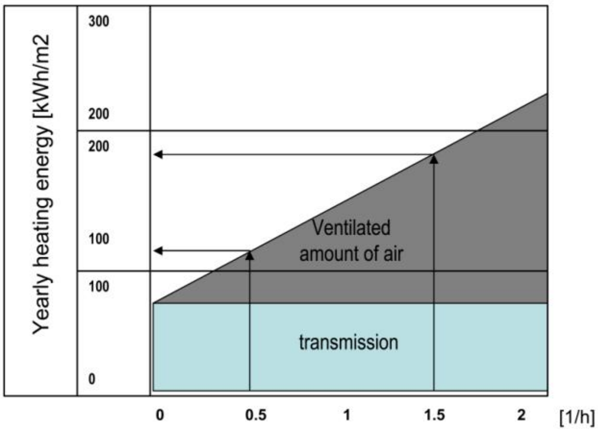


figure 22. Ventilation effects on heating energy needs

Fresh Air on the basis of MSZ EN15251

Category	Unsatisfied inhabitants in PPD [%]	Ventilated air per person [l/s/person]	Ventilated air per person [m3/h/person]
I	15	10	35
II	20	7	25
III	30	4	15
IV	>30	<40	<15

Category U roof [W/m²K]	Ventilated area per sqm [l/(s.m2)]			Ventilated area per sqm [m3/(h.m2)]		
	Very low soiling buildings	Low soiling buildings	Not low soiling buildings	Very low soiling buildings	Low soiling buildings	Not low soiling buildings
I	0.5	1	2	1.80	3.60	7.20
II	0.35	0.7	1.4	1.26	2.52	5.04
III	0.3	0.4	0.8	1.08	1.44	2.88
IV	All other categories					

figure 23. Internal space qualification on the basis of the MSZ EN 15251 standard
(source: www.mmk.hu7/2006.(V.24.) TNM rendelet – Dr. Magyar Zoltán)

Comments:
- I. high requirement
- II. normal
- III. moderate
- IV. all other categories

Our current national standards do not contain requirements for air tightness, but both the German DIN standard and passive house regulations deal with this issue. The foreign documentations define borderline values for air tightness. The ÉMSZ published „Alátéthéjazatok tervezési és kivitelezési irányelvei" guideline for auxiliary waterproofing states that unintentional ventilation must not exceed:

- in naturally ventilated buildings: $n_{50} \leq 3\ h^{-1}$
- in building machinery ventilated areas: $n_{50} \leq 1{,}5\ h^{-1}$
- in building machinery ventilated areas with heat exchangers $n_{50} \leq 1{,}0\ h^{-1}$
- in passive houses: $n_{50} \leq 0{,}6\ h^{-1}$

Low energy buildings - at the time - do not have a requirement for the borderline structures, but on the basis of the above, $n_{50} \leq 2\ h^{-1}$ value is a good recommendation.

When designing building constructions, we should deliberately aim for the reduction of unwanted and uncontrollable filtration at the joint lines of borderline structures. Filtration traffic is seriously influenced by border structure air tightness, where the most relevant factor is the air/vapor tight connection of air/vapor blocking layer overlaps. A dedicated German directive has already been issued on the topic in 2009., The directive lists the basic rules of design and construction in this field (Richtlinie – Ausführung luftdichter Konstruktionen und Anschlüsse).

Continuity in terms of air/vapor tightness is mostly a problem in case of assembled structural elements, since these constructions have a large number of connections as compared to the covered area. Site manufactured reinforced concrete, on the other hand, due to the thickness and solid nature of the material, may, basically be considered air and vapor tight. On the contrary, assembled constructions and window installations need special attention to make them air/vapor tight to the level specified for the given function. Air tightness levels are verified by blower-door tests.

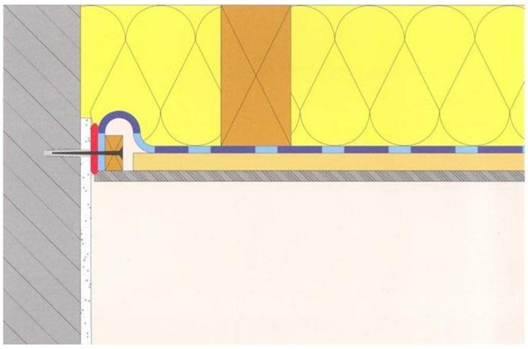


figure 24. assembled structure finish hiding the air/vapor ventilation block layer connection to the wall

In an assembled structure, the recommended position of the air block layer is at the inner surface of the installed thermal insulation. With the method, building machinery elements will not damage the layer. If the layers on the inside of the air block barrier layer have a combined heat transfer resistance value less than quarter of the overall layer heat transfer resistance of the structure, then the inner structure is safe from condensation.

The edge closing of the barrier layers may be solved in many ways, depending on the connecting material. Some variants are glues, glue strips, battens. For windows, dedicated, pre-installed, double sided adhesive tapes are used.

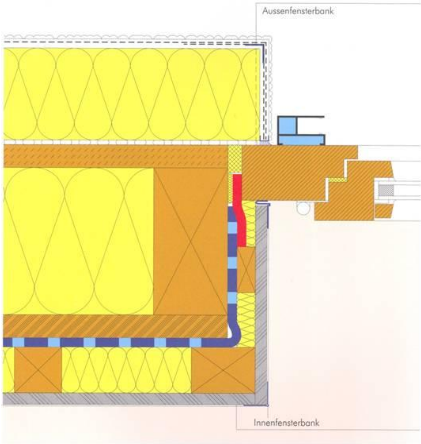


figure 25. air/vapor barrier layer connection to a window via double sided adhesive strips

A special problem area is posed by layers that are constructed from the inside, e.g. after the construction of the roof, as in these cases some joints cannot be made air/vapor tight. Some areas are the resting points of rafters, the connection of double ties, collar beams and pillars. These connections may not be insulated after construction. The solution is to avoid the problem areas thru an alternative definition of the thermal envelope line or to insert air/vapor barriers during the original construction phase.

In case of low energy buildings and passive houses such geometry is to be selected, that allows a simple definition of the thermal envelope line. Another recommendation is to avoid the placing of warm, humid areas into spaces that have layer structures constructed from the inside. The air/vapor barrier is best inserted onto the surface of the inner finishes, before all other layers.

Air tightness as a requirement is independent of vapor blocking; however, when the proper material is used a single layer may satisfy both requirements. A properly constructed gypsum drywall will only satisfy air tightness requirements.

Wall block elements have been designed for enhanced thermal insulation, but for the sake of easier construction, they have lately also been made with nut and groove connections. In the later cases, the vertical gaps between the blocks are not filled with mortar at all, air tightness is provided by internal and external plastering.

3.4. Machinery

The better the air tightness of the bordering structures, the more artificial ventilation becomes an issue. For low energy houses automated ventilation is only a recommendation, however, for passive houses it is a requirement. Ventilation is to be provided via heat exchangers, the energy lost is best replaced thru air heating with a maximum energy need of 10 W/m^2.

Energy used for heating is preferably to be produced from renewable sources (preferably not wood), for example: soil collectors, solar collectors, heat pumps etc.

Air ducts are often led thru the floor structures. This influences the overall thickness and sometimes the insertion of a service layer is unavoidable.

pictures 5-6. Compact HVAC units with heat exchangers

In the case of passive houses, hot water production typically requires more energy than the heating of the house itself. For both building types, it is recommended that as efficient electrical installations are to be used as possible.

4. DESIGN AIDING SIMULATION SOFTWARE

There is an abundance of available models for the handling of building physics and building energy problems, however, the more realistic, multi-dimensional processes have extraordinary calculation needs. Appropriate use is impossible without familiarizing ourselves with the models themselves and the terminology used.

One way to group software is thru the consideration of building size capacity.

- **Building section simulation software**
  The design and calibration of stand-alone layer structures, complex construction elements (e.g. thermal insulation windows, whole window structures) or singular elements of the building machinery (e.g. solar collectors, PV cells) are handled by these applications.

