Structural Survey

Emerald Article: Air Gap Method: drying of a concrete slab on ground construction

Tord af Klintberg, Folke Björk

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Tord af Klintberg and Folke Björk
Royal Institute of Technology, Stockholm, Sweden

Abstract

Purpose – The purpose of this paper is to report on a study which has been carried out on a timber floor construction above a ground-supported concrete slab, which was used in small detached houses built in Sweden during the period 1960-1990. This method of building has turned out to be a risky construction nowadays, but there are 800,000 houses built this way in Sweden.

Design/methodology/approach – By using the patented Air Gap Method inside building constructions, harmful water can be dried out. The method ventilates air gaps inside walls and floors with an air flow driven by thermal buoyancy caused by a heating cable in the vertical air gaps. The drying out process has been studied both by measuring the moisture level in the slab and also by measuring the humidity transport and comparing this with air flow measurements.

Findings – The paper shows that the Air Gap Method manages to dry out water from both the slab and the overlaying wooden construction. The study shows also that the relative humidity (RH) levels in the air space below the floor are reduced in a significant way, thus minimizing mould growth. It is also shown that a thin layer of concrete upon floor beams prevents mould to grow even in a humid situation.

Research limitations/implications – The research reported in this paper is only concerned with timber-framed small detached houses. Similar studies of apartment buildings are ongoing.

Practical implications – The Air Gap Method can thus be useful in the context of renovating a water damaged house of this type built during this 30-year period. The method provides a possibility of drying out such damage without a separate drying period. The inhabitants could therefore be able to use a renovated water-damaged kitchen six/eight weeks earlier compared to ordinary building methods.

Originality/value – The paper is useful because it provides better understanding of the mechanism of RH inside a building construction and how this parameter could be lowered. The paper is also useful in the context of renovating water-damaged small detached houses built by the risky method of construction used in the last decades of the twentieth century.

Keywords Construction materials, Concrete slabs, Drying, Property, Structural timber, Sweden

Paper type Research paper

1. Introduction

1.1 Swedish small detached house built 1960-1990

Small detached houses in Sweden, built during the period 1960-1990, often used an insulated floor construction above a concrete slab. This construction is considered to be

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risky (Harderup, 1991) because water may enter the construction both from the ground through the slab and through regular water damage from above. During this period more than 800,000 houses of this type of construction were built in Sweden (Ström, 2005).

1.2 Water damage

Water damage and mould. Water damage can cause mould growth if the damage results in high relative humidity (*RH*) within the construction. In an exterior wall of a bathroom, even a small amount of water, passing through a damp-proof membrane and trapped by the vapour barrier, may cause mould growth on gypsum boards in the construction (Jansson, 2005). Mould needs satisfactory temperature, enough time and at least 75 per cent *RH* to grow and when the humidity rises, the growth of the mould will become more rapid (Sedlbauer, 2001; Viitanen, 2002). The level of 75 per cent *RH* is also considered to be the critical moisture limit according to BBR (2006).

In Sweden, 0.7 per cent of all buildings are subject to water damage annually (Länsförsäkringar Bengt G. Johansson, personal communication) and small water damage can be hard to detect. There are situations when mould growth could be hidden inside the construction; many mould toxins are also odourless (University of Lund Lennart Larsson, personal communication).

Cost of water damage. Vattenskadecentrum, a Swedish organisation, run by insurance companies and building trade associations, that survey water damage, estimated that water damage cost more than 5 billions SEK, US$650 millions in 2005 (Ström, 2005).

This sum includes:

- actual costs for the insurance companies;
- estimated costs regarding excesses; and
- estimated costs for water damage in the big public real-estate companies.

This sum does not include:

- Water damage costs for buildings owned by the public such as hospitals, schools and other official buildings (Ström, 2005).
- Water damage that the insurance companies do not cover such as water penetrating from the exterior and condensation damage (Villahemförsäkring VH 09, 2009).
- Health costs caused by water damage such as allergy and asthma. Investigations performed by Emenius (2003) and Hägerhed Engman (2006) show that there is a clear correlation between water damage and asthma/allergy.
- Costs caused during the building process and paid for by the building industry. This cost is also difficult to estimate and there are no estimates yet found, calculated by the building industry, although many builders are committed to solving the problem.

