Log Buildings Tradition in Development

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Figure 1-Test set-up for testing the moisture behaviour of log buildings in field conditions. In the foreground, test rail for the systematic part of study; in the background, a test cabin.

Abstract

Even if the principal concept of a log building is simple, there are several crucial points for the designer. Therefore, designers are in general not used to plan log buildings. This paper states some points of view regarding the design principles and properties of log houses. The properties of log walls have been subject of several research studies.

Keywords: Logs, Buildings, Moisture, Thermal insulation, Acoustical properties, Fire safety

Introduction

The composition of a log building is simple. The walls consist only of logs and a seal between the logs, which usually is of some fibrous textile. In addition, a surface treatment is used on the outer side primary to give the building the desired colour. Thus, at a glance there would not be many possibilities to make the composition wrong as there is in common multi-material walls.
It is often claimed that in the past, everybody could build a log house. However, how many of those log houses are used as homes nowadays? Only the houses made by the most skilled builders still fill a function. Most log buildings have been destroyed not only by fungal attack but also being old-fashioned and less beautiful. The skill of building log houses, however, almost vanished in Finland in the sixties and seventies, when the wood framed prefabricated house came to the market and the demand of the second homes still was small.
In Finland, log buildings nowadays are a living tradition. Several companies are producing log buildings industrially. 18 companies are exporting about 400 buildings every year. This is already as much as the domestic market. Most of the domestic market is second homes where people are dwelling only at the holidays. In the export market, also permanent dwellings are popular and appreciated by ecologically minded people. The largest companies have cooperation regarding development and quality assurance. Technical Research Centre of Finland (VTT) has certified the laminated log produced by Finwood Ltd.

Design

Design of log buildings is in short described in the recommendations RT 82-10415.
The most important principle in log design is, that the construction shall be planned and erected carefully. When erected, the moisture content of a log usually is more than 20 % from the dry weight. After some years of use and heating, the moisture content will be even less than 15 %. This means a large settling of a wall caused by the shrinkage of the wood material. If the wall had no load, this settling may occur unevenly and the wall may not prevail it's tightness. The building can settle even 50 mm/m. Therefore, the log building should be designed so that the walls always are supporting a reasonable amount of roof loads.
All details shall be designed so that they allow the settling. The settling must not be prevented by vertical constructional elements as fireplaces or overlong window or door jambs. If some wall should have a cladding of plates or some other material that keeps it's shape, this wall should be made so that an additional sheet is fixed at the log wall allowing the settling. Then, this sheet shall be covered with the cladding. Thus, there will be a movement joint between the log wall and the cladding.
The logs are set on each other so, that the joint cannot be considered to take tension loads. This shall be taken into account when the buckling of the wall and the cross junctions is considered. The walls shall be supported against the buckling with cross junctions or vertical studs. The free length of a wall is typically about 5 m, but this depends strongly on the log profile and the lateral load for the wall.

Mechanical properties

The wood material used for log buildings is the same pine (*Pinus Silvestris)* material commonly used in Finland for other building constructions. Some manufacturers also use spruce (*Picea Abies)*, but in a lesser amount. The characteristic bending strength values in the meaning of Eurocode 5 are 20 or 23 N/mm^2 depending of the shape of the log. A rectangular log has more disturbed fibre and knot structure than a round log and, it's strength is less. The density of the wood material commonly is more than 400 kg/m^3. The quality of the lamination of the laminated logs is controlled by VTT.
The junctions transfer the loads by compression. Thus, the characteristic compression strength perpendicular to grain, 5 N/mm^2, will also be of importance.

Moisture properties

In Finland, a research program is ongoing regarding the moisture behaviour of a log building. The wall is considered as a three-component construction consisting of the log, the seal between the logs and the surface treatment. Laboratory studies and field observations have been used to study how these three components interact (Figure 1).
The preliminary results show, that there are large differences between the behaviour of the seal materials. The traditional materials were linen and moss. The study was begun before there were commercial linen seal on the market and thus, these materials have not yet been proven. In modern log buildings, the polypropylene seal is replacing the glass wool seal. Besides of these two, a cellulose fibre seal was studied.
There is great differences between the moisture behaviour of the seals. Polypropylene and glass wool seals absorb water much less than the cellulose fibre seal. Thus, the logs with polypropylene or glass wool seals will remain drier than the logs with the cellulose fibre seal. On the other hand, the cellulose fibre seal swells when wet and in the test the tightness of the wall against air and water leakage was better than for the other two materials.
Two surface treatments were studied with the untreated logs as a reference. One of the surface treatments was very tight and the other one changed the water absorption properties of the log surface only slightly. As far, the effect of the tightness of the surface treatment has not been significant for the observed variation of moisture content. This might be due to the short time of exposure, but it is also possible that the observation is true.
A surface treatment cannot save a log wall that is poorly made or when the climatic conditions are unfavourable so that the wall is wet most of the time. In field observations, serious damage has also been observed when the surface treatment consists of exaggerated many thick layers.

Thermal insulation properties

According to the Finnish regulations, the log wall thickness 210 mm correspond to a total heat transfer coefficient (U-value) of 0,60 W/m^{2}K which is the minimum requirement. This U-value needs compensating energy conserving action as better quality windows and more insulated ceiling.

