Additional insulation of detached dwelling houses with straw-bale elements

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Abstract. The paper introduces the planning and construction experiences and development ideas of additional insulation of walls made from straw-bale. The energetic refurbishment of existing building is an important priority in the action plan of the EU dealing with the energy efficiency. The additional insulation of walls reduces significantly the energy demand of building but the effectiveness of the insulation has economic and environmental limits. According to our previous research we introduced that the additional insulation of walls made from straw has significant advantages.
The application of straw-bale insulation has large potential in the case of detached dwelling houses in rural environment. The paper introduces through two ready buildings the most important negative and positive experiences of straw-bale insulation. The paper also makes proposals for the development of the technology.

Introduction

There is only assumed data about the energy quality of Hungarian stock of building. In the country there are 4.2 million flats from which 2.5 million are in individual dwelling houses. The energy quality (average U-value) of 1.8 million dwelling houses is at least 2.6 times less weak than the actual requirements. [1, 2] Otherwise these buildings are detached houses in good statical condition, located in rural or small-town environment.

The paper introduces some aspects of a technology which is relatively new in Hungary the application possibilities of straw-bale insulation. The straw-bale as building material appeared in the beginning of the year 2000 in Hungary initiated by non-governmental organizations. The first experiences showed that beside the advantages of the material (good heat insulation capacity, use of waste material, CO_2 storage, etc.) the possible disadvantages (combustibility, risk of putrefaction and rodents) can be prevented with careful design of building construction. A fire-test of straw-bale wall has also carried out in 2008which serves as important guarantee of the adaptability to the builders and to the building regulations. The fire-test was made by the national quality control company (ÉMI) according to the MSZ 14800-1: 1989 standard with the result of REI 45 classification [3]. An Architect Office, led by the author of this paper, has been involved in several design and construction of straw-bale houses since 2007. Based on our experiences we can identify the directions of the technological developments as well as the limits of its distribution.

Case studies

Possibilities of building form straw-bale. There are different application possibilities of straw-bale based on literature and building practice in Hungary. The bales can be used in new houses as element of 1) wall a) with loadbearing function or b) without load-bearing function; 2) attic-slab; 3) ground-floor; 4) attic-roof or can be used for refurbishment of existing 5) wall; 6) attic-slab constructions. [4] Henceforth I will focus only on the refurbishment of wall constructions (5).

Dwelling house in Mány. In this example the straw-bale is not built additionally on the wall, but the process of the construction is very similar to additional wall insulation. The loadbearing construction of the house is 30 thick Porotherm brick wall. On the ring beam, made of reinforced concrete, wood slab and wood roof construction was constructed. To fix the straw-bales properly on the wall they built vertical wood sub-frame every 80 cm along the wall average. The U-value of the wall with the 35 cm thick straw-bale insulation is 0.128 W/m^{2}K. (Fig 1.)

The roof construction is different form the average shape, in order to allow the connection in total thickness of the insulation of the wall and of the slab. In this case 25 cm rock wool was planned in two layers on the slab.

Interesting experience of the project is that because of the matching to the ground the straw-bale insulation starts from different heights. So that the straw-bale were at least 30 cm away from the ground everywhere we designed the upturn of the water insulation on aerated concrete plinth-wall. The straw-bale insulation was plastered with *clay plaster* to protect from rainfall and the fire.

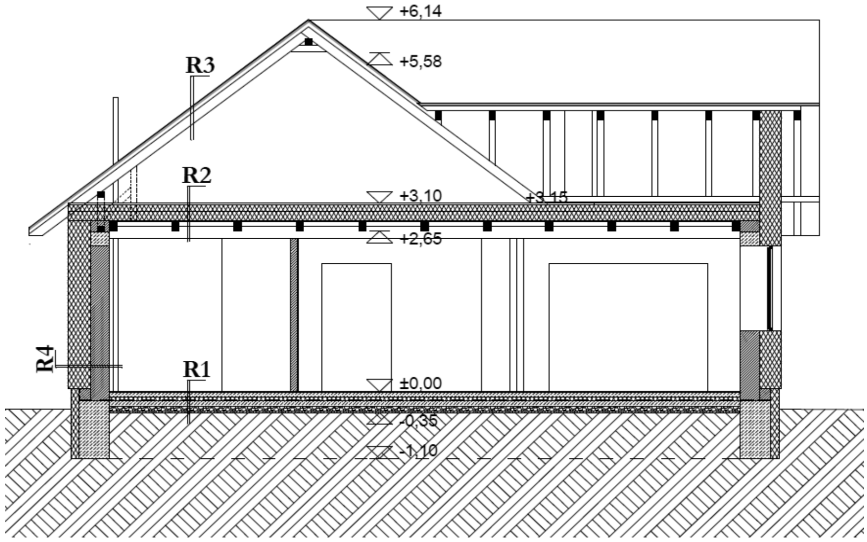

Fig 1. Section from the permission plan [5]

