Low Energy Log Walls Under Cold Climate Conditions

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ABSTRACT

This paper presents the results of the development of low-energy log walls that have internal thermal insulation. Dimensions for moisture-safe applications of interior thermal insulation of log walls under cold climate conditions have been studied with different vapor resistance levels of the inside air/vapor barrier layer. When additional ventilation was required, a local and limited ventilation concept was used to keep the ventilation heat losses low. Design and dimensioning of the required ventilation airflow rates were done using hygrothermal numerical simulation studies. The results under different interior sheathing and moisture load conditions are presented in this paper, and the thermal and moisture performance characteristics of the presented wall system are studied and discussed.

INTRODUCTION

New energy codes set strict requirements for the overall energy consumption of new buildings. Houses built using massive log walls cannot easily meet these requirements without additional insulation. The thermal insulation is usually assembled on the interior of the log layer. The inside insulation has a significant effect on the temperature conditions of the timber layer when compared to uninsulated log walls. In cold climates, the low temperature of the timber layer has an effect on the partial vapor pressure conditions. Thus, the vapor transfer through the thermal insulation toward the log layer may exceed the safe moisture absorption and drying potential of the exterior log layer.

Development of log walls that have interior thermal insulation has been carried out. Two different wall concepts were studied: a conventional unventilated wall and a log wall with local and limited ventilation. The unventilated log wall was studied with different thicknesses of interior mineral wool or cellulose fiber thermal insulation and with different vapor resistances of the interior sheathing layer. Finnish building codes (NBCF 1998) do not require a certain vapor resistance for the vapor barrier, only that the moisture performance of the wall is safe. This enables the application of more vapor open-air barrier layers instead of PE vapor barriers (*Sd* = 20–50 m) (Simonson et al. 2005). These air barriers are typically paper or cardboard laminates, and their vapor resistance (equivalent air layer thickness), the *Sd* values, are typically in the range of 0.2–2 m. The decision to leave the structure without a proper vapor barrier is justified by the original moisture performance of log walls. Simonson et al. (2001, 2004) have studied and shown the positive effects of moisture buffering capacity of building materials on indoor air quality and comfort. The studies have also shown that a vapor barrier inside the structure does not necessarily cut off this interaction. There is a strong demand to build houses without vapor-tight layers in order to enhance the moisture interaction between structures and indoor air. Log house manufacturers have to satisfy the demand for these so-called breathing structures with moisture-safe and energy-efficient practical solutions.

When a structure has increased moisture performance risks, wall ventilation can be used to dry out the excess moisture. Locally and limited ventilated structures have better U-factors than those with typical ventilation covering the whole wall area. Dimensioning the required ventilation airflow rates and chan-

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nels was performed using hygrothermal numerical simulation models and laboratory experiments. The results under different interior sheathing and moisture load conditions are presented, and the thermal and moisture performance characteristics of the wall system are studied and discussed.

This study was limited to only relatively cold Finnish climate conditions (5050 heating degree-days in Jyväskylä and 6430 in Sodankylä). This approach includes some safety when the net drying efficiency of the wall is compared to the performance under more moderate climate conditions.

EFFECT OF INTERNAL THERMAL INSULATION ON THE HYGROTHERMAL PERFORMANCE OF LOG WALLS

Exterior thermal insulation typically improves the moisture performance of structures in cold climates (Ojanen 1998), but interior thermal insulation may cause moisture risks and special requirements for the properties of other material layers. Some earlier studies carried out using cold climate conditions (Simonson et al. 1995, 2005) have shown the possibilities to build moisture-safe walls without a vapor barrier. They have also given practical guidelines for maximum thickness of the interior thermal insulation of log walls with blown cellulose fiber insulation (having about the same thermal conductivity as mineral wool) and a relatively vapor open paper-type air barrier on the interior of the wall. These studies have shown that safe moisture performance of a 125 mm thick log wall could be maintained with 50 mm maximum interior insulation thickness. This means that the U-factor of a log wall should not be improved to more than about half of the original (from 0.88–0.42 W/Km^2 in this case) with interior insulation. This result has been adopted as a rule of thumb in most practical assemblies of log walls having interior insulation. The adoption of this one value is due partly to a lack of understanding of the moisture performance of such wall assemblies and partly to the need to ensure safe moisture performance in structures that may have miscellaneous ways to implement the inside air barrier and sheathing layers.

