IOP Conf. Series: Materials Science and Engineering **728** (2020) 012017 doi:10.1088/1757-899X/728/1/012017

Experimental Measurements of Wooden Solid Log Wall

Petr Kacálek [1], Tomáš Petříček [1]

[1] Brno University of Technology, Faculty of Civil Engineering, Institute of Building Structures, Veveří 95, 602 00 Brno, Czech Republic

kacalek.p@fce.vutbr.cz

Abstract. The contribution brings findings accrued from alternative design of log-wall's lateral joint. The lateral joints present without question a thermal bridge highly repeating in the construction of external log wall. Field of the research was a theoretical design of wall models, simulation in software ANSYS and comparison theoretical results with results gained from the laboratory measurements of wall samples. Bed joints of wooden solid log walls are still a problematic detail in terms of thermal technology. By reason of weakening in the place of lateral joint and the value of coefficient of thermal conductivity, the solid wooden log wall does not meet requirements of Czech Standards ČSN 73 0540-2 posed to the value of wall's thermal resistance. That is why we have focused on measurement of surface temperature, which is also one of the classified factors in term of construction quality. The project particularly focused on monitoring of surface temperatures in the areas of critical details – bed joints.

1. Introduction

The paper concerns a Canadian style solid timber log house wall in terms of thermal technology, wherein the main goal was to compare construction variants of such wall. The comparison concerned a circumferential wall of a Canadian style log house, using different types of heat insulation. The wall models were simulated in ANSYS software. Due to weak spots near bed joints and the wooden thermal conductivity coefficient, the solid wooden wall has difficulty complying the existing strict requirements of the standard ČSN 73 0540-2 [1] for heat transmission coefficient value U. Therefore, surface temperature and the internal surface temperature factor were concerned this time. They are one of the quality evaluation factors for structures and the internal environment in buildings.

2. Bed joints

Bed joints are regarded as a weak spot especially in peripheral solid timber based walls, where they are repeated all over the surface of the vertical structure. Such details of bed joints are however more problematic in case of log wood wall in comparison to those made from lumber, since the weakening of bed joints is much more seen.

The connection of logs must be perfect in all aspects. It must create a permanent barrier between the interior and exterior of the building. Although the logs for log houses are carefully selected (the logs can show any torque in fibers) after drying it may come to a deformation, thus a change in their shape. Such changes do cause a leakage and weakening of the joints. Materials for the final sealing of all bed joints must have certain insulating properties, both in terms of thermal resistance and also in

IOP Conf. Series: Materials Science and Engineering **728** (2020) 012017 doi:10.1088/1757-899X/728/1/012017

terms of air infiltration. Nevertheless the material must also exhibit shape memory and must be able to deal with creep.

Earlier the bed joints between the logs were stuffed out by moss which was then covered by a layer of clay screed. The surface of the clay screed was then dyed white or coated by a different material. The system in overall acted as a sealant. As the years moved on and it came to a development of newer materials and technologies polyurethane foam became the number 1 sealant used. Nonetheless, polyurethane foam when hardened is dimensionally stable and is unable to respond to the volumetric changes of wood. Consequently cracks are formed which must be additionally sealed to prevent heat loss. Concurrently it was found out that the best solution would be to and also is to use a two-stage isolation, where the thermally insulating capabilities are maintained by mineral or sheep wool, and the air leakage is prevented by memory tapes based between the logs on the external and internal side of the wall likewise.

Mineral wool is positioned at contiguous locations of the longitudinal groove placed between logs used to make a structure separating a heated environment from that of a non-heated one, since the grooves may have a different shape and size. The memory tapes are then made from permanently elastic materials based on specially treated foam impregnated with a substance that increases its resistance to UV radiation and reduces water absorption. Memory tapes do also secure the structures against seeping of water, air infiltration and also against the entry of insects into the longitudinal groove.

3. Internal wall surface temperature factor evaluation

The calculation of the internal wall surface factor fRsi and internal surface temperature (°C) was performed for other possible comparisons. The comparison selected a bed joint of a log house wall, so-called double insulated, which means that a storage tape ILLBRUCK is circumferentially applied on the joint, and the joint area is filled with heat insulation – mineral wool. Total joint width was designed to be 15 cm. Meeting of the requirement $f_{Rs}i \geq f_{Rsi,N}$ was monitored.

The calculations make it clear that the requirement f_{Rsi} (0.936) $\geq f_{Rsi,N}$ (0.808) is met for the critical detail of the circumferential log house wall – bed joint. Internal surface temperature $\Theta_{si} = + 17.7$ °C.