1.3 Modern-day robust constructions

The author claims that a majority of Swedish dwellings are susceptible to water damage because moisture may become trapped within the building construction. Some examples to support this proposition are the Vaska concept, which is a regular building method and also a number of ventilated methods for the construction of floors and bathrooms.

Vaska concept. The Vaska concept was developed by the county authority of Västerbotten and Länsförsäkringar/Västerbotten during the 1980s. This method implies systematization of water protection and specifically a secure installation of pipes (Länsförsäkringar Vaska, 2006). The building costs increase by 1 per cent, but the water damage caused by broken pipes and floods in kitchens is drastically reduced (Andersson and Kling, 2000).

The ventilating plastic membrane. This kind of membrane is supplied by different manufacturers, (see, for example, www.floordry.se and www.isola-platon.se). The membrane creates an air gap of about 5 mm above the water damaged floor and provides the physical preconditions for construction air ventilation, which should be executed by mechanical appliances. The ventilation rate in this type of system was investigated scientifically by Elmroth *et al.* (2009) and Hagentoft and Holmberg (2005).

The ventilated prefabricated bathroom. This method is used to build prefabricated bathrooms, which are installed inside an old bathroom, also with possible water damage (see www.inwall.nu and www.rumirum.se). The method is constructed with an air gap between the old and the new bathroom, where ventilating air can circulate. Construction damp can dry after the prefabricated bathroom is installed. The time for this drying could, according to experience, be about six to nine months (Inwall AB, Hans Tjulander, co-personal communication).

The floor on joists (Nivell floor). The floor is built on joists attached to the structural slabs of the building and creates an air gap below the insulation (www.nivellsystem.se). The floor system gives the physical preconditions for construction air ventilation, which also could be executed by mechanical appliances. The manufacturer estimates that the air flow should be in the range 0.15-0.20 l/m^2 s.

1.4 Air Gap Method

The Air Gap Method is a modification of the common way of building indoor walls and floors, leading to more robust houses in respect of water damage. The method is a building construction design of walls and floors, with an air gap and a heating cable, The Air Gap Method provides for convective airflow that can remove dampness that has entered the construction in case of water damage and the method has been described in two papers in this journal: af Klintberg *et al.* (2008) and af Klintberg and Björk (2008).

The first paper describes that the air gap manages to drain and dry out a flooded intermediate floor in 13 days and also that the method prevents all mould growth provided that the indoor *RH* is not too high. The second paper quantifies the air flow inside a wall built by the Air Gap Method and shows that there is a relationship between the power of the heating cable, the increased temperature in the wall and the air flow.

New issues. There are two more issues to investigate in this context:

(1) It ought to be studied how the Air Gap Method manages to establish an air flow in a combined wall and floor construction.

(2) If such a flow is detected and quantified, the dry out effect from such a flow should be investigated.

Limitations. This work deals only with small detached houses, built with a timber frame. How the Air Gap Method may work in an apartment building will be investigated in forthcoming research.