It is obvious that one value does not give adequate possibilities to implement structures under different conditions and performance demands. The safe limits for the dimensions of the inside thermal insulation of a log wall depends especially on the inside vapor resistance of the wall, thickness of the log layer, wall orientation and solar effects on the temperature conditions, exterior moisture load levels (rain and humidity), etc. The objective was to give practical values and guidelines to design and build moisture-safe log walls with interior thermal insulation.

NUMERICAL TOOLS USED IN MOISTURE PERFORMANCE ANALYSIS

The numerical simulations were carried out using a WUFI 4.0 Pro (IBP 2005) simulation model. The analysis consisted of sensitivity studies of the main parameters affecting the moisture performance of the structures. The main moisture performance requirements and parameters were analyzed and quantitative property limits were given when possible. The moisture mass of the structure and especially the conditions on the critical boundary layer, i.e., on the inner surface of the log layer that was in contact with the thermal insulation, were studied as criteria. The temperature and relative humidity histories derived using WUFI were post processed, and a mold growth index was solved for the critical boundary.

The mold growth index values that represent the possible level of mold growth on the surface are presented in Table 1 (Viitanen 1996; Viitanen et al. 2003). Mold index values that are lower than 1 do not represent a risk for mold growth. Level 3 is the first sign of mold on the surface when detected visually without a microscope. Values between 1 and 3 represent some limited risk for mold growth.

MOISTURE PERFORMANCE OF UNVENTILATED LOG WALLS WITH INTERNAL THERMAL INSULATION

The objective was to set moisture-safe limits for the dimensions of internal thermal insulation with different structural parameter values. In the following, the thermal resistance of the insulation layer is presented as a simplified quantity, the insulation thickness. The actual thermal resistance can be derived from the set thermal conductivity of the insulation material, 0.040 W/K·m, which represents a relatively low value for glass wool or cellulose fiber insulations.

Table 1. Classification of Mold Growth Index for Experiments and Modeling (Viitanen et al. 2003)

Index	Growth Rate	Description
0	No growth	Spores not activated
1	Some growth detected only with microscopy	Initial stages of growth
2	Moderate growth detected with microscopy	Coverage more than 10%
3	Some growth detected visually	Spores are produced
4	Clear visually detected growth	Coverage more than 10%
5	Plenty of visually detected growth	Coverage more than 50%
6	Very heavy and tight growth	Coverage around 100%

Analyzed Structures

The assumption was that, first, the thermal resistance of the log is maximized and only after that is the thermal insulation added to improve the U-factor. Thus, the analyzed wall had a 200 mm thick timber layer (dry density 500 kg/m^3) that corresponds well to practical log wall thicknesses: 205 mm laminated log and massive round 230 mm thick log. A comparison to a 100 mm thick laminated log wall was made in some cases to show the effect of log dimension on moisture performance.

The thermal insulation was 17 kg/m^3 glass wool in cases with a PE-vapor barrier and 35 kg/m^3 cellulose fiber insulation in cases with a vapor-permeable air barrier and internal sheathing layer. The thermal conductivity of both the insulations was set to be 0.040 W/K·m, and the thicknesses of the thermal insulation layer were 50, 70, 100, 145, and 200 mm.

Three typical structural cases with different vapor resistances of the inside material layers were chosen for the analysis.

Case 1. Structure with PE-vapor foil (0.2 mm) vapor barrier. Diffusion resistance of the foil is 2.5 e+11 (m^2·s·Pa)/kg (*Sd* = 50 m).

Case 2. Air barrier paper and inside sheathing with some vapor resistance, such as 20 mm wooden paneling. The diffusion resistance of these layers was 1.5 e+10 (m^2·s·Pa)/kg (*Sd* = 3 m).

Case 3. Air barrier paper and gypsum board with vapor open paint finishing. The diffusion resistance of these layers was 5 e+9 (m^2·s·Pa)/kg (*Sd* = 1 m).

The presented vapor resistances are set to represent the order of magnitude of the typical practical cases. Variation of the actual resistance is possible with different materials and assemblies. Cases 1 and 3 represent the extremes in practical wall applications, and case 2 is a more typical assembly without a plastic vapor barrier. The *Sd* value represents the thickness of the still-air layer that produces equal diffusion resistance.

Climate Conditions and Simulation Periods

Numerical simulations were carried out using the climate data for Jyväskylä in central Finland and Sodankylä in Lapland. The indoor conditions corresponded to the medium high moisture load in dwellings. Table 2 presents summary data for the climates.