Dwelling house in Nyíregyháza. The introduced building located at the eastern part of Hungary in a garden suburb. The planning program was refurbishment and extension of an existing house built from adobe. For both purpose the use of straw-bales was required. On the existing adobe wall 35 cm thick straw-bale insulation was established, which increased the U-value of the wall from 1,18 W/m^{2}K to 0,15 W/m^{2}K. (The wall of the extension was built as non-loadbearing straw-bale construction in 50 cm thickness with the U-value of 0,12 W/m^{2}K.) As the existing wall with the straw insulation became thicker, new supplemental constructions had to build at the top and at the bottom of the wall. (Fig 2.)

Beside the foundation and the plinth-wall 15 cm thick XPS insulation and 20 cm thick concrete wall were established. The vertical XPS insulation helps to reduce the heat loss through the ground-floor, as the concrete wall heightens and supports the water resistant straw-bale insulation.

The owner decided to break down the roof because of the bad state of the construction. In this case become possible to build-up the geometry of insulation without heat-bridges. Otherwise the thick insulations of the wall and the slab (each 35 cm) would be reduced significant at the upper corner of the wall, which would mildews the inside surface.

The straw-bale insulation was plastered both on the wall and on the slab with 3 cm *clay plaster* and 0.5 cm lime, which solve the surface- and fire-protection questions of constructions'. At the most sensitive places (plinth-wall, connection of wall and slab, etc.) additional steel net was built under the plaster to avoid the accession of rodents into the construction.

The ready building passes into the neighboring built environment, the marks of the straw-bale technology are almost invisibles. (Fig 2.)

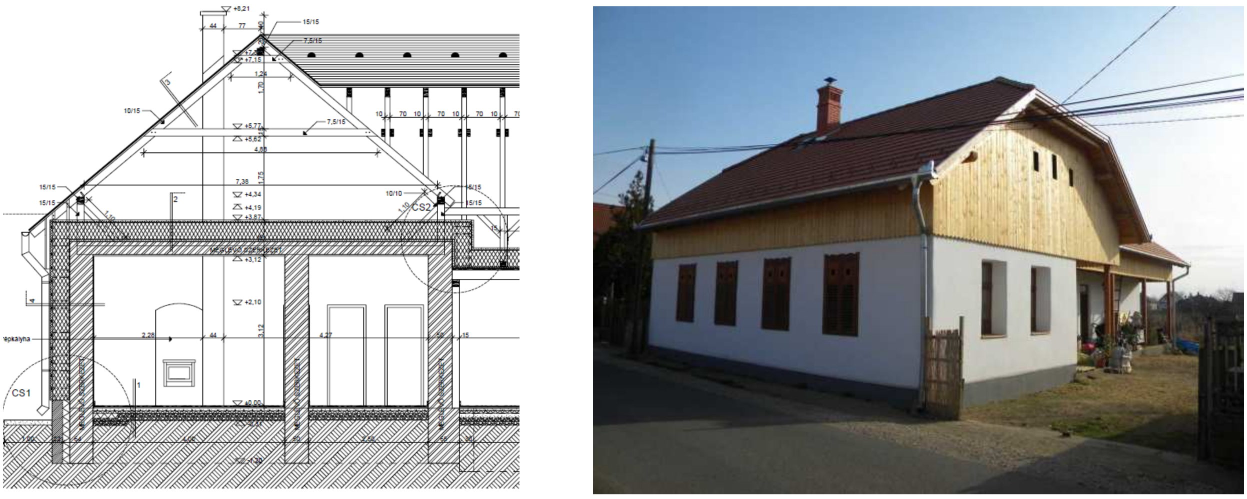

Fig 2. Part of the section from the final plan [6] and the street-view of the ready house [Foto: Márton Révész]

Summary of positive and negative experiences

Positive experiences. Both introduced and other realized, but because of the limit of the paper not presented projects give several positive experiences.

First, the insulating properties are highlighted. Owners of the houses measured low energy consumption, in accordance with the previous energy performance calculations. Despite of that the heating period did not reduced significantly, the natural gas consumption became much less than by an average detached dwelling house. In year 2012 the heating period by the house in Mány finished at 18th April and started at 27th October. (Fig. 3) Owner measured 1346 m^3 natural gas consumption between 06th June 2012 and 07th June 2014 for heating and domestic hot water production. It means that the house, with its 120 m^2 heated area, has 53 kWh/m^{2}a gross consumption (counted with 9,45 kWh/m^3 gas conversation rate). Although this value does not contain the auxiliary electricity consumption of mechanical instruments, it is much better than the present suggested requirements of near-zero energy buildings in Hungary (80 kWh/m^{2}a primer energy). [7] The mechanical system of the house consists of condensing gas-boiler, radiators and solar system for DHW, so the primer energy consumption from the measured data is approximately 59 kWh/m^{2}a. (53 kWh/m^{2}a natural gas consumption counting with primer energy exchange rate 1 and 2,5 kWh/m^{2}a auxiliary electricity consumption counting with primer energy exchange rate 2,5.)