2. Nomenclature

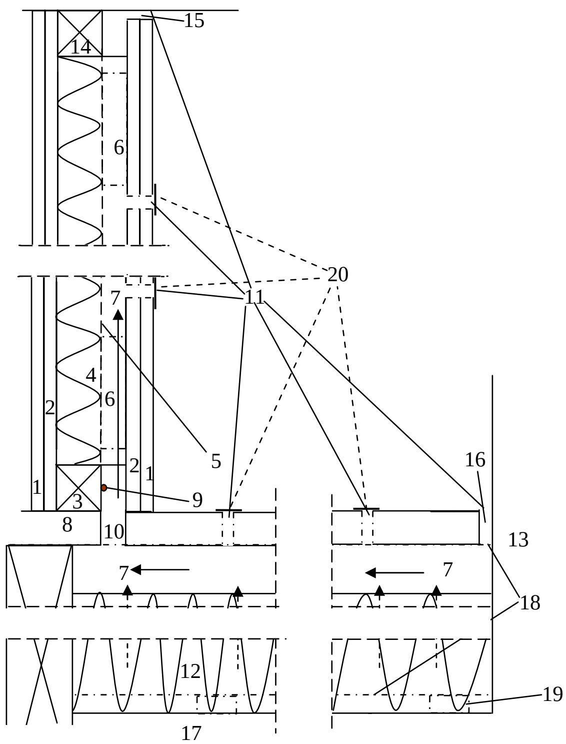
In this paper, the following terms are used:

A-K	*RH* and temperature measuring points
$A_{1\text{-}10}$	Air velocity measuring points
a	Constant in saturation moisture content equation
b	Constant in saturation moisture content equation
d_I	Width of inlet to air gap (m)
I	Current of heating cable (A)
l_W	Length of wall (m)
M	Mean value of molecular weight of air (kg/kmol)
n	Constant in saturation moisture content equation
Nr	Experiment number
p	Number of heating cables
p_s	Air pressure at saturation point (Pa)
Q	Air flow (m^3/s)
Q_D	Total air flow per metre wall during 24 hours ($m^3/24\,h$)
R	General gas constant (J/kmol K)
RH	Relative humidity of air (%)
ΔT	Temperature difference between T_{AG} and T_R (K)
u	Air velocity at air inlet (m/s)
w	Moisture content in concrete (kg/m^3)
v_A	Moisture content at air inlet, point A (kg/m^3)
v_s	Vapour concentration at saturation point (kg/m^3)
v_x	Actual vapour concentration at each measurement point A to M (kg/m^3)
Δv_x	Moisture addition v_x-v_A (kg/m^3)

3. Experimental studies

3.1 Constructions above concrete slab

This floor was constructed with a concrete slab foundation and with mineral wool insulation placed on top of the slab. Two floors were constructed for comparison. The first was built using the air gap system and connected to an air gap system wall (Figure 1) the second in the ordinary way of building. Some of the beams of the air gap floor were covered by a suspension of cement powder mixed with water. Mould seldom grows upon formwork when used in crawlspaces (Aimex AB, Aime Must personal communication). In both floors the timber beams were placed on blocks of timber upon the concrete surface.



Note: Arrows show the direction of ventilating air and moisture transport

Figure 1.
Cross-section of wall and lower floor construction using the Air Gap Method with the "slab on ground" construction with thermal insulation above the slab

The second room lacked the air gap in the wall, as well as the air inlet, gap in the chipboard and also the outlet. In this ordinary construction (Figure 2), the bottom and the top sill also had the same width as the standing studs.

3.2 Heating cable

The heating cable, named T-18 is manufactured by Ebeco AB. The intended use for this cable is to melt ice inside gutters and roof drains. The cable is made of two electrical conductors embedded in a semiconductor material whose resistivity increases with temperature, so the maximum temperature lies in the range of 28-40°C, which also means that the cable cannot be overheated.

The cable is supposed to give different levels of power because of the temperature of the surrounding air "If this air is colder it takes more power to reach the maximum temperature of the cable" (Ebeco AB, Kent Svensson, personal communication). The manufacturer also states that T-18 cable gives a power of 15 ± 3 W/m at room temperature. Each batch (around 3,000 m length of the cable) gives different levels of power, because of minor variations in the properties of the semiconductor material.