The climatic data used in simulations were meant to be used as a reference year for thermal performance simulations and, thus, represent a significantly cold year. The Jyväskylä data are sufficient for most parts of Finland (and other Nordic countries), and the Sodankylä data represent extremely cold conditions for residential purposes. The assumed indoor relative humidity values caused yearly average 3.7 g/m^3 (Jyväskylä) and 4.8 g/m^3 (Sodankylä) increases of moisture content compared to that of outdoor air. The maximum moisture increase of indoor air moisture content was detected during the cold winter period. The indoor conditions include sufficient safety for the analysis.

The initial moisture content of the structure layers were set to correspond to the equilibrium moisture under 80% relative humidity. The simulations started on October 1, and each case was simulated for at least a three year period or more when sufficient information about the performance was required.

Assumptions and Analyzed Cases

The analyzed structures were assumed airtight without any air leakages or convection affecting the moisture transport. Leakage of indoor air to the insulation layer could severely affect the moisture performance of the wall (Ojanen and Simonson 1995). The moisture loads were caused by the partial vapor pressure levels of the air spaces and the driving rain hitting the outer log surface. The orientation of the wall was that with the highest driving rain (south-east in both climates) on the wall surface of a low single-family house.

In the base case there was no solar or long-wave radiation on the wall surface. The effect of solar radiation was studied in some cases. The solar absorption coefficient was set to 0.4, representing a light-colored untreated wood surface, and the emission coefficient was 0.9. When the orientation of the wall was north, most of the solar radiation hitting the wall was diffuse. One case was studied using a south-facing façade. The north-facing wall was considered to represent such solar radiation conditions that can safely be assumed to represent the prevailing conditions of any wall in general, without comprehensive analysis of the orientation, shading conditions, etc.

Table 2. Temperature and Relative Humidity Conditions of Jyväskylä and Sodankylä Climates in Finland and the Increase of Moisture Content of Indoor Air Compared to Outdoor Air

	Jyväskylä		$\Delta\rho_{indoor}$	Sodankylä		$\Delta\rho_{indoor}$	Indoor Air	
	T	RH	$\Delta g/m^3$	*T*	RH	$\Delta g/m^3$	*T*	RH
Average	2.8	81.3	3.7	–0.8	79.3	4.8	21	50
Minimum	–34.8	15	0	–40.2	24	0	20	40
Maximum	27.5	100	7.9	25.5	100	8.9	22	60

* *T* = temperature; RH = relative humidity.

Simulation Results

The safe moisture performance analysis was based on several criteria:

1. Moisture mass development in the whole structure and especially in the log layer
2. Mold index solved for the critical boundary between log and thermal insulation
3. Prevailing conditions at the critical boundary: yearly average relative humidity and the yearly incidence of mold growth conditions

If there is moisture accumulation in the structure or exterior log layer, or the numerically solved mold growth index exceeds the set pivot value (level 3 at the inner critical boundary), the structure has severe moisture performance risks. The third criteria can be used to predict the possibly increased risk level.

Figures 1–3 present the history for the total mass of moisture in the walls solved per structure surface area (kg/m^2). In all of these cases, the log was 200 mm thick and the varying parameters were the thickness of the thermal insulation and the climate. In some cases, the effect of solar radiation was taken into account.

Effect of Log Thickness. The effect of the thickness of the log layer on the moisture performance was studied in some cases. The simulation results are presented in Figure 4.

Mold Growth and RH Conditions. The summary of all the analyzed cases and their results are presented in Table 3, which presents the thickness of the log and thermal insulation layers, the vapor resistance value for the inside surface layer, solar radiation conditions, and the orientation of the wall. The results for mold growth index, time for possible mold growth conditions, and the average and maximum relative humidity values during the last simulation year are presented for the critical boundary. These results give relevant information, in addition to the mass of moisture and moisture content curves, to analyze the moisture performance risks of the wall.

Analysis of the Simulation Results

The objective was to set maximum levels for the thickness of the inside thermal insulation layer of a log wall under relatively cold Finnish climate conditions. The following conclusions and recommendations were drawn for the cases with 200 mm thick logs.

Structures with Vapor Barrier. In all the analyzed cases, the mass of moisture in the walls had a decreasing tendency and no mold growth conditions were detected. With a properly installed vapor barrier having vapor resistance in the order of Sd = 50 m, the internal thermal insulation may have 200 mm of thickness in both the analyzed climates. Most probably, the thermal insulation could be even thicker than 200 mm without moisture problems. The risks caused by the workmanship of the vapor and air barrier layer increase with thicker insulation. The moisture performance would be safe also with a 100 mm log layer.

