A Field Study of Heat and Moisture Condition in a Slab on the Ground with Floor Heating- Results

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1 INTRODUCTION

Slab on ground foundations with floor heating systems have increased in number in new residential buildings in Sweden. A common floor heating system is based on embedded coils in the concrete. Questions have been raised concerning the risk of high levels of relative humidity in the slab. In the late spring, when the heat is turned off, moisture can migrate from the soil below the slab into the slab, driven by the temperature difference between the soil and the slab. With the soil temperatures being higher than the slab temperature, and a relative humidity of the soil being close to 100 %, a moisture flow will occur with a direction from the soil to the slab.

The magnitude of the moisture flow depends on the temperature difference between the soil and the slab and on the vapour resistance of the intermediate layers, normally the insulation. The temperature difference is a function of the heating power to the coil, the width of the slab and the thickness of the insulation below the slab. With a large width of the slab, the thermal insulation of the ground itself becomes more important, and a reasonable temperature difference between the slab and the soil is difficult to sustain.

Another important question to answer is if buildings, with a slab on the ground foundation, with floor heating have a higher heating demand than buildings with a traditional heating supply system, i.e. radiator system.

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This paper only deals with the occurrence of high moisture levels in the concrete slab. The upper layers of the slab, immediately below a plastic floor covering are of particular concern. The paper describes experimental investigations of the moisture distribution above and below the heating coil in order to see if there is any difference.

The heat flow distribution in a slab on the ground is also reported from the field measurements.

2 MOISTURE TRANSFER FROM THE GROUND

In a slab on the ground the floor covering is often very vapour tight. The moisture transport in the foundation will then more or less only take place between the concrete slab and the soil below the slab. The magnitude of the moisture transport depends on the temperature difference cross the insulation and the vapour permeability/resistance of the insulation. The temperature difference cross the insulation will also govern the direction of the moisture transport. If the temperature in the soil is higher than the slab, the direction a moisture transport from the soil to the slab will occur, assuming that the construction damp has dried out.

In a slab on the ground with floor heating, the temperature in the slab is higher than the temperature in the soil during the heating season. In the spring, when the heat is turned off, the temperature in the soil can be higher than the temperature in the slab. The moisture content in the slab will then increase due to the moisture transfer from the soil. The increase in the moisture content will depend on how long time the temperature in the soil is higher than the temperature in the slab, which is influenced by the geometry of the slab. In slabs with a large width, the temperature in the soil in the middle of the slab can be higher that the temperature in the slab during a long time period, caused by the thermal resistance and capacity of the soil. This can lead to high levels of moisture content in the slab and cause damage. However, when the heat is turned on, the slab will dry out during the heating season. One can therefore conclude that the risk for high moisture content depends on the moisture capacity in the slab, the geometry of the slab, the heating power of the coils and the vapour resistance of the insulation material. In single family houses with well-insulated slabs with normal width, the temperature difference cross the insulation will be high. This will reduce the moisture transport from the soil to the slab. The moisture capacity of the slab will also reduce the risk for peaks in the moisture content, since the seasonal variations will be dampened out.

3 MEASUREMENTS

Measurements have been made in order to determine the moisture conditions in a slab on ground foundation in a residential timber-frame, one storey house in Bromölla, in the south of Sweden. It is a single- family house with floor heating. The floor area is 137 m^2. The U-value of the ceiling/loft space is 0.192 W/(m^2·K), from 400 mm of insulation, while that of the walls is 0.130 W/(m^2·K), from 240 mm of insulation.

Figure 1 The experimental house in Bromölla, a single-family residential timber-frame, and one storey house with the floor area 137 m^2.

Measurement is undertaken in the living room, see Figure 2. The floor in the room has no water waste pipes that could affect the heat and moisture flow in the slab. However, the width of the considered part of the building is not representative for a normal width of a building. The width is smaller than a normal house, and this will thereby affect the heat losses.