3.3 Studies

The full-scale study in "Air gaps in building construction avoiding dampness and mould" by af Klintberg *et al.* (2008) described a flooded intermediate floor. It was found

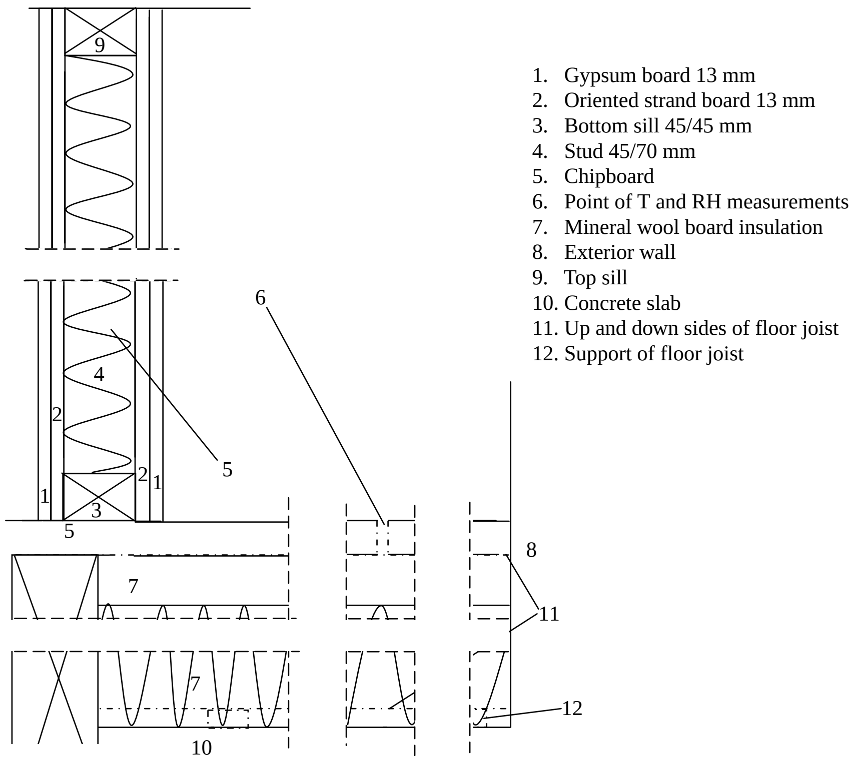


Figure 2.
Cross-section of wall and lower floor by an ordinary construction using the traditional slab on ground with thermal insulation above the slab

that the main part of the flooding water disappeared by drainage and evaporation through the ceiling of the "room" below. Therefore, it was difficult to estimate the amount of water that was ventilated away by the air gap system. One aim of these studies is to provide such an estimation. The second aim is to compare the *RH* values in a floor construction built with air gaps with an ordinary ground floor system. The third aim is to determine whether it is possible to prevent mould growth by covering construction timber with a thin layer of concrete.

Experimental rooms. Two rooms were constructed with chipboard floor and insulation on the slab, the first by application of the air gap system (Figures 1, 3 and 5), the second is built in a more traditional way of building, scientifically described by Harderup (1991) – see Figures 2 and 4. Both rooms measure 2.75 $\times$ 2.25 m (6 m^2) and the concrete (quality C 32/40-K40) slab is 0.1 m thick, giving a volume of each slab of approximately 0.6 m^3. The volume of the space between the under side of the floor and the slab is 1.5 m^3 as the floor beams are 0.25 m high. This space was filled with mineral wool board insulation up to a height of 0.20 m.

Before casting the slabs, the forms were covered with two layers of polythene film (0.20 mm) in order to avoid moisture transport between the slab and the ground. Also the floors were covered, for experimental reasons, with polyethylene (PE) foil to prevent moisture transport through the chipboard. Thus, all moisture transport out from the construction passes through intended or unintended gaps in the construction.