  Such softwares are (not a complete list) simple cold bridge simulators (LBNL THERM, HEAT2D/3D, ANTHERM, WinIso, Physibel, etc.), more complex thermal and vapor calculation aids (Heat Air and Moisture modeling: WUFI, COND, Delphin, Champs-BES, HAM4D-VIE, HAMLAB, MOIST, etc.).

- **Software that simulate complex systems and processes**
  These softwares operate in a scale that is larger than individual building structures, but their capacities do not reach that of a whole building (e.g. flow or lighting simulations). These programs are also abundant, some are simple, focusing on the energy balance of a single room (e.g. Therakles) and some are more complex, focusing on a special area (e.g. lighting - Radiance, Dialux, Visual, flows - Fluent, OpenFoam, or ventilation CONTAM, COMIS etc.) that also requires highly specialized user knowledge.

- **Software that simulate the whole building**
  These softwares model the whole building, or buildings with a detail level appropriate for the application. Beginning with the architectural concept, thru the modeling of the building machinery systems, all the way to the most detailed calculations, these softwares may perform many tasks. The physical model used depends on the complexity of the software and can range from a tabular calculator (e.g. 7/2006. TNM regulation models), thru monthly energy balance applications (e.g. PHPP) and boundary structure layer modeling to whole building machinery simulating applications that can even connect to flow management software (ECOTEC, EnergyPlus, BuildOPT, DesignBuilder, Esp-r, DOE-2, eQuest, Trnsys, etc.).

The other more relevant grouping consideration is the time factor:

- **Stationary models**
  These softwares consider the input data as stationary in time, in other words, that the materials, the environment and the operation of the system itself is not changing. An example would be the thermal resistance calculation of a window or a wall.

- **Quasi-stationary models**
  This is a model used by calculations in the national building energy conservation regulation. Most of the system's components are considered stationary or calculated with an average value (e.g. bordering material heat transmissions or ventilation amounts etc.) and only one time dependent factor is included. In this case the time dependent factor is the changing of the internal and external temperatures which is considered with a single integral value.

- **Non-stationary models**
  These models calculate all factors in a time dependent manner. A dynamic building simulation can consider real climatic conditions, thermal storage capacities, solar course dependent direct and indirect gains, the time dependent changing of the building's use and the overall interaction of all of the above with the building machinery system.

5. ACOUSTIC LEGISTLATION REQUIREMENTS

Low energy buildings and passive houses must satisfy legal acoustic requirements. Acoustic requirements for these two building categories are identical to all other building types, however, the materials and technologies used differ from traditional buildings.

Noise source	Evaluation	Maximum value			Comment
		Unit	Daytime dB	Nighttime dB	
Central HVAC unit noise thru air ducts towards the exterior	At 2 m distance in front of the façade of the neighbouring building	L_{AM}	45	35	L6 zone
Central HVAC unit noise thru air ducts towards the exterior	At 2 m distance in front of the façade of the neighbouring building	L_{AM}	50	40	L5 zone
Central HVAC unit noise thru air ducts towards the exterior	In the living area of the apartment (living room, bedroom, library, study, child's room etc.)	L_{AM}	40	30	
Traffic noise entering from the exterior thru the façade structure with closed windows	In the living area of the apartment (living room, bedroom, library, study, child's room etc.)	L_{Aeq}	40	30	

table 5. Acoustic requirements

For buildings, the MSZ 15601-1-2007 standard lists required transmitted and radiated sound insulation values in relation to functional use of the space. (see the examples in tables 6 and 7.).

Connecting rooms	Number	Noisi apartment or room, structure exposed to the acoustic load	The area to be protected from noise	Airborne noise protection				Structure borne noise protection	
				Base requirement		Heightened requirement		Base req.	Heighte-ned req.
				R' C	R C	R' C	R C	L'	L'
Neighbouring apartments	1.	any area within the apartment	any area within neighbouring apartments	51	-	54	-	-	-
Apartment and traffic areas (corridor, stairwell, hanging corridor)	2.	Stairwell, corridor, traffic area wall	any area within neighbouring apartments	-	51	-	54	-	-
	3.	Stairwell, corridor, traffic area floor	any area within the apartment	-	-	-	-	55	52
	4.	Entrance door of the apartment that opens into the noise protected living room or living area	living room of the apartment	-	33	-	36	-	-
	5.	Entrance door of the apartment that opens into the foyer	front room, traffic areas of the apartment	-	25	-	28	-	-
	6.	Any space within the apartment, there is no door within the wall adjacent to the protected room	to be protected living room of the apartment	-	-	39	-	-	-
Apartment and basement, attic, storage and common areas	7.	Attic, basement, storage, common space wall	any area within the apartment	-	51	-	54	-	-
	8.	Attic, basement, storage, common space floor	any area within the apartment	-	51	-	54	55	52

table 6. Sound insulation requirements in multi-apartment residential houses, at horizontally adjacent room units.

Connecting rooms	Num ber	Noisi apartment or room, structure exposed to the acoustic load	The area to be protected from noise	Airborne noise protection				Structure borne noise protection	
				Base requirement		Heightened requirement		Base req.	Heighte-ned req.
				R' C	R C	R' C	R C	L'	L'
Neighbouring apartments	1.	any area within the apartment	any area within neighbouring apartments	51	-	54	-	55	52
	2.	Kitchen, bathroom, storage, toilet, front room of the apartment	Kitchen, bathroom, storage, toilet, front room of the neighbouring apartment	49	-	51	-	55	52
Apartment and traffic areas	3.	Stairway, landing of the stairway, corridor, hanging corridor floor	any area within the apartment	-	51	-	54	55	52
Apartment and basement, attic, storage and common areas	4.	Attic, basement, storage	any area within the apartment	-	51	-	54	55	52
within an aparment	5.	Multi story apartment, any area	Multi story apartment, living area	-	*	45	*	55	52

table 7. Sound insulation requirements in multi-apartment residential houses, at vertically adjacent room units.

Low energy building and passive house architecture and technical solutions will affect both internal and external acoustic behavior. BME (Technical University of Budapest) acoustic laboratory prepared studies describe, to what degree harmonized EU standards (EN 12354 standard pages 1. and 2.) and the standard DIN 4109 may be used during building energy related detail design. Layer structures and detail drawings found in specialized literature will only serve as partial solutions to the acoustic quality problems. Furthermore, these recommendations have not been verified by field measurements. Generally, we may state, that the satisfaction of the building's energy requirements will not necessarily mean that the acoustic requirements are also satisfied.

Some details, recommended for consideration:

- façade wall: a thermal insulation layer on heavy walls (lime-sand or small standard brick, r.c. etc.) will decrease the wall's acoustic insulation property by 4-5 dB. There are no known performed measurements in this field, but a large amount of insulation is expected to have an increased effect. These structures will most likely still satisfy the regulations.
- doors and windows: typical triple layer glass with proper installation will be satisfactory. The installation position is relevant: when the window plane falls into the insulation layer - in order to achieve acoustic continuity - sealing is to be complemented by high mass false frames. The decreasing of the thickness of the air layer may result with the decreasing of the sound insulation property. For this reason, in areas with high noise loads or where the protection requirements are above standard, dedicated calculations are required.
- roof structure: low energy buildings and passive houses often have inaccessible attics with thermally insulated top slabs. The slabs are typically heavy constructions (e.g. r.c. slab) and as such will simultaneously satisfy acoustic requirements as well. Semi-monolithic or light weight top slabs, however, will need to be investigated. Habitable attics with high standards will have a r.c. false roof structure ("coffin" slab), these have acoustic properties

similar to that of the r.c. structural wall. Lightweight constructions need to be individually calibrated.

- apartment separation wall: an appropriately heavy wall, on an independent foundation will most likely be satisfactory as an apartment separator. In this case problems will arise from the need to eliminate cold bridge effects. Dual wall constructions will typically have acoustic problems at the continuous slab foundation; here the foundation forms a sound bridge. The problem is to be eliminated by sound insulation gaps. In case of assembled roof structures the apartment separation walls, that reach the roof will be problematic from an acoustic (and fireproofing) standpoint. When the wall rises beyond a false ceiling, the thermal insulation will be the issue.