Vapor Open Inside Wall Surface. When the material layers of the inside surface of the wall are very vapor open (the vapor resistance level is in the range of Sd = 1 m), the inside thermal insulation thickness should be under Jyväskylä climatic conditions less than or equal to 70 mm. Under extremely cold Finnish climates in Sodankylä, this upper limit for the insulation thickness is 50 mm. This corresponds to the results of the earlier studies and the commonly applied general rule for insulation. The 50 mm rule is valid under extreme climatic conditions and with very vapor open wall structures. Even more vapor open surface layers could be possible, but the use of inside insulation could not be recommended in these cases.

Moderate Vapor Resistance. When the vapor resistance of the inside layers of the wall is increased from the relatively vapor open case, thicker thermal insulations can be applied. With a vapor resistance level of Sd = 3 m, the thickness of the inside thermal insulation can be 100 mm under Jyväskylä climates and 70 mm under Sodankylä climates.

Effect of Solar Radiation. Only a limited effect of solar radiation was taken into account when setting the maximum thickness for the thermal insulation layer. To be on the safe side, the performance criteria were studied using the results for north-facing walls without shade. In Jyväskylä climate, the solar radiation could clearly improve the yearly moisture performance of north-facing walls, but in Sodankylä conditions, the effect of solar radiation was quite limited.

The effect of solar radiation is quite case-sensitive, and it can have significantly higher effects on the moisture performance of structures, mainly on the drying efficiency, than shown in these general conclusions and recommendations. It would be possible to have quite high thermal insulation thicknesses in walls with more solar radiation. A south-facing wall (Sd = 3 m) without any shading could have safe moisture performance even when the insulation is 140 mm thick. Thorough case studies should be applied to determine the thermal insulation thicknesses under specific conditions with different orientations, climates, and shadow factors.

Effect of the Thickness of the Log Layer. The analysis was based mainly on thick 200 mm log layers. The critical boundary in the wall is that between the log and the thermal insulation. Conditions of this boundary have an effect on the moisture transfer rate into the wooden layer and out of the structure. The thermal conditions are quite critical for the moisture transfer potentials. The effect of the overall vapor resistance of the log layer is not that important. More significant is the moisture capacity of the wooden layer and the moisture transport potentials in and out of the timber layer. A thick log wall has better capability to buffer the seasonal moisture loads than a thinner wooden layer. Also, the utilization of the seasonally varying solar radiation effect on the yearly moisture performance is possible partly due to the high moisture

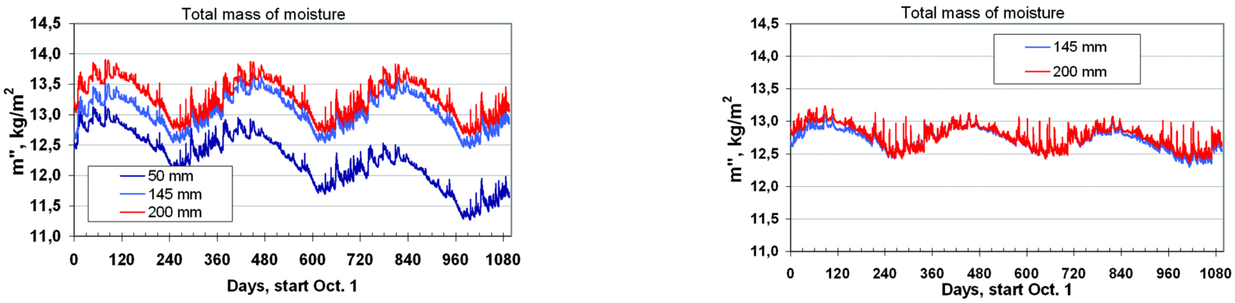


Figure 1 *Simulation results of log walls with internal insulation and vapor barrier. Simulation results of a total mass of moisture in log walls (per wall surface area, kg/m^2) with internal insulation and inside vapor barrier* Sd *= 50 m during the last three simulation years under Jyväskylä (left) and Sodankylä (right) climate conditions.*