Two measurement sections are chosen, one in the middle of the slab and one at the edge beam, see Figure 2

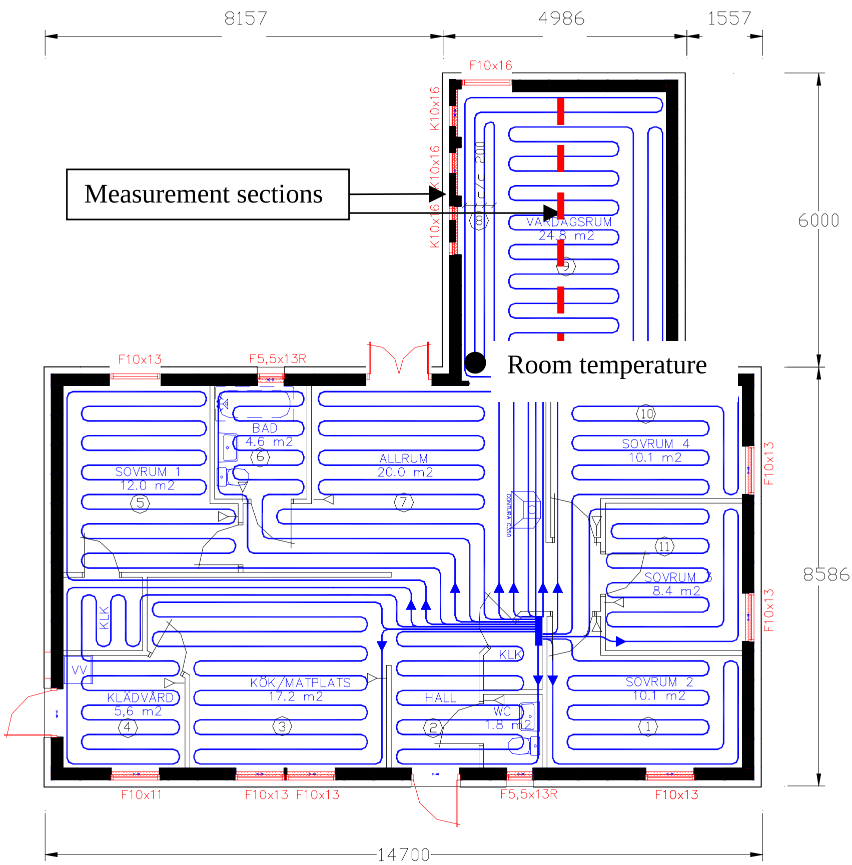

Figure 2 The instruments are mounted in the middle of the living room. Indoor climate is measured 1.2 m above the floor.

The floor insulation consists of 300 mm of expanded polystyrene below the centre region of the slab, and 150 mm below the edge or perimeter region. The heating coils, using water as the heat carrier, are cast into a 100 mm thick concrete screed. A fairly vapour-tight floor covering is used at the upper surface of the slab.

The heat flow density and the relative humidity are measured at different positions in the foundation, as shown in Figure 3. Heat flow is measured by a heat flow meter built up by cellular plastic layers and thermocouples. The temperature is measured by Pt 100 thermocouples, and the relative humidity is measured using a Vaisala instrument.

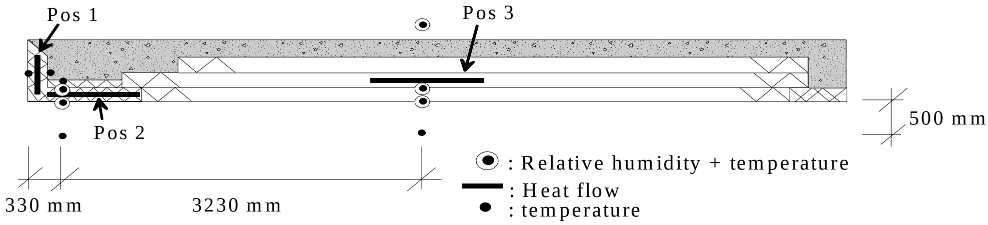

Figure 3 Measurement points in the slab.

The outdoor and indoor climate were measured simultaneously, se Figure 4.

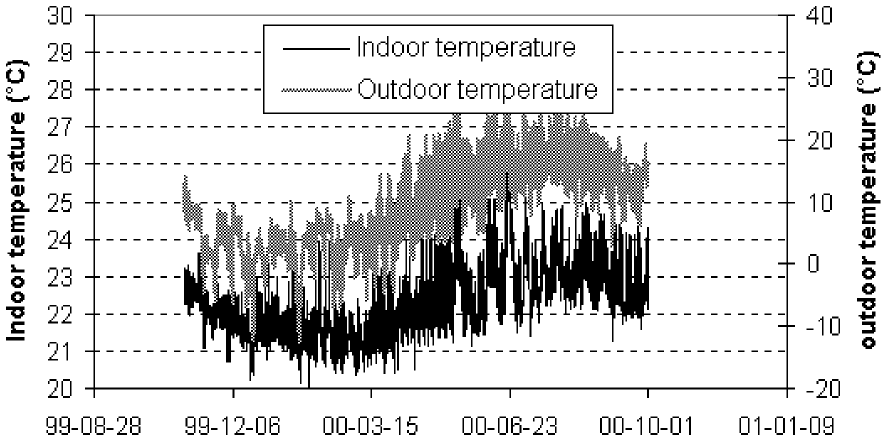

Figure 4 Measured indoor and outdoor temperatures in the Bromölla house.