6. FIRE PROTECTION LEGISTLATION REQUIREMENTS

Low energy use buildings and passive houses differ from regular houses not only in terms of general technical manners, but also in terms of fire protection problems. Thick, often non-combustible thermal insulations, building construction specialities, layered, assembled structures, passive, active and hybrid solar energy systems all pose new fire protection challenges. The international literature does not deal with, or does not elaborate on this topic; even sources in Germany are limited to a few technical articles. When we consider the thermal envelope as a whole, the following problems and suggested solutions may be gathered.

In terms of fire protection, low energy buildings and passive houses differ from regular houses in the following relevant areas:

- In case of these buildings, lightweight constructions are preferred to the otherwise widely typical silicate structures. The structures are normally made of wood; both internal and external separation constructions are usually assembled.
- Because of an emphasized need to conserve energy, we will seldom find an external wall without thermal insulation; the insulation is often of 20-30 cm thickness[1]. When thermal insulation is applied in a plaster system, low thermal transmission materials are preferred, such as EPS or PIR foam. These materials will satisfy thermal insulation requirements in less thickness than fibrous materials.
- Façade doors and windows are mostly inserted at the line of the thermal insulation, more specifically, at the inner surface of the insulation. Isotherms are best balanced by this practice. Due to the inflated thickness of the thermal insulation, the positioning of the doors and windows into the wall structure cavity is unlikely.

[1] using λ=0,04 W/mK (as per the most often used XPS or mineral wool products)

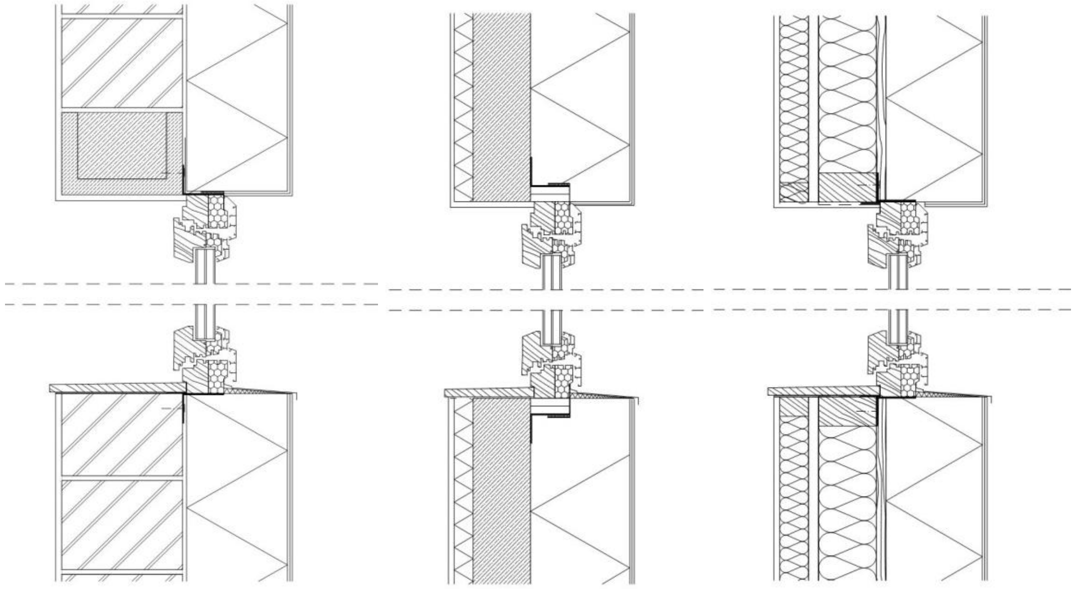
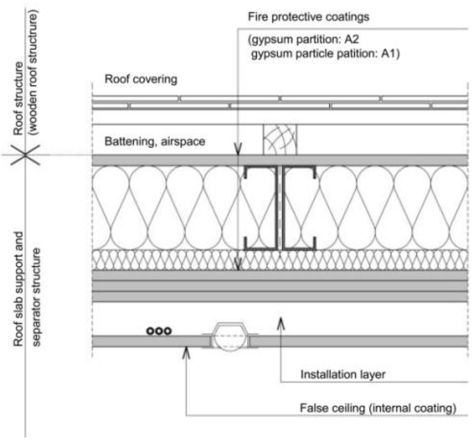


figure 26-28. Typical window installation details (source: Zoltán Dévai): elemental wall, EPS form wall and lightweight construction

- Apart from general energy balance houses, pitched roof thermal insulations are also much thicker in low energy buildings and passive houses. The cold bridges at wooden roof structure elements are to be avoided. This means the insertion of thermal insulation layers at above, below and/or between the rafters. A popular solution is a continuous line of insulation above the rafter position, this eliminates cold bridges completely. A wide variety of insulation materials may be used.

An appropriate level of fire safety may be achieved thru the adhesion to the following recommendations when designing the thermal envelope of low energy use buildings and passive houses:

- The fire protection plane is to be made continuous, this is especially difficult in case of assembled structures. Wooden structural elements, when the appropriate statics design codes are used, normally satisfy the 30 minute fire resistance requirement. When higher requirements are to be satisfied, the structure may be oversized or encompassed by fire retardant coatings. The proper designation of the fire retardant coating is a defining fire safety factor for the protection of the structural elements as well as the building as a whole.



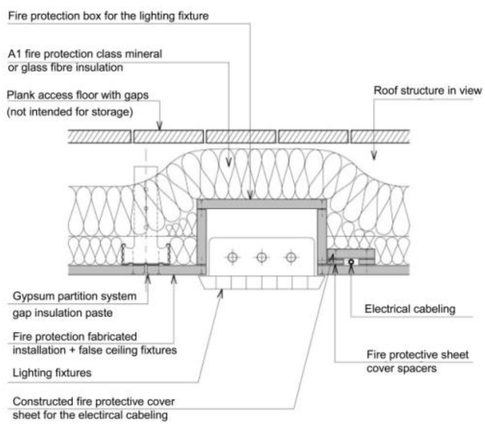


figure 29-30. Fire retardant coating alternatives for structural elements (source: Lajos Takács)

- The current relevant fire protection regulation is the "28/2011 (IX.06.) BM rendelettel kiadott Országos Tűzvédelmi Szabályzat" (OTSZ). The regulation states fire diffusion limits for facades with openings: in case of 2-3 levels min. 15 minutes, 4-5 levels 30 minutes and 5+ levels 45 minutes. This, however is not valid for maximum 2 level or single unit buildings (such as family homes). Façade fire diffusion calculations are included in the MSZ 14800-6:2009 standard. The standard is a national speciality, as there is neither regular international practice nor a harmonized EU standard for façade fire diffusion limits. The reason: lack of professional compromise.
- All of this also means the end of the practical combination of various thermal insulation systems on façades. The applied solution – with the exception of family houses - must have a national value for fire diffusion. The determined value will influence the allowable maximum thickness of the thermal insulation. Previously published fire diffusion values were applicable for systems with a maximum of 10 cm thick insulation material, however, nowadays 12, or even 20 cm thick evaluated thermal insulations systems are to be found.
- The fire regulation OTSZ, as of October 6., 2011. requires - in case of façade thermal insulation systems without an insulation core and when system based A1/A2 plaster types are used - that horizontally, A1 or A2 fire resistant material fire diffusion gaps are to be inserted regardless of the system's classification at:
  - above window cavities and extending on both sides by 20-20 cm,
  - or on the whole façade surface with openings running continuously around at a height of maximum 50 cm above the windows.

  The position of both doors and windows pose similar issues for all façade plaster insulation systems, regardless of thickness.
- In case of ventilated facades, the thermal insulation – with the exception of the footing area – must be made of materials with A1/A2 fire resistance class. The ventilation cavity of the façade is to be sectioned off from that of the pitched roof.
- Pitched roof ventilation cavities, due to their flue effect, increase the danger of fire diffusion. When the ventilation cavities are bordered by combustible materials, fire diffusion may be very rapid. Pitched roofs thus may contain "E" fire resistance category hard foam type thermal insulations (XPS, PUR, PIR) only in case of single units and in a maximum height of floor level + attic (G+A). Phenol resin based hard foams may be used for the thermal insulation of attics in G+1+A level buildings. The positioning of electrical installations within the thermal insulation or within the continuous line of the fire protection layer is to be avoided in all cases, as electrical installations are ignition sources.