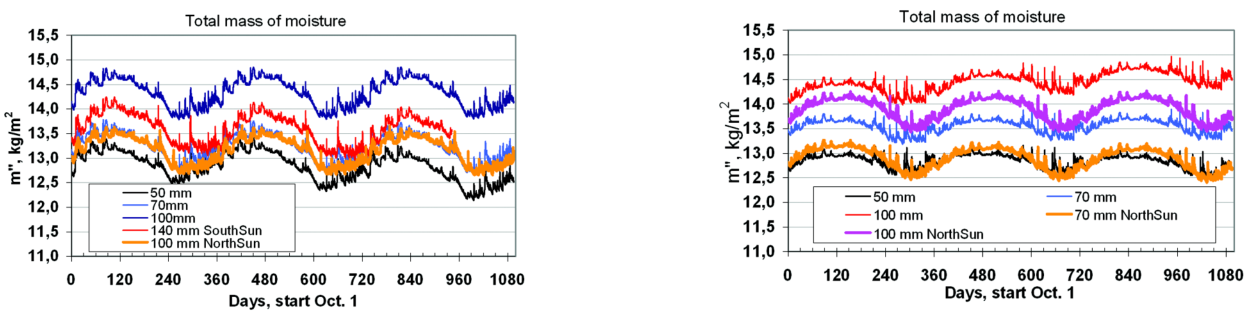


Figure 2 *Simulation results of total mass of moisture in log walls (per wall surface area, kg/m^2) with internal insulation and inside vapor diffusion resistance* Sd *= 3 m during the last three simulation years under Jyväskylä (left) and Sodankylä (right) climate conditions.*

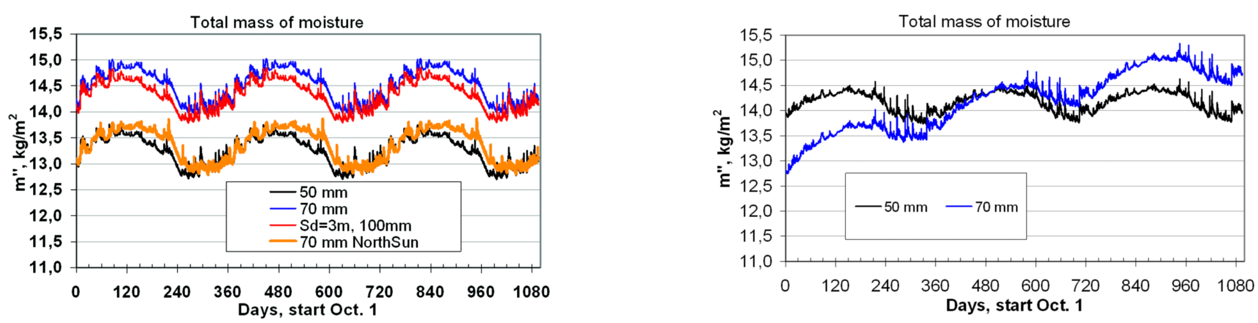


Figure 3 *Simulation results of total mass of moisture in log walls (per wall surface area, kg/m^2) with internal insulation and inside vapor diffusion resistance* Sd *= 1 m during the last three simulation years under Jyväskylä (left) and Sodankylä (right) climate conditions.*

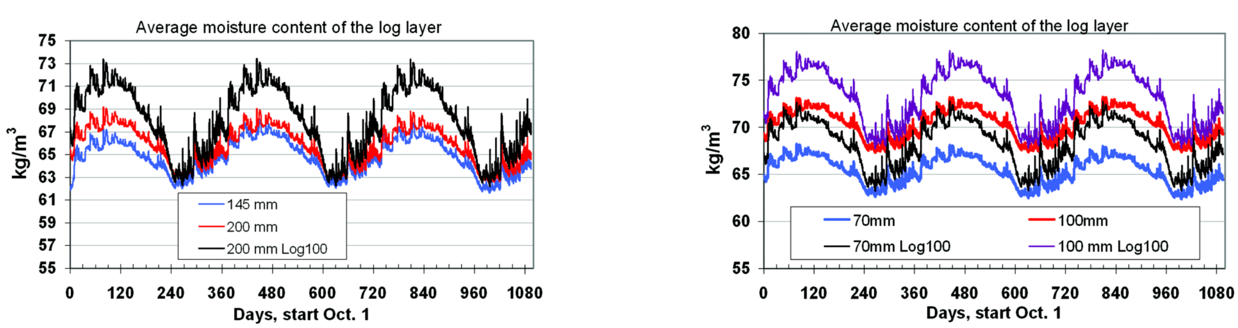


Figure 4 *Effect of log layer thickness (200 / 100 mm) on the average moisture content of the log layers with vapor barrier (left) and inside vapor diffusion resistance* Sd *= 3 (right) during the last three simulation years under Jyväskylä (left) and Sodankylä (right) climate conditions.*

capacity of the log layer. When applying inside thermal insulation, a reasonable thickness of the log is recommended in all cases and especially when the inside surface layers permit more moisture transfer to the wall than in cases with a vapor barrier.