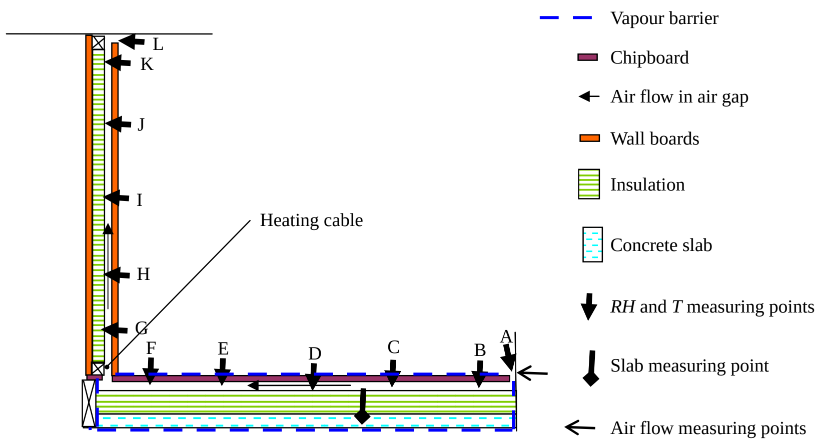


Figure 3. Schematic cross-section of wall and floor construction by the air gap system, supplied with measurement points for *RH* and *T* in air gaps and concrete slab

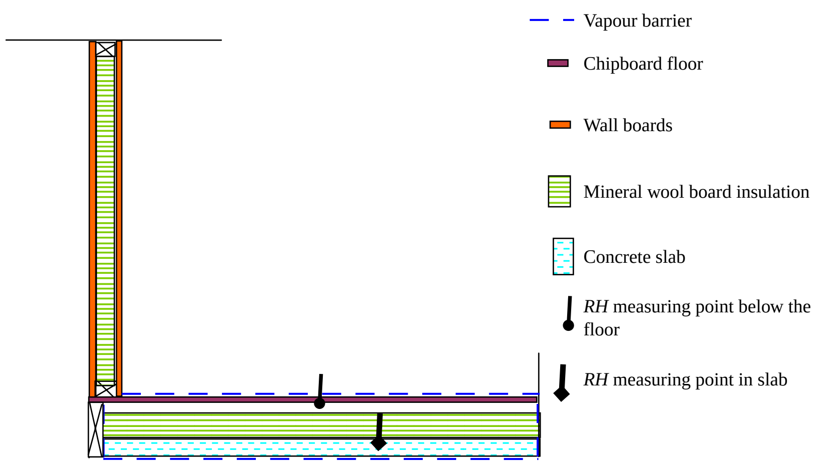


Figure 4. Schematic cross-section of an ordinary wall and bottom floor construction used in the extra *RH* studies, supplied with measurement points for *RH* and *T* in concrete slab and in floor

For the purpose of this study, five holes were drilled in the panelling and five holes in the chipboard of the floor, for insertion of measurement devices. The holes in the floor chipboard were situated along a line 25, 75, 125, 175, and 225 cm from the air inlet, see points A-F, Figures 3 and 5, and the holes in the wall were situated along a line 20, 70, 120, 170 and 220 cm height from the floor, see measuring points G-L in Figure 3. The holes were covered with adhesive PE tape to prevent moisture escaping between the measurements. The holes were only open for short intervals when measurements were taken. There were also points for measurement of room air in both rooms.

Measurement points for air flow are placed at points A_1-A_{10} (Figure 5), all measurement points are placed in the middle infill space between the two centre floor beams.

The hypothesis concerning the air flow is that the air enters the air gap at the air inlet, which in this case is 0.008 - m wide, in the wall/floor angle, goes subsequently