7. BUILDING MACHINERY CONSEQUENCES

We have earlier elaborated upon the fact that the conscious design and careful construction of the thermal envelope, paired with dedicated building machinery calibration, may seriously reduce the energy loss of our buildings. In parallel, the elimination of the air loss of the building's envelope focuses our attention on the regulated ventilation of the interior. The reduced energy requirement is practically satisfied by renewable energy sources. Such are:

- the use is not affecting the source:
  - solar energy (e.g.: collector, cell, solar power plant),
  - water,
  - wind,
- the use is limited to reproduction:
  - bio mass,
  - geothermal energy.

Passive and semi-passive techniques combined with structure integrated building machinery solutions just as active systems may produce considerable energy gain. Such are:

- passive solar systems:
  (e.g.: transparent thermal insulation, wall mass, trombe wall, phase changing materials);
- solar zones (e.g.: winter gardens, glass houses, atriums);
- solar chimney, air collectors, hybrid systems;
- thermal pumps.

In the zone divided floor plan, vented, flushed and influx areas are to be designated. Vented areas should be the closed, high vapor content rooms (bathrooms, kitchens etc.). Air ducts are to be consciously positioned in shafts and/or in false ceilings. In the family house scale, the heat exchanger is a compact HVAC combination unit that may be positioned in any general storage space.

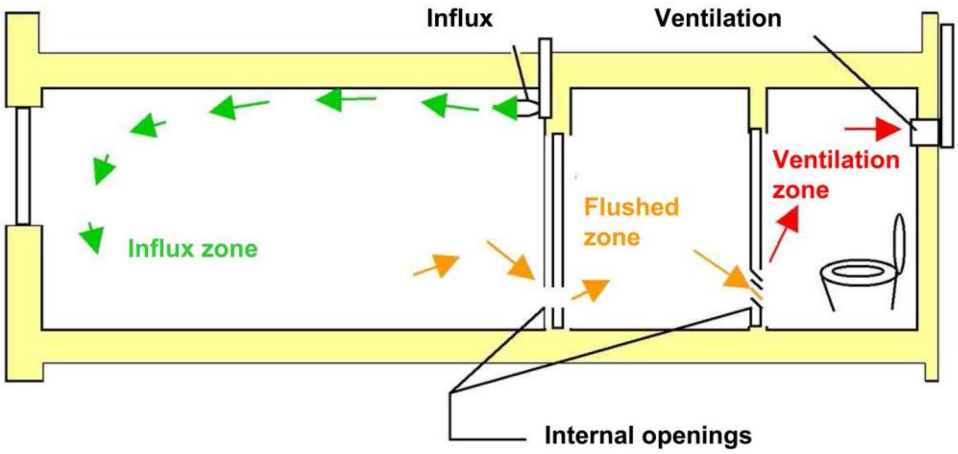
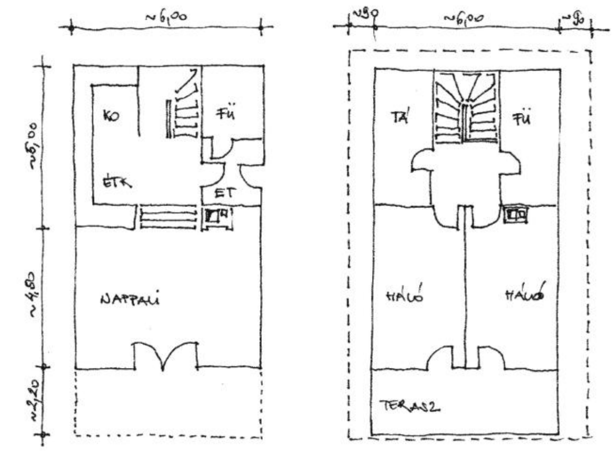


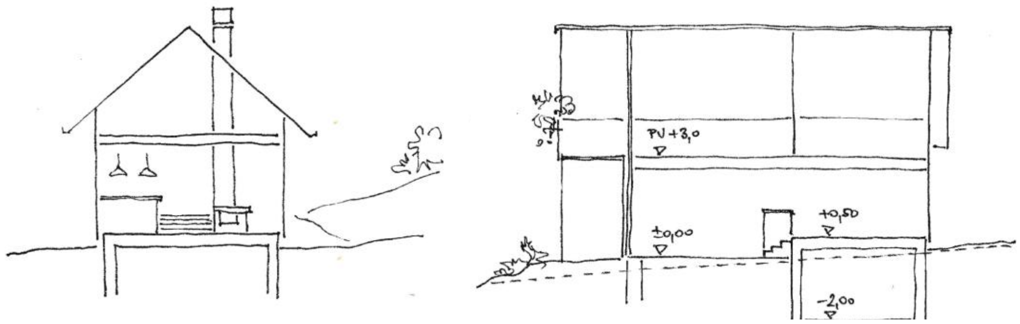
figure 31. Ventilation scheme

8. A FAMILY HOUSE SCALE EXAMPLE

The example shows an assembled building’s theoretical disposition, focusing on plane coordination and layer suggestions. The house is on a slope and has a partial basement.



figures 32-33. Ground floor and attic floor plans



figures 34-35. Cross sections

The basement of the two story house is of r.c. construction, outside of the thermal envelope. The basement, however, is accessible and the structural elements in it need protection, so the basement area is by tempered by 10 cm thermal insulation. Strip foundations are prepared below all walls. Concrete floor bases will separate areas directly on the ground level. The structure of the building is a plank construction with identical structural elements in the walls, slabs and the roof. Connection to the basement intermediate floor slab and to the floor base is made with a load diffusing foot plank and nail plates. In between the external wall structure planks, homogenous thermal insulation is inserted in the full cross section area (e.g.: paper foam, mineral wool, other foam insulations etc.). The basic principle of the assembled space separator layer composition is that the thermal insulation is of a multi-layer construction which eliminates cold bridges in all wall areas. Onto the outside surface of the structure frame a 10 cm thick, wind protected, load bearing (e.g.: mineral wool, wood fibre, wood wool etc.) thermal insulation layer is inserted. Outside of this last insulation layer, a ventilated wooden façade covering is laid. In the interior, a 5 cm thick service gap allows the comfortable positioning of all electrical and water piping. The service gap is to be filled by fibrous (mineral) thermal insulation. Internal separators are also of a frame construction, these are covered by drywall finishes (gypsum boards).