The heating system stops providing heat to the floor heating system when the mean outdoor temperature is above 17°C.

4 MEASUREMENTS – RESULTS - DISCUSSION

The measured temperature difference in the middle section of the slab, and at the edge, shows that the difference in the middle is at least 8 °C, see Figure 5. The temperature difference between the slab and the gravel leads to that the relative humidity in the concrete slab reaches a maximum of 70 % in the stationary case, i.e. there should be no risk of moisture problems.

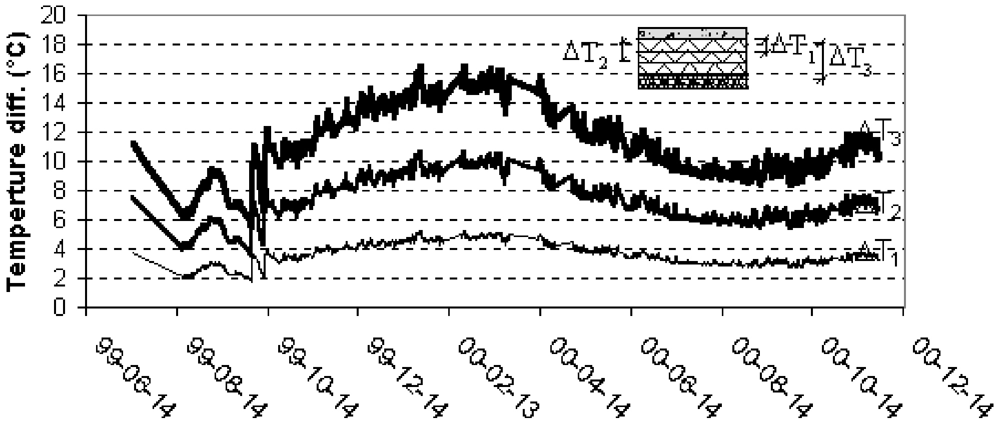

Figure 5 The temperature difference between different layers in the middle section of the slab.

At the edge section, the temperature difference is at least 4 °C, see Figure 6. The concrete is thicker at the edge, and moisture flow from the soil to the slab in the spring is probably very small. The moisture storage capacity is also considerable, which will reduce the seasonal variations in the relative humidity, i.e. the risk of moisture damage in this is low.

The measurements show that, for a slab with different insulation thicknesses, it is necessary to both consider the risk of moisture damage in the middle section and at the edge.

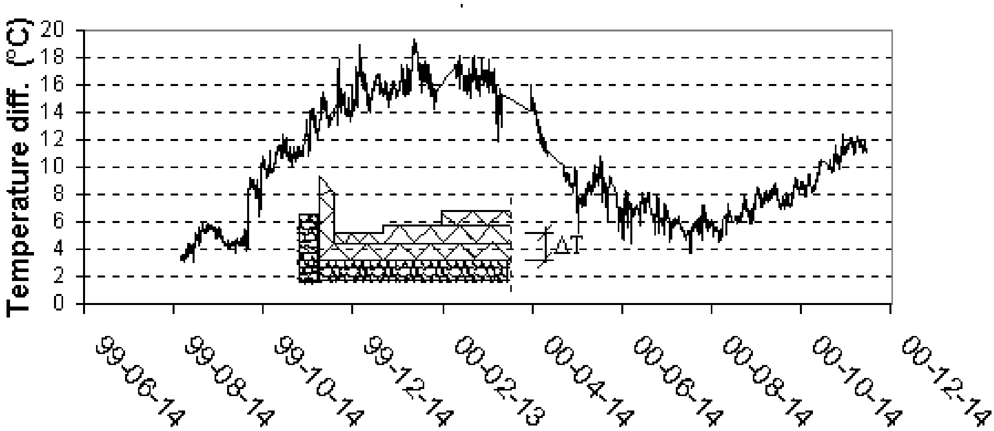

Figure 6 The temperature differences at the edge of the slab.

