Thesises of the PhD. dissertation

Energetical certification method of wooden frame housing system, and application for development

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Introduction

Community energy consumption take a major share of the national energy usage in Hungary. This appear in the heating usage of natural gas in winter, and cooling usage of electical energy in summer. Saving the energy is our global interest, but the 2002/91/EK Energetical Directive of the European Union is a more exact reason. In Hungary, the 7/2006 (V.24.) Ministerial decree about the energetical calculations and the 176/2008 (VI.30.) Governmental decree about the energetical certificate of buildings regulate the energy consumption of buildings in harmony with the european regulations. These rules control the thermal and energetical requirements of building directly, but the rapidly rising price of the natural gas, and the gradual decreasing of the subsidies are also pressing the bettering of the energetical efficiency of hungarian building stock. The wooden frame houses have got favourable energetical properties, so this kind of buildings can get significant mission on the market of the energy-saving houses. The average hungarian wooden-frame-construction can be suitable for the highest energetical classification after some development. This dissertation examine the necessary development from the point of decreasing the energy-need and heating cost, rising the building cost and time of refunding. The common methods are usable for the „traditional" brick and concrete structures, but the wooden-frame buildings need some changes in calculaton method. These changes were to be worked out. The modificated method had to be exact, detailed, fitted to the specialities of the wooden-frame system, but simple and quick, because the maximal time of making a certification will be two hours (according to the 176/2008-VI.30.). The dissertation turns significant attention to calculation of glased structures. This part of the calculation method is very useful for the certification of the traditional (brick) buildings, too.

Preliminaries

Significant changes are expected in building-energetics in Hungary.

The energy eficiency of hungarian building stocks are underdeveloped. Almost half of the 4,3 million hungarian houses are energetical classified as „very wrong”, 33 % is „wrong” and further 11 % is „weak”. The energy usage of the family houses are higher, than the blockhouses: 75 % of the heating energy consumption can be attached to the family houses.

The good quality wooden frame houses are coming into general also in Hungary, due to the official regulations and the work of the professional corporations. These building are made with large quantity of thermal insulation materials, so they energy need is lower, than the traditional (massive) houses. The most polular property of these houses is the low energy-cost, wich rises their demand.

The price of the russian import natural gas is following the world market price of the crude oil (WTI). The price of the oil has been doubled in the last year, and it will be rising longer. These explosion of the oil-price is larger than the famous one in year 1973. The hungarian government can not ease the rising of the gas-price for the community, moreover, the subsidy will be decreased because of the reorganisation of the energetical-politics. This steps are expected either by the International Energy Agency or by the financial position of Hungary.

The Governmental decree about the energetical certification of buildings were poclaimed on the 30th of June 2008. This decree enforces providing the buildings with energetical certification from 1.st of January 2009. The conditions of the certification precedure are in the decree, even the accountable time for the calculation. This timeis two ours, which is very short, so the applicated calculation method has to be simple, quick, but detailed and exact enough.

The external limiting constructions of a wooden-frame house are inhomogenous, so calculating method of thermal transmittance is more difficult, than in the case of a massive building. The calculation method is reguled by the standard MSz EN 6946. This standard is english, so application is difficult. The glased constructions like window can cause energyloss and energy winning. The phisical properties, wich are needed for the calculation are rarely given correctly by the catalogues of the manufacturer. The known properties are not suitable for the calculation method, so these details can be applicated only after more or less simplifying. Detailed analysis of glased constructions need a lot of time. Considering the thermal bridges can be made with a simplified or a detailed method. The simplified method contains so large roundings, that it can destroy the result the energetical classification of the building. But the interest of the owner of the building is, that the building do not get worse classification, that is deserved, because it can destroy the market value of the building. All together, applicating the detailed method is reasonable, but in this case, the properties of the thermal bridges and the glased structures are needed.

Targets of research

The first target of this research is a calculation method for the energetical certification including the speciality of wooden frame houses. The basic idea of the method is the following: if the necessary data and relations are known, and these can be integrated easily into the detalied calculation method, than we can get the detailed results in the time of the simlified method.