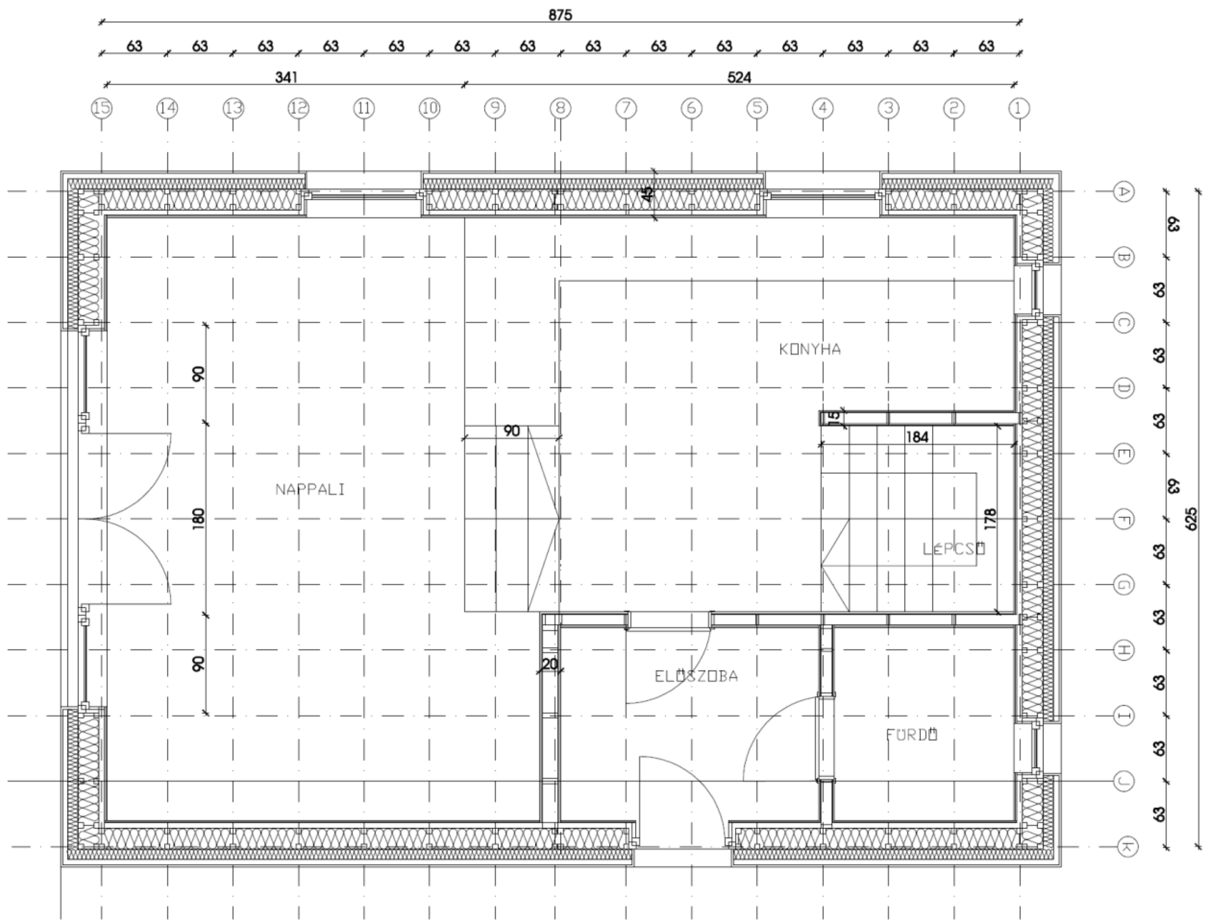


table 36. cold bridge reduced wooden I frame construction floor plan

Suggested theoretical layer composition (without actual sizes and product names):

Roof construction:

- roof covering
- ventilation layer (recommendation: 8 cm)
- wind blocking auxiliary waterproofing
- load bearing thermal insulation, above the rafters
- I frame rafter line, filled with thermal insulation
- drywall
- air and vapor block layer
- service gap, filled by thermal insulation
- interior finish

Wall structure:

- façade covering
- ventilation layer (recommendation: 5 cm)
- wind blocking façade foil
- load bearing thermal insulation, outside of the wall frame
- drywall (foundation or plane reinforcement)
- I frame rafter line, filled with thermal insulation
- drywall

	air and vapor block layer service gap, filled by thermal insulation interior finish
floor (at basement):	finishing floor base (e.g.: estrich, or 2 layers of nut-and-groove connected dry walling) load bearing thermal insulation (floating) and service gap r.c. floor slab
floor (at ground):	finishing floor base (e.g.: estrich, or 2 layers of nut-and-groove connected dry walling) load bearing thermal insulation (floating) and service gap waterproofing r.c. floor slab with construction layer vibrated sand / gravel mixture
basement wall:	water resistant thermal insulation, footing plaster waterproofing r.c. basement wall

8.1. Details

8.1.1. Footings

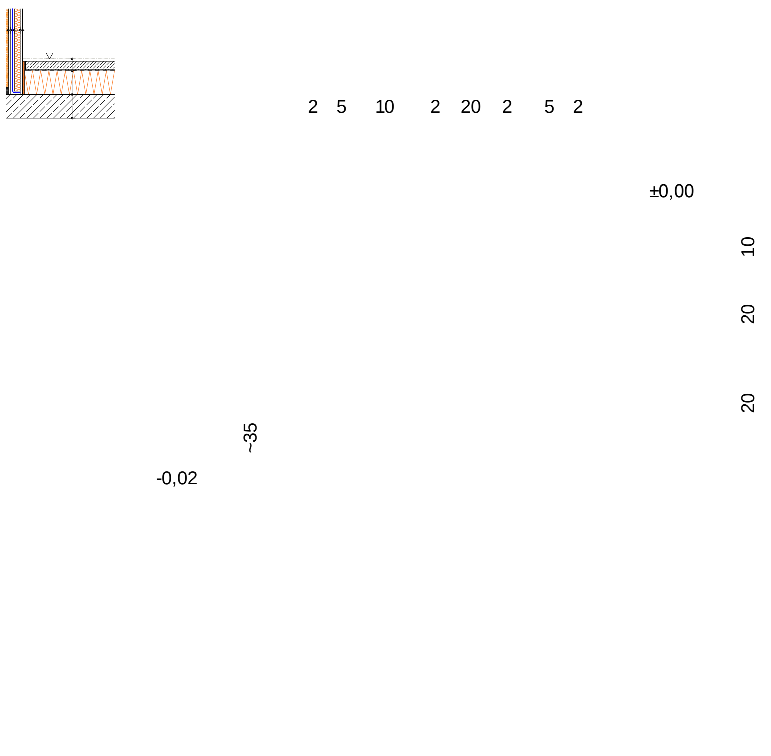


figure 37. Assembled building, basement wall / ground level wall base detail

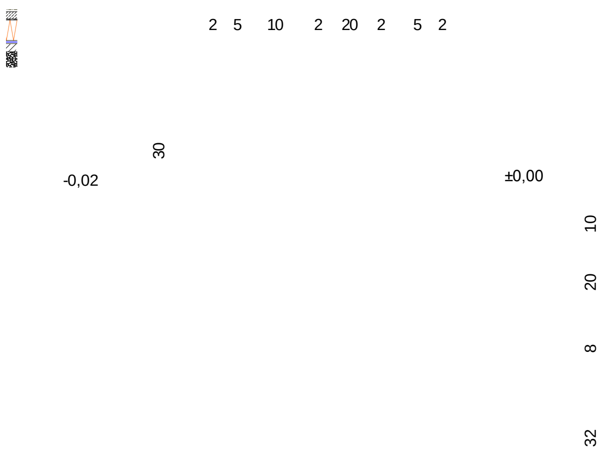


figure 38. Footing detail, floor base at the ground

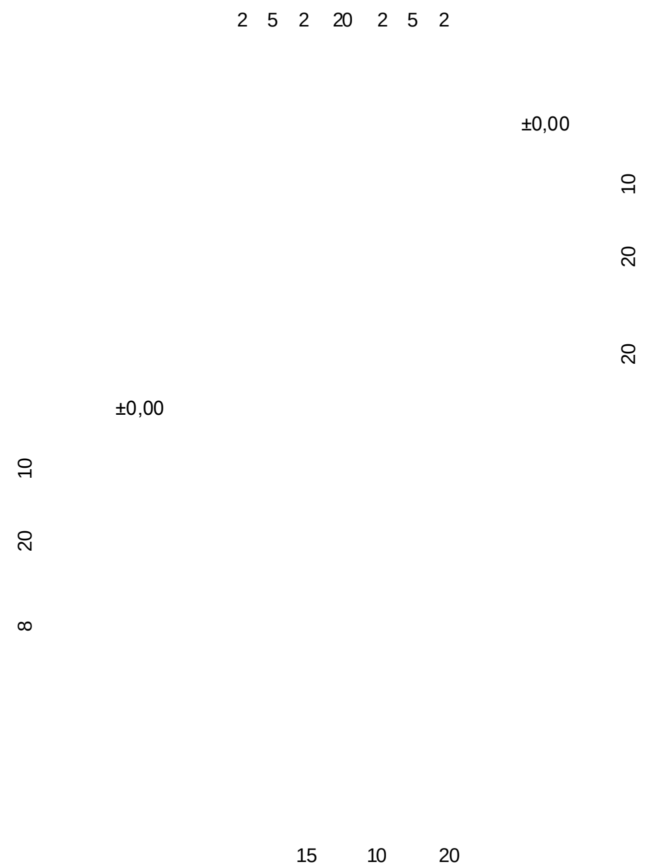


figure 39. level change detail

8.1.2. Slab connection

2 5 10 2 20 2 5 2

3x2
2
5
2
20
2

figure 40. slab connection

8.1.3. Window insertion

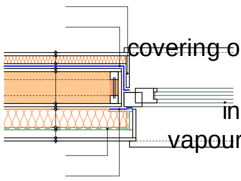


figure 41. Window insertion horizontal cross section detail (no shading)