When a 100 mm log layer is applied instead of the 200 mm thick layer in a wall without a proper vapor barrier, the recommendation for the internal insulation thickness should be decreased to the next lower level of the analyzed thicknesses (e.g., from 70 to 50 mm, etc.).

CONCEPT OF LOCAL AND LIMITED VENTILATION

When the thermal insulation layer thickness exceeds the recommended safe levels, the additional moisture load can be dried out from the wall with ventilation. An open ventilation cavity between the log and thermal insulation would enable sufficient moisture drying, but it would also significantly affect the U-factor of the wall. One solution is local and limited ventilation that allows the utilization of part of the thermal resistance of the log layer and still produces sufficient ventilation to dry the additional moisture out of the wall. The prac-

Table 3. A Summary of the Analyzed Cases and Simulation Results*

Log	Vapor Resistance,	Insulation,	Solar Radiation,	Mold Growth Index,	Mold Growth Time,	RH of Log, Average,	RH of Log, Maximum,
d, mm	*Sd*, mm	*d*, mm	Orientation	Mo.	h/a	%	%
Jyväskylä							
200	50	50	—	0	0	66.6	69.9
200	50	145	—	0	0	74.7	78.7
200	50	200	—	0	0	75.7	80.3
100	50	200	—	0	0	78.5	84
200	3	50	—	0	0	73.5	77.7
200	3	70	—	0	0	77	83.2
100	3	70	—	0	144	80.9	88.8
200	3	100	—	0.2	1290	81.9	88.7
200	3	100	North	0	15	80.6	88.6
100	3	100	—	0.9	4117	85.1	89.5
200	3	140	South	0.4	773	80.3	89.3
200	1	50	—	0	0	77.5	85.2
200	1	70	—	0.5	4185	82.7	89.4
200	1	70	North	0.4	2768	81.4	89.2
Sodankylä							
200	50	145	—	0	0	74.5	78.9
200	50	200	—	0	0	75.4	80
200	3	50	—	0	0	75.5	80.5
200	3	70	—	0	0	79.9	86.6
200	3	70	North	0	0	79.5	86.4
200	3	100	—	0.8	4032	84.9	89.4
200	3	100	North	0.4	3635	84.3	89.3
200	1	50	—	0.2	2681	81.8	88.8
200	1	70	—	2.3	6824	86.7	90.3

* Two climates, thicknesses of the log and thermal insulation, vapor resistance of the inside layers, orientation of the wall with solar radiation, solved maximum mold growth index and time for mold growth during one year, and yearly average and maximum relative humidity values. All the results are those solved for the critical boundary during the last year of the simulation period.

tical arrangement of the local ventilation can be achieved using relatively small dimension ventilation channels at the boundary of the log and thermal insulation. The distance between the channels should be such that the thermal effects of the ventilation are only local and limited.

Practical Solution for Locally Ventilated Log Wall

Timber frame forms separated thermal insulation cavities on the interior of the logs. Typically, the distance between the wooden studs was 600 mm. A practical solution is one vertical ventilation channel in each insulation cavity. The additional moisture loads that are to be ventilated should match the possible airflow rates and moisture transport inside the thermal insulation and be sideways from wooden studs to the channel area in the middle of the cavity and through the material of the ventilation channel walls. It is obvious that the possible moisture flow rates and needed ventilation rates are relatively low. Figure 5 shows a schematic of the ventilation system for the log wall.

Determination of Ventilation Flow Rates

To determine the ventilation requirement in different cases using a two-dimensional numerical simulation approach requires a quite massive set of case studies containing several parameters. Before applying these models, a first approximation for the ventilation airflow was solved using a simplified-solution procedure. The required ventilation flow rates were solved using average design conditions for indoor and outdoor air. The idea of this approach is that the moisture capacity of the log and dimensional lumber layer can smooth down the extreme moisture peak loads at the critical boundary. Thus, the ventilation airflow rate does not need to meet these peak values, only the average for the entire heating season. The ventilation is required to keep the moisture conditions at the critical boundary at a safe level during the worst-case conditions. The first assumption was that the log layer is totally vapor tight, so all the moisture transported from the indoor air to the wall had to be ventilated. This gives an additional safety factor for the analysis.