The heat flow and the heat flow density are measured in three positions in the slab. Each position represents a part of the surface where heat is flowing to the surroundings i.e. at the vertical (Pos. 1) and horizontal (Pos.2) part of edge and the remaining part of the slab (Pos. 3). The integrated heat loss for the three areas is presented in Figure 7 and the heat loss density in Figure 8. The heat flow is approximately the same at the edge beam and in the middle section in both cases. The reason for this is that the insulation thickness is larger in the middle compared with the insulation thickness at the edge beam. The heat loss through the edge beam constitutes about 2/3 of the total heat loss through the slab to the ground and it represents a considerable thermal bridge.

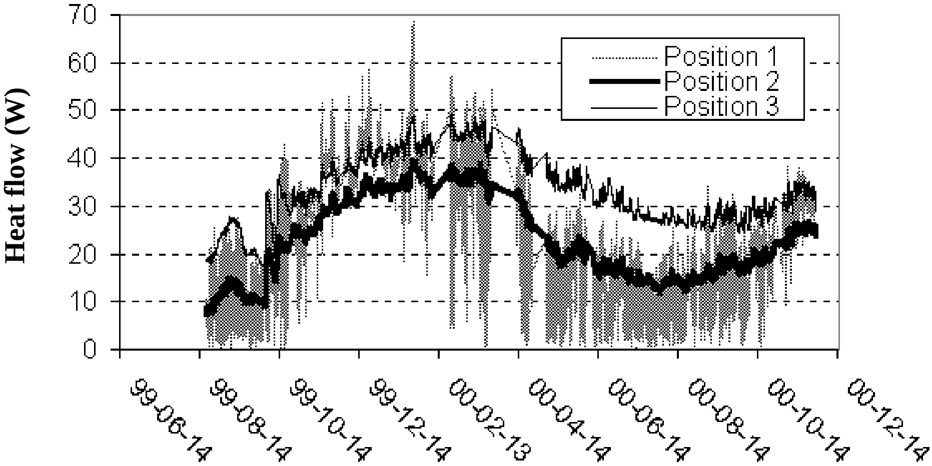

Figure 7 Integrated heat flow at the different positions.

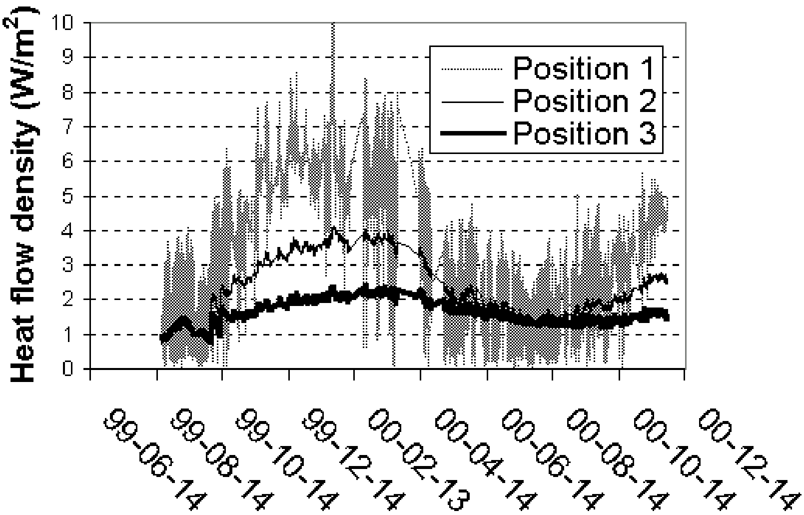

Figure 8 Heat flow density at the different positions.

The total use of energy, during the first year for the building was, on an average, approximately 80 kWh/(m^2year) or 11 000 kWh/year, which means that the building system is quite energy efficient. Similar buildings including the same technical installations have a good chance of being efficient system as well.

5 CONCLUSIONS

Measurements and analyses of the results from the house in Bromölla have shown that the risk of moisture problems, due to water vapour transfer, in the foundation can be considered as minor. It can also be concluded that it is not only the conditions at the centre of the slab (which are normally regarded as the critical zone) that must be considered, but also the perimeter regions of the slab, since the insulation thickness in this area differs from the rest of the slab.

The registered heating demand for the first year, shows that this kind of building and it's technical installations can be considered energy efficient. The heat loss through the edge beam is large in the monitored part of the building. Nearly 66 % of the total heat flow in this part passes through the edge beam. However, in this part of the studied building the proportion of the perimeter area, to the total one, is very large.

ACKNOWLEDGEMENTS

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