2 5 10 2 20 2 5 2

external
precipitation block

internal air
and vapour block

external
precipitation block

internal air
and vapour block

2 5 10 2 20 2 5 2

Figures 42-43. Window insertion, vertical cross section detail (no shading)

2 5 10 2 20 2 5 2

high thermal insulation
(pl. PUR/PIR)

shading

external
precipitation block

TJI - lintel

gap cover

internal air
and vapour gap

external
precipitation block

internal air
and vapour gap

2 5 10 2 20 2 5 2

figures 44-45. Window vertical cross-section, with shades

8.1.4. Eaves

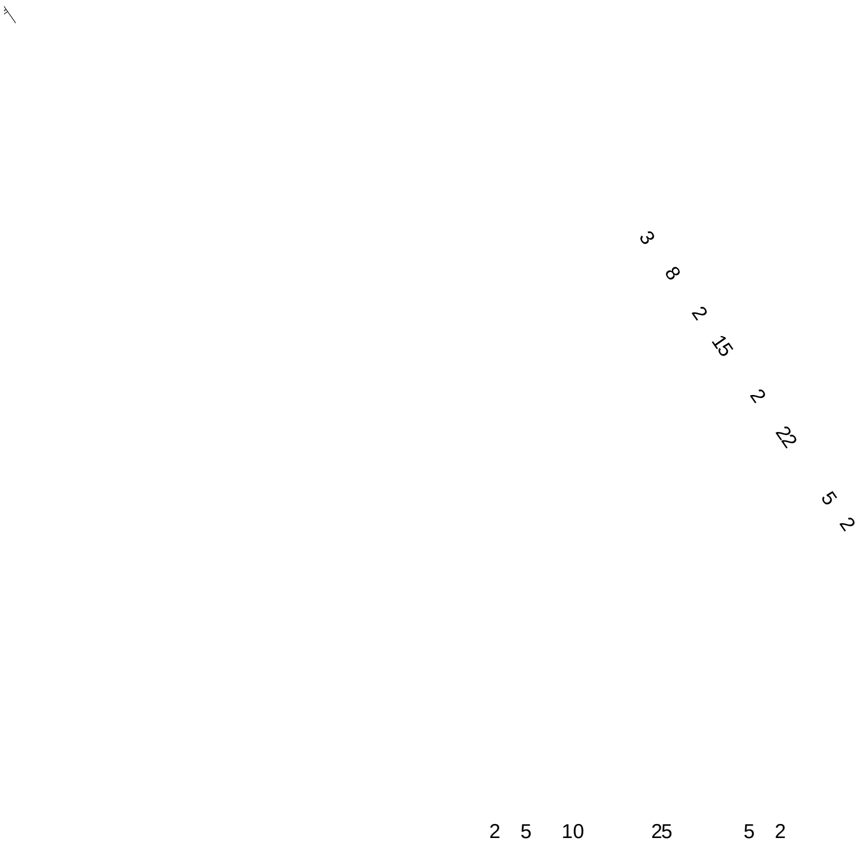


figure 46. Wall and roof connection

8.1.5. Wall corners

2 5 10 1 20 2 5 2

2 5 10 2 20 2 5 2

figure 47. external wall corner

9. SMALL APARTMENT OR SAME SIZE PUBLIC BUILDING EXAMPLE

The mixed function example is selected from the work of winning nominees of a design competition, announced together by the BME (Technical University of Budapest) Building Construction Department, the “Nem Adom Fel Alapítvány” foundation and the Hungarian Passive House League (MAPASZ). The competition entailed the design of a boarding house for physically challenged people and their relatives[2]. Functionally the building had to accommodate areas for working, resting and other community activities for handicapped people with varied levels of physical disabilities. The competition defined that passive house rules must be applied.

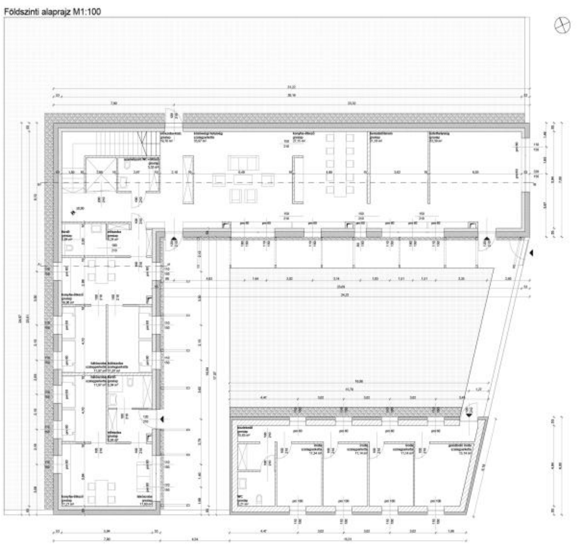


figure 48. Ground floor

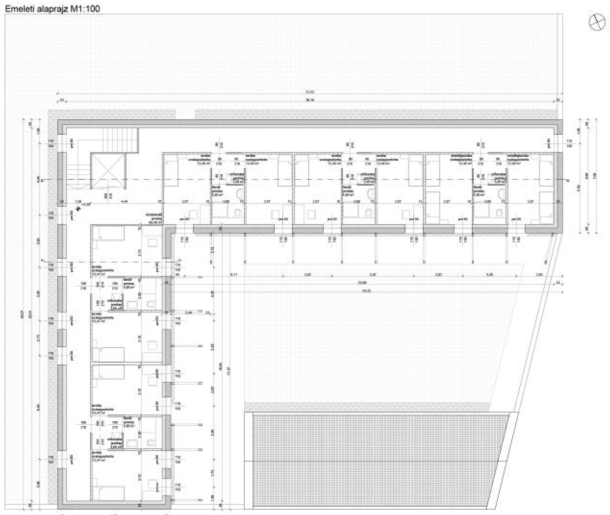


figure 49. Attic floor

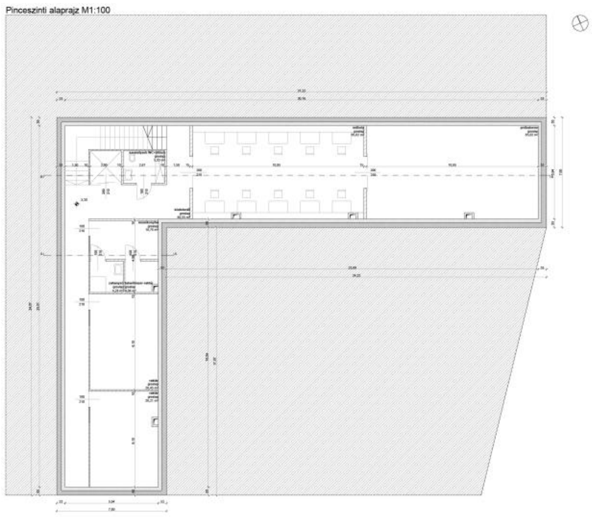


figure 50. Basement floor

2 The selected plan was awarded second position. Designers: Bálint Bakos, Péter Batizi-Pócsi, Gábor Zsolt Berecz, Zoltán Dévai, Júlia Ivicsics, Norbert Juhász, Máté Ligeti, Eszter Vágvölgyi, Zsolt Várszegi