4. Assessed structures

We created an experimental sample of timber log wall using 3 m long logs with diameter of 350 mm. Spruce logs were based on asphalt sheets [2,3]. We tested 3 types of different thermal insulation installed in the bed joints. Memory tapes were used in all variants, only the insulating material was changing:

- In 1st variant there was only the memory tape without any added thermal insulation in the joint;
- In 2nd variant the joint was filled with mineral wool;
- In 3rd variant the joint was filled with fleece.

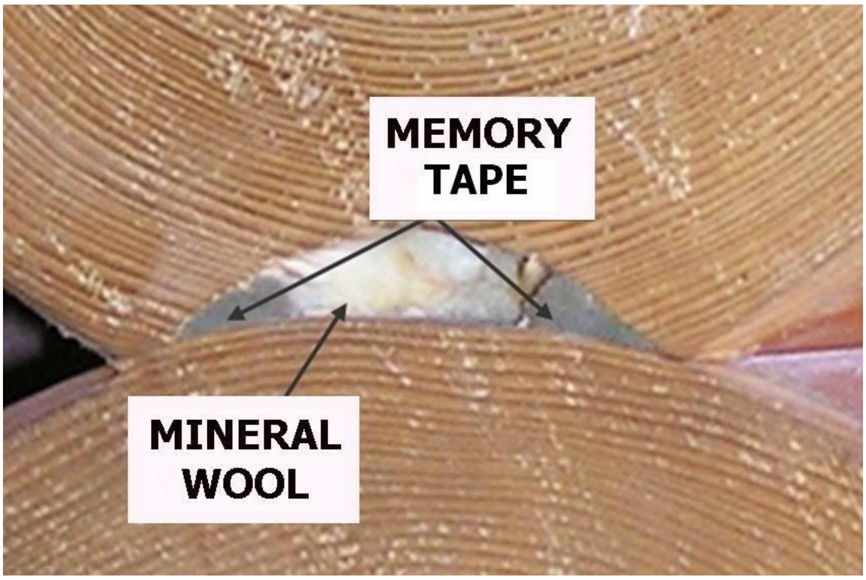

Figure 1. Schema of the assessed log wall's bed joint.

5. Results of the ANSYS assessment

We compared the lowest surface temperatures at the critical location of any solid timber log wall – the bed joints. Installing the thermal insulation into the bed joints has a positive effect on the results of the assessment. The difference between used insulation materials (mineral wool and fleece) is not significant. In 1st variant (without added thermal insulation) the lowest surface temperature $\theta = + 13.735$°C. In 2nd variant (mineral wool) the lowest surface temperature in the bed joint was $\theta = + 13.995$°C. In the 3rd variant (fleece) the ANSYS calculated that the lowest surface temperature was $\theta = + 13.999$°C.

6. Results of the experimental measurements

The experiments were carried out in the laboratory of Institute of Building Structures on the sample of timber log wall. One side of the wall was exposed to inner climate of the laboratory (simulating common indoor environment), on the other side we simulated the outdoor environment (temperatures between - 15 and - 18°C). The record contains a total of 13 000 values for each temperature.

The cooling device (the evaporator from Klimastar s.r.o. Cologne) was set to maximum temperature - 15°C with slight decreases in 30 minute intervals.

The experimental measurement does not take into account the effects of the base, atypical details of objects, etc. [4, 5]

IOP Conf. Series: Materials Science and Engineering **728** (2020) 012017 doi:10.1088/1757-899X/728/1/012017

Figure 2. Experimental sample of timber log wall with installed cooling chamber and measuring equipment.