This detailed method needs such data for the calculation, wich are not given correctly in the catalogues. This are the energy-loss of the thermal bridges or the real thermal transmittance of the glased structures, not mentioned the energy-winning of the windows. I wanted to complete or working out the suitable relations, and determinating the nessesary data for the calculations using these relations. There will be two categories, one for the average housing-system, and one for the developed, increased energy-safe housing system. The necessary data will be publicated as a design handbook.

The first application of the method is a certification of an average wooden frame family house, presenting the calculation steps. The results of the certification can help us defining the dimension of the development, wich is needed for bettering the average house to the ’A+’ (increased energy-safe) category. My target is defining the nessesary insulation-thiskness and placing method, for reaching the requirements of the highest category

The analisys expand to the definition of the optimal wall-thickness and a harmonised ceiling and roofing system. I examine the energy loss of the average and the developed housing system, and its ratio. I determine the effect of each developing step and all together. The consideration are the energy-saving and the building costs. I can calculate a refunding time by using a predicted natural gas prise. This time can not be calculated exactly, because the price of the energy-carrier materials are not changing uniformly. The real refunding time is propably shorter than the calculated.

The methodic of the research

Studying the technical literature and getting the most personal experiences as possible, these can be mentioned as preparation of the analysis. I read articles and papers about energetics, energy-politics, management with energy-carriers and case studies about building projects from develeped countries like Germany or Austria, wich is famous about the large number of passive houses. Meanwhile reading this case studies the difference in approaching the energy-usage between West-Europe and Hungary can be realised unambiguously. I got my knowledge about the wooden-frame housing system either by working in design, prefabrication and building projects, or field trips in Hungary and abroad. I got a good command of the building phisical standards and regulations due to my former researches and design projets.

The thermal transmittance of the inhomogenous structures can be calculated with a weigthing method. The wall is calculated by single wighting, the ceiling and the roofing are calculated by double wighting. The ratio for the weighting were definied grafically by my former reserach results.

For determining the characteristic properties of the thermal bridges, meteorological data from the database of the Hungarian Meteorological Service were needed. The marginal conditions for the computation can be definied by instruction of the hungarian standards. The analysis of the thermal bridges was made by *Therm*, a finite element method software. Processing the results, *Excel* spreadsheet-software was applicated. The drawings about the details and the plans of the sample building were made with *AutoCad*.

The results of this analysis can be collected in a thermal bridge catalogue. The *Therm* provides partial results for the vapour-phisical analysis, these must be converted by the *Mollier h-x diagram*.

Examination of glased constructions is a complex work. The thermal transmittance of the glasing do not describe the energetical behavior of the window. Data for a detailed calculation are rarely available. In my method I analysed the window-frame firstly as a linear thermal bridge. After it, I analysed this detail built into the wall (or into the roof, in the case of a the skylight windows). The merged energy-loss and energy winning of a glased construction can be calculated from basic-data, summarizing the results for standard window sizes in tablets can ease the certification method.

The energetical analysis of the sample building was made according to the 7/2006 and 176/2008 decrees. Some simplifying are possible, bacause wooden-frame systems are generally used for living houses.

The cost-analysis of the development was made according to offer of several building-material stores and a building company. This company is a member of the MAKÉSZ (Alliance of the Hungarian Prefabricated House Factories). The importance was on the material-costs, because the wages are the same on the two level of thermal-insulation capacity. The prime-energy usage of building can be converted into natural-gas usage, and predicted heating cost. The price of natural gas and electrical-energy can be found on the website of the energy-service-company The refunding time can be calculated with actual and predicted energy-prices. We can get more exact data, when we pay attention for rising the prices. In the next time, we must count on extremly rising of gas-price, but it is hoped, that rising will decrease, and will join an acceptable, lower value in long term. I definied the long-term rising as 15 % yearly, lower rising is hardly to exepted, higher rising will shorten the calculated refunding time.