Buildings worked well although in summer period. During the hottest period the house in Mány could reduce the outside temperature with more than 10°C, so the inside temperature was only in short time over 26°C. (Fig. 3)

Owners have not complained about the occurrence of animals (like mouse) in the house.

Any statical or moisture problem of the wall or the insulation has not occurred.

The additional wall insulation made of straw-bale is cost-effective even in 50 cm thickness, because of the relative high heat-insulation capacity and the low cost of the straw. [8]

Negative experiences. Stability problem of the plaster come up at some part of the house in Nyíregyháza. On the wall face to the garden, where the overhang of the roof did not protect the wall enough, the two different materials of plaster (clay and lime) separated from each other.

Also negative experience is that the permission process of straw-bale buildings is fairly difficult. Straw-bales are produced not as "building product". The identification and responsibility of the "manufacturer" are not evident, that's why in some case the authorities did not allowed the application of straw-bale technologies.

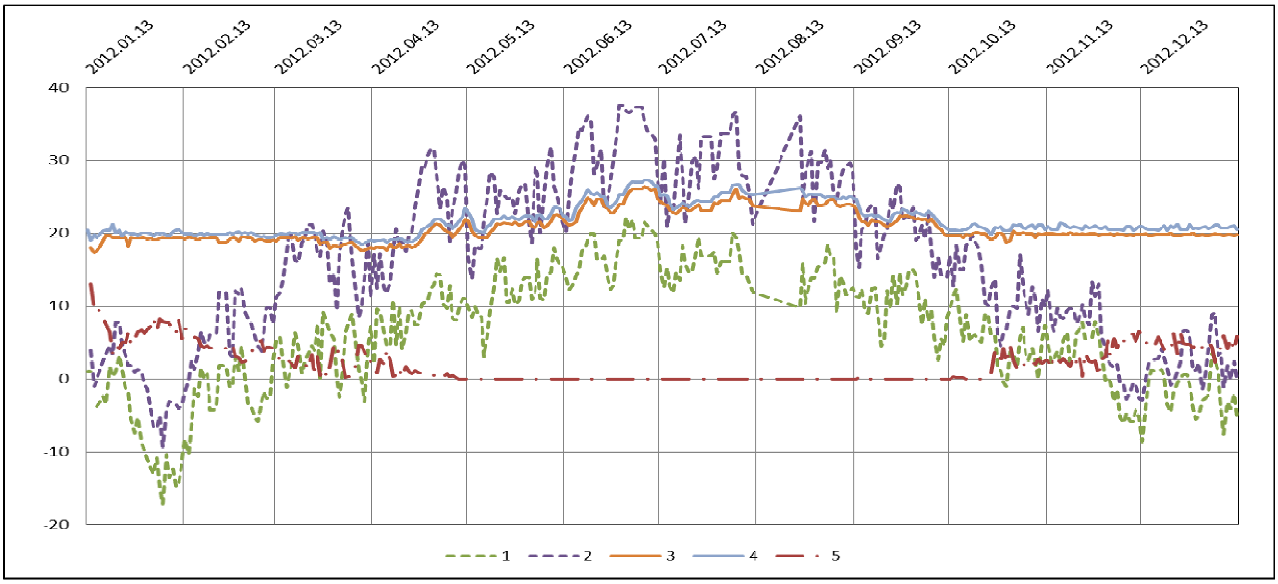

Fig 3. External and internal temperatures and natural gas consumption of dwelling house in Mány (1: Minimum external temperature [°C]; 2: Maximum external temperature [°C]; 3: Minimum internal temperature [°C]; 4: Maximum external temperature [°C]; 5: Natural gas consumption [m^3]. Data are collected by Gergely Pechán, the owner of house in Mány.)

Conclusion

The additional insulation of walls with straw-bales is energy efficient and cost effective solution. With careful design of the constructions, except of the plaster resistance in special cases, safe solution can be built. The development of covering of straw is necessary because only the right protection of straw-bale insulation can result an energy efficient and economical solution in long time. The Low-Tech Workgroup at the Department of Architectural Engineering at the Budapest University of Technology and Economics started two projects on elimination of the defined insufficiency. We would like to develop qualified building systems for new buildings and for refurbishments using straw-bale elements.

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