Design Conditions

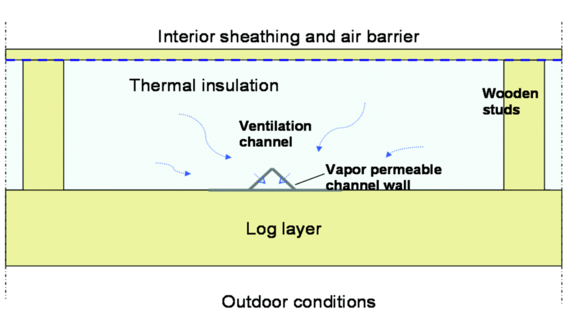
The design conditions were set to correspond to about the average heating period conditions in the Jyväskylä climate. The outdoor air was set at 0°C and 90% RH. The indoor conditions were +22°C with RH = 40%, representing a 3.4 g/m^3 yearly average increase of moisture content. The temperature of the critical surface between the log and thermal insulation depends on the thermal resistances inside and outside that layer. The temperature level and warming of the ventilation air depend on the temperature conditions of this boundary. When the ratio between inside and outside thermal resistances increases, the temperature of the critical boundary decreases and has a lower drying potential (to outside or ventilation air) and higher wetting potential from indoor air.

With very low flow rates, the ventilation air will warm close to the adjacent structure temperature, i.e., that of the critical boundary. The limit conditions for mold growth were used to set the target values for the relative humidity of the ventilation air flowing out of the wall. For example, at 5°C this limit would be 88% RH.

Ventilation Flow Rates

The design moisture flow rates and ventilation flow rates solved per structure area are presented in Figure 6. In the analysis, the vapor diffusion resistance of the inside layer of the wall had two values, *Sd* = 1 m and *Sd* = 3 m. The log layer was either 100 or 200 mm thick, and the thermal transmittance of the wall was set to 0.30, 0.25, 0.20 or 0.17 W/K·m^2. The solution was based on the simplified procedure under set design conditions. These results include some uncertainty due to the approach, but they represent how the moisture flow rate into the structure and the required ventilation flow rate depend on different parameters of the wall structure.

The case with *Sd* = 3 m and U-factor = 0.25 W/K·m^2 corresponds relatively well to the case with internal insulation thickness 100 mm (and *Sd* = 3 m) that was proved to be moisture safe under Jyväskylä climates without ventilation. The solved design average moisture flow into the structure was, in this case, as low as 0.03 g/h·m^2. When the moisture content of the 200 mm thick log is 80% RH, the vapor resistance of the



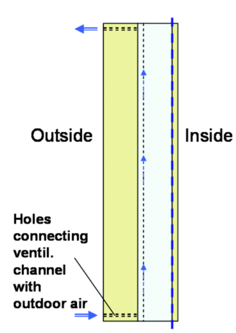


Figure 5 *Schematic of the horizontal (left) and vertical (right) cross sections of the log wall with interior thermal insulation and ventilation through the air channels.*

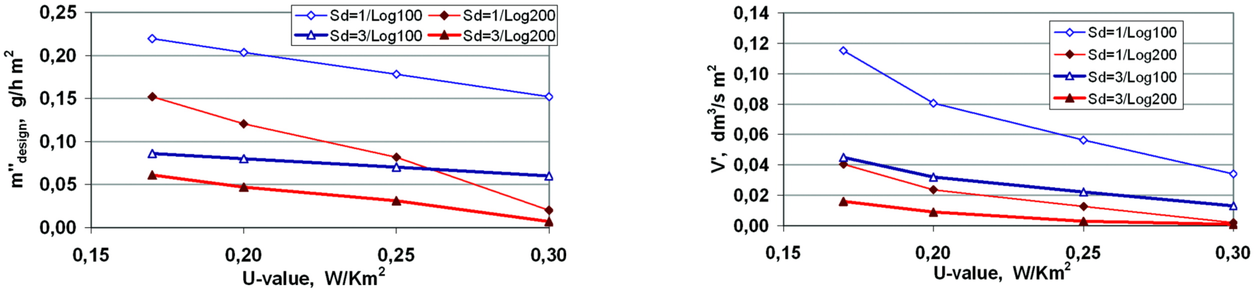


Figure 6 *Design average moisture flow rates into the structure (left) and the needed average airflow rates to ventilate the moisture out of the wall structure (right) as a function of the U-factor of the wall. The results for two different log thicknesses (100 and 200 mm) and two inside vapor diffusion resistances (*Sd *= 1 m and* Sd *= 3 m) are presented.*

layer is about 2.5e+10 ($m^2 \cdot s \cdot Pa$)/kg. The 0.03 g/h·m^2 average moisture flow through this layer can be achieved with 215 Pa average partial vapor pressure difference over the log layer. Due to the temperature conditions of the log, the yearly average moisture transport potential is significantly higher and the drying efficiency at least that which was predicted.