Thesises

After the analysis I can state the followes:

1. The thermal bridge effect of the beams (studs, joists or rafters) in a wooden-frame building system is not negligible. For calculating the thermal transmittance, the method for inhomogenous layers according to EN ISO 6946 is suitable, more complex method is not needed. After the weighting, the wall (or ceiling or roof) construction can be count as a homogenous layer.
2. A wooden-frame wall construction made of 16 cm thick studs and further 12 cm frontal insulation is able to reach the highest 'A+' (increased energy-safe) category. More insulation like this do not cause a spectacular improvement in thermal insulattion capacity of the building. Application of more insulation material is justified only in special cases, like bulising passive houses.
3. The continous thermal insulation layer on the outer side of the building construction can definitely decrease the effect of the thermal bridges in a wooden-frame system. This kind of insulation is able the make the thermal bridge totally disappear, if the right thickness is applicated. In this case, we can make a fully homogenous constuctrion.
4. The lowest surface temperature on a wooden-frame building construction is measurable in the center plane of the beams. The lowest surface temperature can be determinated by the thermal transmittance in the plan of the beam. The better insulated space between the beams can not cause higher surface temperature, than the calculated.

5. The linear thermal bridge between the inhomogenous construction is also inhomogenous. Weighting is to be applicated for deteremination of this kind of thermal bridges. For calculation the the linear thermal-bridge factor, the following relation is suitable:

$$\psi_e = \left(0.1 \cdot L^{2D}{}_{Borda} + 0.9 \cdot L^{2D}{}_{Bordaköz}\right) - U_1 \times l_1 - U_2 \times l_2$$

Where:

ψ_e: weighted linear thermal-bridge factor

$L^{2D}{}_{Borda}$, $L^{2D}{}_{Bordaköz}$: calculated heat loss on the beam and between the beams

U_1, U_2: weighted thermal transmittance of the connected constructions

l_1, l_2: length of the conected constructions

The surface temperature must be calculated on the center of a beam, the better thermal insulation between the beams can not be counted for rising the surface temperature.

6. The 7/2006 Ministerial decree defines the upper limit of the thermal transmittance of the glased constructions. For calculation the resulted thermal transmittance the following relation can be applicated:

$$U_w = \frac{U_g \times sz \times m + \left(\psi_{pa} + \psi_{pf}\right) \times sz + 2 \cdot \psi_{po} \times m}{sz \times m}$$

Where:

U_w: resulted thermal transmittance of the glasing and the frame construction

U_g: thermal transmittance of the glasing

sz, m: nominal width and height of the glased construction

ψ_p: linear thermal-bridge factor of the framing

(indexes: a: lower; f: side; o: upper)

The linear thermal-bridge factor of the framing can be determinated as the follow:

$$\psi_p = L^{2D} - U_g \times l$$

Where:

ψ_p: linear thermal-bridge factor of the framing

L^{2D}: resulted heat loss of the construction

U_g: thermal transmittance of the glasing

l: length

7. The inner surface temperature of wooden framed windows can be rised significantly by using three layered glasing and foamed insulation layer on the outer side of the frame. The temperature rising by these steps is generally enough for avoiding the risk of misting over or mould formation on the inner surface. This developing steps are necessary on skylight windows, because the average constructions do not perform the minimum requirements.
8. Total heat loss of built in glased constructions, wich contains the heat loss of the glasing, the framing and the thermal bridge of the window-border can be calculated by this relation:

$$Q_w = U_g \times sz \times m + (\psi_{ba} + \psi_{bf}) \times sz + 2 \cdot \psi_{bo} \times m$$

Where:

Q_w: total heat loss of the glased construction

U_g: thermal transmittance of the glasing

sz, m: nominal width and height of the glased construction

ψ_b: linear thermal-bridge factor of the built in framing

(indexes: a: lower; f: side; o: upper)

The linear thermal-bridge factor of the framing can be determinated as the follow:

$$\psi_b = L^{2D} - U_g \times l$$

Where:

ψ_b: linear thermal-bridge factor of the built in framing

L^{2D}: resulted heat loss of the whole construction

U_g: thermal transmittance of the glasing

l: length

9. The 7/2006 Ministerial decree defines the considerable heat winning of the glased constructions. The total heat winning of each window of a wooden frame building can be calculated for the whole heating-period by this relation:

$$Q_w^{+} = s \times g \times 0{,}3622 \cdot A_w^{1{,}38}$$

Where:

s: the siting factor of the glased construction

g: sunlight-penetration factor of the glasing

A_W: area of the window calculated from the nominal sizes

The *g* factor and the constant 0,3622 can be reduced, because typical glasing has got the same *g* value.