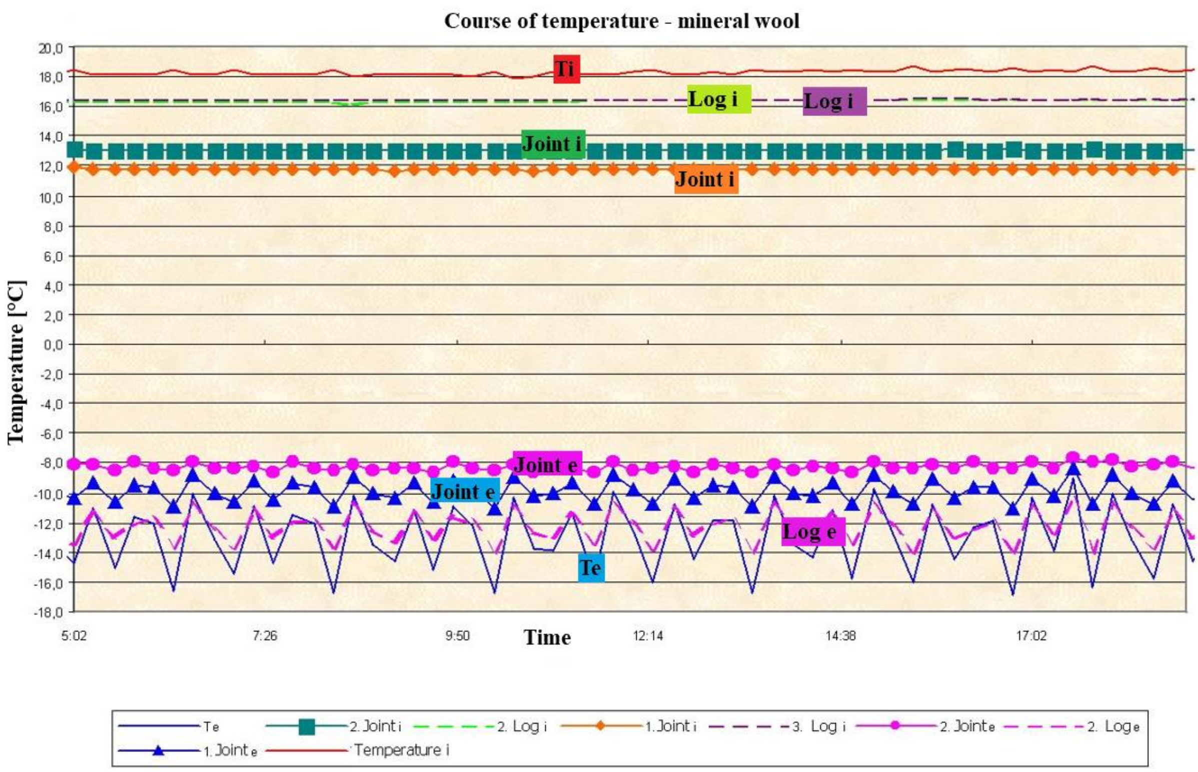

Figure 3. Results of the temperature measurements on both sides of the wall

Figure 3 clearly shows variations in surface temperatures on the “outer” side of the experimental wall, depending on the changes of the surrounding air temperatures. On the “inner” surface of the wall the temperature changed only negligibly.

7. Conclusions

To conclude, solid wooden structures fail to comply with a thermal technological standard ČSN 730540-2 requirement for heat transmission coefficient value U, which may have energy impacts in relation to higher demands to heating of such buildings. Regarding the capacity of wood to sequester CO2, however, a log house from solid wood is a low-energy house in terms of the so-called grey energy spent on construction materials during their production and inclusion in the structure. Solid wooden houses also have a range of positive properties. They are beautiful in appearance and they can create a pleasant atmosphere in the interior thanks to wood specific properties.

Recently the energy efficiency of buildings moves from assessing the energy performance of buildings only according to the thermal-technical point of view to assessing the energy requirements of the building's whole life cycle. This includes the energy consumed during the production of materials, construction process and the use of the building. From this perspective the log buildings are better than common masonry buildings, because wood is available renewable material, the construction of the log building (including proper design of structural details) is simple and the use of such building is inexpensive too.

Deep focus onto the quality of every details execution is required for wooden buildings. Every single cleft between two logs must be filled with sufficient amount of thermal insulation including careful edge memory strips sticking. The correct foundation of the first log is the base, especially it is very important to interrupt the hydro-physical stress and focus onto the proper design of the water proof layer [6].

Acknowledgment(s)

This paper has been produced within the project FAST-S-19-6045 - Study of physical processes in critical details of building envelope structures with near zero energy consumption.

References

[1] CSN 73 0540-2. *Thermal protection of buildings – Part 2: Requirements*, Czech Office for Standards, Metrology and Testing, Prague, 2005, 2007, 2011.
[2] J. Plachý, V. Petránek, and Z. Caha, "Bitumen Substance Analysis," *Advanced Materials Research*, vol. 897, pp. 103-106, 2014.
[3] T. Petříček, P. Kacálek, and T. Hlavačka, "Characteristics of the mechanically fastened joints of one-layer bitumen sheets," *MATEC Web of Conferences*, vol. 93, 03007, 2016.
[4] P. Kacálek, T. Petříček, and R. Smolka, "The Effects of the Soils Thermal Field onto the Energy Performance of Buildings," *Advanced Materials Research*, vol. 899, pp. 58-61, 2014.
[5] R. Smolka, J. Sobotka, and J. Šulistová, "Design proposal for door thresholds," *MATEC Web of Conferences*, vol. 93, 01009, 2016.
[6] J. Sobotka, and R. Smolka, "Use of EMW radiation in the building industry at defects in buildings," *MATEC Web of Conferences*, vol. 93, 01008, 2016.