Correlation between the moisture flow rate and the ventilation airflow rate is not straight due to the varying safe conditions of the ventilation air flowing out of the wall.

The moisture load and required ventilation flow rates increase with lower U-factors (thicker thermal insulation), thinner log layer, and lower vapor resistance of the inside surface. For example, the wall with a U-factor of 0.20 W/K·m^2 and *Sd* = 3 m inside vapor resistance has a design moisture flow rate of 0.05 g/h·m^2 with 200 mm logs and 0.125 g/h·m^2 with 100 mm logs. With *Sd* = 1 m, the corresponding values are 0.08 g/h·m^2 and 0.20 g/h·m^2. The required average ventilation airflow rates in these cases were in the range of 0.01–0.08 dm^3/s·m^2. When the ventilation channel was made from folded cardboard with about 40 mm side length of triangle shape, the airflow velocities in a 2.5 m channel (A = 750 mm^2) serving a 600 mm insulation cavity would be, depending on the case, 0.05–0.16 m/s. When the ventilation air warms 3°C during the flow, the pressure difference due to temperature differences would be about 0.34 Pa, which would allow about 0.17 m/s velocity in this channel. Natural convection can cause airflow in the channel high enough to dry out the additional moisture from the wall, and the pressure conditions of the wind may increase the average flow significantly above this level.

CONTINUATION OF THE RESEARCH

Thermal Performance of Ventilated Log Walls

In the first phase, the objective of the research was to set the moisture performance criteria and requirements for the thermally insulated log walls with or without ventilation. The target for the U-factor is 0.25 W/K·m^2 for structures fulfilling Finnish building code requirements (WBCF 1998) and 0.17 W/K·m^2 or lower for structures suitable for low-energy buildings. The next phase is to design the ventilation channel system in detail and to study the thermal performance with both a two-dimensional numerical simulation and hot-box measurements in cases with fully controlled ventilation flows. These studies will finalize the structure design and give information about the range of practical U-factors under natural and forced pressure conditions.

Evaluation of Moisture Performance

The structures will be studied using two-dimensional simulation models (Ojanen et al. 1994, 1996), the ventilation requirements will be confirmed, and the thermal performance and energy issues will be studied. Field studies regarding the moisture performance of insulated log walls with different ventilation schemes have begun and the results can be utilized in this research.

SUMMARY AND DISCUSSION OF INSULATED LOG WALL APPLICATIONS

The effect of internal thermal insulation on the moisture performance of log walls was studied numerically using relatively cold climate conditions from central and northern Finland. A moisture-safe wall application is possible without ventilation, but the vapor resistance of the inside sheathing layers set requirements for the thickness of internal thermal insulation. Table 4 provides a summary of the recommended thicknesses of the inside thermal insulation in a log wall with a 200 mm thick log layer.

A properly installed vapor barrier makes it possible to apply quite high thicknesses of thermal insulation and reach low energy levels. High log thickness has a positive effect on the moisture performance; it increases the temperature level between log and insulation and improves the drying potential of the wall and increases the moisture capacity needed to level down the high seasonal moisture loads.

Solar radiation can have a significant influence on the moisture performance of the structure. The upper limits presented in Table 4 can safely be exceeded if the solar radiation incidence on the wall surface is sufficient. This should be studied separately for each case.

When the demand is to have a log wall with a reasonable thermal insulation layer but without a vapor barrier, one solution is to adopt a limited ventilation scheme. The required ventilation level increases with lower internal vapor resistance levels. A low-energy log wall can be implemented with a

Table 4. Recommended Thickness of the Internal Thermal Insulation Layer in a Log Wall

Vapor Resistance of Interior Material Layers		Jyväskylä	Sodankylä
***Rd*, m²·s·Pa/kg**	***Sd*, m**	***d*, mm**	***d*, mm**
5 · 10 + 9	1	70	50
15 · 10 + 9	3	100	70
250 · 10 + 9	50	>200	200

reasonable internal vapor resistance level, $Sd = 3$, and using limited ventilation in vertical air channels in the middle of each 600 mm wide insulation cavity. The moisture loads and ventilation airflow rates can be determined and the adequate ventilation channel dimensions can be designed. The evaluation and monitoring of the thermal and moisture performances of such wall assemblies will be finalized in the next phase of the research.

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