VTT has carried out a research project where the thermal insulation properties of the log wall were studied both theoretically and experimentally. The results support the opinion that a better U-value can be used. Thus, according to one laboratory measurement, a value of 0,49 W/m^2K was achieved with 208 mm thick rectangular logs and glass wool seal. In the theoretical calculations regarding the U-value for the heating period, even better value was achieved. According to the measurements for pine material and log walls, the value of the coefficient of thermal conductivity 0,12 W/(mK) can be used in the calculations. Cracks of the logs or the small grooves of the rectangular logs can be omitted in calculations, and the round logs can be calculated according to the geometrical equivalent thickness of the log.

Acoustical properties

The acoustical properties of a log house are often doubted. A log wall manufactured by the company Honkarakenne Oy was tested in the acoustical laboratory of VTT. The thickness of the rectangular logs was 140 mm. The sound insulation of the wall was measured according to the standard ISO 140-3:1978 and ISO 717-1:1982 for six modifications of the wall. For the plain wall independent of seal, the measured insulation number R_w is about 40 dB. When an additional cladding is made of 13 mm gypsum board with or without air gap, the insulation number R_w is about 50 dB. When another gypsum board or a panel is added, the insulation number is still slightly improved.
These values have been measured for the log profile manufactured by the company Honkarakenne Oy. If other kind of log profiles were used, the results may be different. The most important property in this test is the air tightness of the wall.
Thus, according to the Finnish regulations the log walls can be used eg. in kindergartens where there is a modest requirement for sound insulation. Between the rooms, in that case, additional cladding shall be used.

Fire safety

Wood is a combustible material. Logs are, however, massive and the time for a log building to collapse because of fire will be considerable. A more serious risk is the spread of smoke, if the log wall is not tight enough.
The fire safety of a log house can be demonstrated experimentally. A log wall manufactured by the company Honkarakenne Oy was tested in the fire laboratory of VTT. The thickness of the rectangular logs was 140 mm and polypropylene seal was used. The wall had a vertical load of 6,1 kN/m on the centre line. The test method was according to the standard DIN 4102 part 2. In this standard, the wall is additionally exposed for an impact of a ball with the energy of 20 Nm, just before reaching each time limit for the fire-resistance, 30, 60, 90 120 or 180 min. Else, the method follows the standard ISO 834. Oil burners were used to heat the furnace. The integrity of the wall was proven with cotton wool pads.
In this test, the cotton wool pad was ignited after 112 min. The thermal insulation of the wall remained sufficient in still one minute. The wall kept it's loadbearing capacity through the whole test and also survived the impact ball at 30, 60 and 90 min.
Also in this test, the log profile certainly has an effect on the results. Good tightness is the primary condition for the successful test. The charring rate of a log will in any case be so low, that if the construction is made massive enough, the capacity can be kept long times. But if hot gases can have passage through the wall due to insufficient tightness, the test will fail.

Certifying principles of logs

In Finland, as in most countries, the certifying of logs is not presupposed by the law. However, VTT has awarded Finwood a voluntary certificate for the laminated logs. For most glued constructions, there will be a requirement of a third part quality control. The certificate presupposes that this kind of quality control will be done. At the present, there has been awarded no certificates for whole log houses or for combinations of log and seal.
The voluntary certificate also takes up the properties of the log that are needed by the designer. Thus, the structural performance, thermal insulation performance and behaviour in relation to fire will be considered. Also, the overall directions for installation and use will be given. These values will be based on the common praxis or standards or on test results, if the manufacturer claims for better values than given in the standards.
If a log has not been certified by any third part, it can be used as timber or lumber as usual. The design values shall, in that case, be considered separately by each designer, which leads to different estimates.

Concluding remarks

Logs are perhaps one of the eldest building materials. The modern log houses are an industrial product that is supported by much research work. The properties of the log wall will be equally well known as those for the wood framed walls.
The capacity of a log wall can be calculated as for an ordinary timber construction. The log wall performs well also in such conditions, where some acoustic insulation or fire resistance is needed.
The enemy number one is the moisture. If the logs are poorly sheltered during the erection, moisture may cause damage for the surface of the logs. If the log walls are exposed for water without having the possibility to dry properly in between, whole the construction may be damaged with time. Also, if the walls are poorly made and not tight, water may come through the wall. For best result, the instructions of the manufacturers regarding the storage and installation shall be carefully followed.

References

RT 82-10415. Design principles of log buildings. Recommendations given by The Building Information Institute, Helsinki, Finland.
DIN 4102 Teil 2. Brandverhalten von Baustoffen und Bauteilen, Ausgabe September 1977.
ISO 140. Acoustics - Measurement of sound insulation in buildings and of building elements.
ISO 717. Acoustics - Rating of sound insulation in buildings and of building elements.
ISO 834. Fire-resistance tests - Elements of building construction 1075.
Riipola, K. R., 1996. Log-seal-surface treatment: The cooperation of three components. VTT Research Notes, Technical research centre of Finland, Espoo (in press).
Unpublished VTT Research reports

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