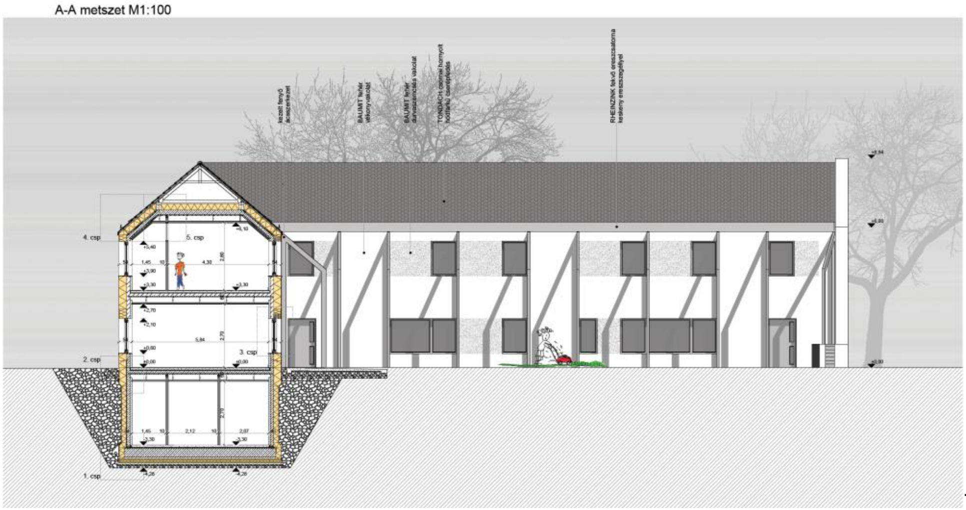


figure 51. Cross-section


Figure 52. Perspective

The design program requirements were satisfied by a stand-alone, B+G+A (three story) building that was oriented south in order to maximize solar gains. The building is composed of silicate structures, which will entail more the familiar design of the Hungarian practice, but at a low energy or passive house standard.

9.1. Recommended details

This section contains the more relevant details of the design. The details are typical examples, they do not necessarily contain all information required for construction. As may be seen, the design as a whole cannot disregard the necessary level of exact detailing. Passive house standards may impose further requirements during construction.

Each detail suggests materials to be used. On some cases these do not mean exclusivity, other solutions are possible (e.g.: battened thermal insulation that is blown into the cavity of the façade), alternatives must be weighed during design.

Although the details are in scale, they still do not contain numeric values. As seen before, all specific material and construction applications must be preceded by careful and detailed calculations.

9.1.1. External wall – foundation connection to the heated basement

When a heated basement is a requirement, the boundary structure of the basement becomes part of the thermal envelope. Both the wall and the floor must, therefore, have extensive thermal insulation. When there is a full basement, the recommended solution is a slab foundation. The structures in the ground must be protected against the given level of water saturation. The waterproofing layer may be below or above the floor base slab.

Recommended materials:

- basement wall: solid wall structure (small brick, form blocks, concrete, r.c. etc.)
- thermal insulation below the floor base slab: high load bearing capacity (protected against wetness: glass foam, XPS, PUR/PIR)
- basement wall thermal insulation:
    - protected against wetness: EPS, mineral wool, PUR/PIR
    - not protected against wetness: XPS, form foam EPS

25 30

PV

30

15

20

8

figure 53. Foundation-external wall connection detail with heated basement

9.1.2. Ground floor footing at the basement

When a heated basement is a requirement, the boundary structure of the basement becomes part of the thermal envelope. When the basement is not heated, the boundary structures are not part of the thermal envelope, thus the thermal insulation must be positioned above or below the basement ceiling slab. The wall structure will produce cold bridges; this may be reduced by the continuing of the thermal insulation down along the basement wall. When the thermal insulation is positioned above the basement ceiling slab, the insulation line is to be made continuous thru the load bearing wall structure (e.g. glass foam insertion). All structures in the ground must be protected against dampness.

A. Heated basement

Recommended materials:

- external wall: high mass wall structure (e.g.: reduced weight small brick, porous concrete, lime-sand brick, adobe, r.c.)
- external wall thermal insulation: above the footing line mineral wool, EPS, PUR/PIR, woodchip, reed for example as part of an insulating facade system
- basement wall: solid wall structure (small brick, form blocks, concrete, r.c. etc.)
- basement wall thermal insulation: XPS, form foam EPS at least to the footing height)

25 30

30

-0,02 ±0,00

15

20

figure 54. footing detail in case of a heated basement

B. Non-heated basement, thermal insulation below the slab

Recommended materials:

- external wall: high mass wall structure (e.g.: reduced weight small brick, porous concrete, lime-sand brick, adobe, r.c.)
- external wall thermal insulation: above the footing line mineral wool, EPS, PUR/PIR, woodchip, reed for example as part of an insulating facade system
- basement ceiling slab thermal insulation: mineral wool, EPS, PUR/PIR, woodchip, reed for example as part of an insulating facade system
- basement wall: solid wall structure (small brick, form blocks, concrete, r.c. etc.)
- basement wall thermal insulation: XPS, form foam EPS at least to the footing height)

25 30

30

-0,02

±0,00

15

20

20

a

> 4a

25 30 20

< FROST LINE

5

figure 55. footing detail in case of a non-heated basement 1.

C. Non-heated basement, thermal insulation above the slab

Recommended materials:

- external wall: high mass wall structure (e.g.: reduced weight small brick, porous concrete, lime-sand brick, adobe, r.c.)
- external wall thermal insulation: above the footing line mineral wool, EPS, PUR/PIR, woodchip, reed for example as part of an insulating facade system
- basement ceiling slab thermal insulation: load bearing mineral wool, EPS, wood chips
- basement wall: solid wall structure (small brick, form blocks, concrete, r.c. etc.)
- basement wall thermal insulation: XPS, form foam EPS at least to the footing height)

25 30

30

-0,02

±0,00

15

20

cold bridge gap,
e.g. foam glass

20

a

>4a

min. frost line

figure 56. footing, non-heated basement 2.

9.1.3. Door and window insertion

In case of narrow thermal insulation layers (≤20-25 cm) the insertion planes of the external balcony and terrace doors are defined by the shading mechanism. In case of entry doors, the position is best selected as is best for the thermal insulation. When the door or window insertion line falls outside of the load bearing structure's external surface, false frames need be used. When the thermal insulation layer thickness is considerable, the insertion plane will be defined by both the thermal insulation and the construction method: the door or window usually at least partially covers the external wall.

The thermal insulation is to cover the window structure, thus sometimes a system based, cold bridge gap frame extension may be necessary. When the balcony slab is made with a site inserted cold bridge gap element, the ideal position for this element is in the plane of the door or window frame.

Internal air and vapor block is assured by an air and vapor blocking strip or, when the back structure is rigid, with permanently elastic filler. Precipitation is kept out by a dedicated membrane on the external surface. The membrane is connected to the waterproofing in a watertight manner. Sometimes the mechanical and UV protection of the thermal insulation in the door sill connection area is a problem, this is often solved by inserted steel sheets.

The floor layer structure may be altered by the necessity to lead building machinery or electrical lines above the floor slab, the resulting service gap is coordinated with the thickness of these lines.

A. Ground floor door sill

Recommended materials:

- basement wall thermal insulation: XPS, form foam EPS
- door: dual or triple layer thermal insulation glass preferably with a cold bridge gap structure

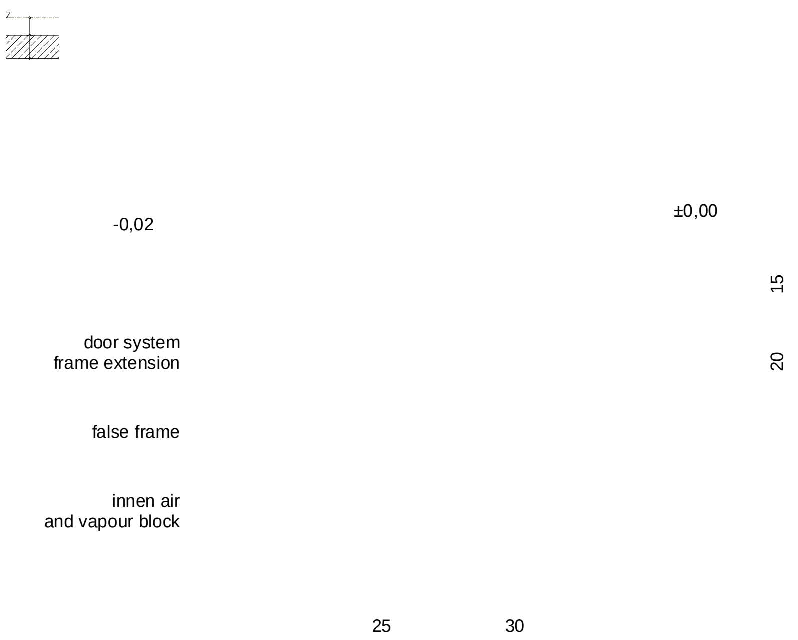


figure 57. ground floor external door insertion

B. Windows with shades

Recommended materials:

- window: dual or triple layer thermal insulation glass preferably with a cold bridge gap structure
- external wall: high mass wall structure (e.g.: reduced weight small brick, porous concrete, lime-sand brick, adobe, r.c.)
- external wall thermal insulation: above the footing line mineral wool, EPS, PUR/PIR, woodchip, reed for example as part of an insulating facade system

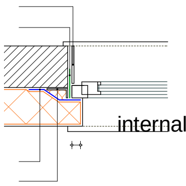


figure 58. window insertion, horizontal cross section

25 30

PV.

enchanced thermal insulation capacity material (e.g. PUR/PIR)

5

15 15 25

shades

external perticipation block

20

false frame

gap cover

internal air and vapour block

internal air and vapour block

gap cover

4

false frame

internal air and vapour block

25 30

figure 59-60. window insertion, vertical cross section 1.

C. Balcony door, built-in cold bridge gap slab

Recommended materials:

- door: dual or triple layer thermal insulation glass preferably with a cold bridge gap structure
- external wall: high mass wall structure (e.g.: reduced weight small brick, porous concrete, lime-sand brick, adobe, r.c.)
- external wall thermal insulation: above the footing line mineral wool, EPS, PUR/PIR, woodchip, reed for example as part of an insulating facade system

door system frame extension
external precipitation block
false frame
internal air and vapour block
1%
PV.
15
20
25
30
cold bridge gap
5
high thermal insulation capacity material (e.g.PUR/PIR)
15
15
25
shades
external precipitation block
20
false frame
gap cover
internal air and vapour block

figure 61. balcony door

D. Window insertion in case of increased thermal insulation thickness

Recommended materials:

- window: dual or triple layer thermal insulation glass preferably with a cold bridge gap structure
- external wall: high mass wall structure (e.g.: reduced weight small brick, porous concrete, lime-sand brick, adobe, r.c.)
- external wall thermal insulation: above the footing line mineral wool, EPS, PUR/PIR, woodchip, reed for example as part of an insulating facade system

35
30
PV.
15
20
external precipitation block
15
20
shades
15
internal air and vapour block
gap cover
external precipitation block
internal air and vapour block
35
30

figure 62-63. window insertion, vertical cross section 2.

9.1.4. Pitched roof

In case of silicate based walls, the roof structure may be either constructed as an r.c. “coffin” slab, or out of traditional wood. In the latter case, design may follow recommendations in section 8. The thermal envelope, however, will have better acoustic and thermal insulation integration if the first solution is used.

A. Eaves

Recommended materials:

- external wall: high mass wall structure (e.g.: reduced weight small brick, porous concrete, lime-sand brick, adobe, r.c.)
- external wall thermal insulation: above the footing line mineral wool, EPS, PUR/PIR, woodchip, reed for example as part of an insulating facade system
- roof thermal insulation: load bearing („above rafter”) thermal insulation out of mineral wool, XPS, form foam EPS, PUR/PIR, wood chips
- auxiliary waterproofing: wind blocking, vapor transmitting foil

figure 64. eaves

B. Gable

Recommended materials:

- external wall: high mass wall structure (e.g.: reduced weight small brick, porous concrete, lime-sand brick, adobe, r.c.)
- external wall thermal insulation: above the footing line mineral wool, EPS, PUR/PIR, woodchip, reed for example as part of an insulating facade system
- roof thermal insulation: load bearing („above rafter”) thermal insulation out of mineral wool, XPS, form foam EPS, PUR/PIR, wood chips
- auxiliary waterproofing: wind blocking, vapor transmitting foil

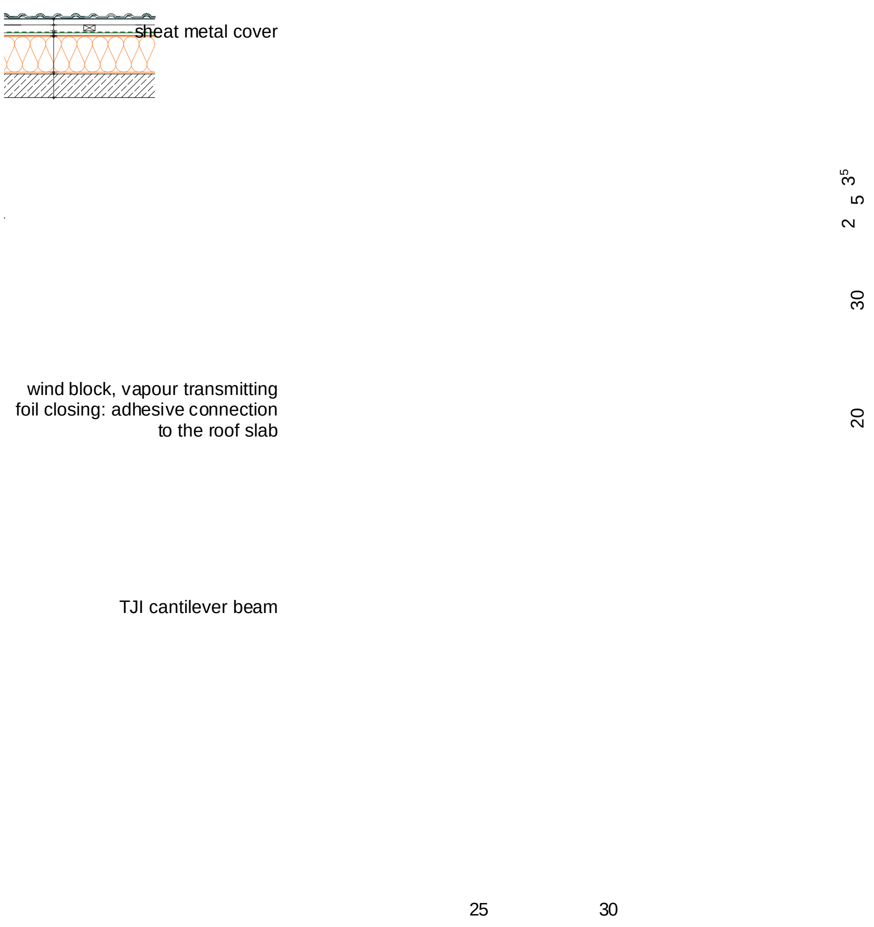


figure 65. fire protective gable detail

10. A LIST OF CURRENTLY VALID REGULATIONS AND STANDARDS

[1] MSZ-04-140:1979 Épületek és épülethatároló szerkezetek hőtechnikai számításai

[2] MSZ-04-140:1985 Épületek és épülethatároló szerkezetek hőtechnikai számításai

[3] MSZ-04-140:1991 Épületek és épülethatároló szerkezetek hőtechnikai számításai

[4] 7/2006. (V.24.) TNM rendelet az épületek energetikai jellemzőinek meghatározásáról

[5] 253/1997. (XII. 20.) Korm. rendelet az országos településrendezési és építési követelményekről (OTÉK)

[6] MSZ EN ISO 10211

[7] MSZ EN ISO 10456

[8] Richtlinie – Ausführung luftdichter Konstruktionen und Anschlüsse 2009.

[9] MSZ-EN 13829

[10] 28/2011 (IX.06.) BM rendelettel kiadott Országos Tűzvédelmi Szabályzat

[11] MSZ 15601:2007 Épületakusztika

[12] 27/2008 KvVM-EüM rendelet

[13] 9/2008 (II.2.) OTM rendelet

[14] MSZ 14800-6:2009

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[10] Alátéthéjazatok tervezési és kivitelezési irányelvei. Épületszigetelők, Tetőfedők és Bádogosok Magyarországi Szövetsége (ÉMSZ) 2006.

[11] A. Bobocinski – J. Pogorzelski:, Építési Piac, 2006. 1-2. szám

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