Double glased, average glasing: $Q_w^{+} = s \times 0{,}2354 \cdot A_w^{1{,}38}$

Triple glased, special glasing: $Q_w^{+} = s \times 0{,}1992 \cdot A_w^{1{,}38}$

The value of the *s* factor must be choosen as follow:

On sunny, S sited facade	s_D:	4,0
On sunny SE or SW sited fasade:	$s_{DK/DNy}$:	3,0
On sunny E or W sited fasade:	$s_{K/Ny}$:	2,0
On sunny NE or NW sited fasade:	$s_{ÉK/ÉNy}$:	1,5

On N sited and not sunny fasade: $s_É$: 1,0 (negligible)

For calculating the heat winning on skylight windows, the *s* factor can be multiplied by 1,5.

10. The 7/2006 Ministerial decree defines a simplified and a detailed calculation method. The results of the simplified method are about 10 % higher, than the results of the detailed method. This difference can causes, that the building get a worser certificatation, than it deserves. For making a perfect certification, the simplified method is unfavourable. The largest disadvantage of the simplified method is that it overvalues the heat-loss of the thermal bridges. The heat loss of thermal bridges are less than 10 % of the total heat loss, even if the building is in the „strongle heat-bridged" category. The 20 or 30 % value of the increasing factor are groundless. Modifying the category-borders, or the applicated increasing factors is suggested. Till then, the detailed method is recommended.
11. If more thermal-insulation is built in into the construction, the decreasing of the thermal transmittance is more significant, than the rising of the building costs. From this point, the developmenet can be considered effective. But decreasing the total energy usage of the building is not so spectacular due to influence of more other elements. This is the reason that the refunding of the costs of the investment calculated with the actual price of natural gas can not be shown.

Results of the research

The primary result of the research is the calculating method, wich is suitable for determinating the necessary design data of wooden-frame houses. The design reference book compiled on the basis of this method includes the design data of the average and the developed wooden-frame house-system. These data are the ψ_e linear thermal-bridge factor of the connects, the f_{Rsi} inner surface temperature, the φ_{80} and φ_{100} limit-values. The tablets of the design reference book gives the f_{Rsi}, φ_{80} and φ_{100} values of the punctiform thermal bridges. Other tablets contains the resulted thermal transmittance of nominal sized glased constructions. Further tablets contains the heat-loss and the heat winning of average and high-insulated built in windows for the heating period. So necessary design data are available for the simplified and also for the detailed certification method.

Secundary result is the calculation method, using the previously calculated data for certification of wooden-frame houses. The certification of a building become a simple and quick procedure by using the data in the design reference book. The method needs the time of the simplified method, but products the results of the detailed method. Application of this method is on behalf of either the certificator or the customer.

The results of the calculations prove, that woden-frame houses are very energy-safe. The average construction suits the requirements of the category 'A' (energy-safe). With the help of the created method, I have defnied a developed wall, ceiling and roof construction, wich are able to reach the highest category 'A+' (increased energy-safe), even if average building engineering is built in the house. The results give information, what kind of further developments are needed to create a passive-house, wich does not use fossil energy-carrier for heating.

The cost analysis gives an another proof, that the present subsided price of natural gas causes long refunding time. This long refunding time suggests to builders, that energetical investments are not worth. But increased rising of the energy carriers – especially the natural gas– shortens the refunding time, even if this effect can not be shown exactly.

Presentation of the results can help the trade and market business federations bettering the judgemenet of wooden-frame housing systems, and increasing their market share continously.

Publications and research projects connecting to the subject

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