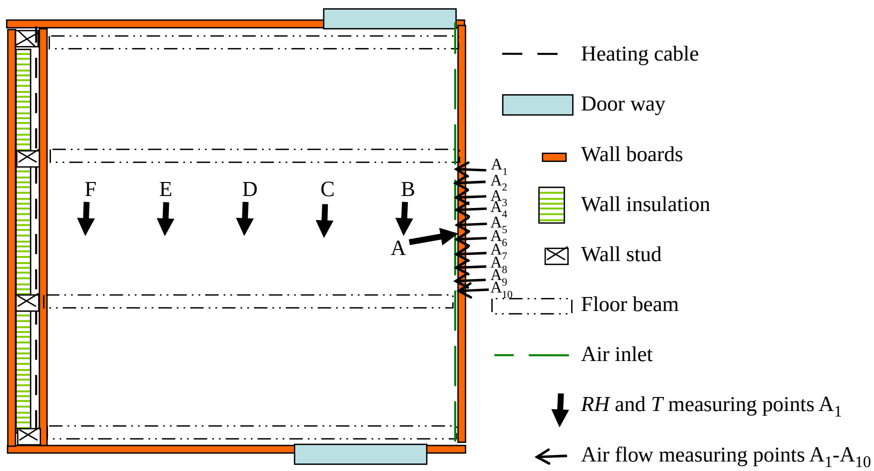


Figure 5.
Schematic plan of room construction by the air gap system, supplied with heating cable and air inlet, also showing measurement points for air flow, *RH* and *T*

above the mineral wool insulation, through the gap of the floor and up through the inside of the interior wall. The construction air outlet is in the interior wall/ceiling angle, at point L.

Experiments. The function of the air gap system in walls and floors can be tested by comparing the drying out process in the two rooms described above. If the method works, the wet concrete slab of the air gap room should dry faster than the slab of the ordinary room. It should also be possible to detect higher and similar moisture concentrations in air gaps of the wall and floor, shown in Figure 3.

This experiment was thus divided into four parts.

A. *RH* decrease in slabs on ground. When the slabs were still wet after casting, one detector for *RH* and *T* (Vaisala Intercap Humidity and Temperature Probe HMP5) was installed at a depth of 50 mm into each slab. The concrete slabs were almost saturated by water and the *RH*-decrease was followed during 56 days. Location of the sensors is shown in Figures 3 and 4. The investigation was performed at the same time for both experimental rooms, during summer time at ordinary indoor conditions.

The influence of the air gap construction on the concrete slab was evaluated by comparison between the two rooms. The heating cable in the room with the air gap was turned on when the experiment started.

B. *RH* and vapour concentration in construction air. In this study, the “slab on ground” constructions needed to be moist. Therefore, the constructions were flooded in advance in order to provide the necessary dampness. As the slabs had dried out unequally in the “A. *RH* decrease in slabs on ground” study, 26 l of water were added to the air gap slab and 12 l were added to the ordinary slab. This study was undertaken over a period of 54 days.

This second study is divided into two parts:

(1) *RH* levels in the air gap construction compared to ordinary.

(2) Distribution of *RH* and vapour concentration in the air gap system.

B.1. RH levels in air gap construction compared to ordinary construction
High *RH* level is an important factor for mould growth. If the air gap system manages to lower *RH* inside a building construction, it could lead to a more robust method of construction. This study registered the difference in *RH* in air between the inside of an air gap construction, compared to the ordinary floor construction. *RH* measurements were performed at the "*RH* and *T* measurement points", see Figure 3 (point D) and Figure 4 (below the chipboard floors).

B.2. Distribution of vapour concentration in the air gap system
It is of interest to see whether a higher vapour concentration is distributed in both floor and wall constructions of the air gap system. This may indicate that the system actually transports the vapour away. If the heating cable manages to create a temperature rise in the air gap wall, it would result in increasing values of vapour concentration even in the air gap wall.

In this study, *RH* and temperature values were intermittently registered from the "*RH* and *T* measuring points" A-L, see Figure 3, below the floor and inside the wall during the experimental period. The hypothesis is that it should be possible to detect higher moisture content inside the total air gap compared to the room air.

The moisture vapour concentration is calculated by the equations (1)-(4) (Nevander and Elmarsson, 1994) and presented in Tables AI-AVIII (Appendix):

$$v_s = p_s \cdot \frac{M}{[R \cdot (273.15 + T)]} \tag{1}$$

where:

$$p_s = a \cdot \left(\frac{b + T}{100}\right)^n \tag{2}$$

$$vx = vs \cdot \frac{RH}{100} \tag{3}$$

$$\Delta v_x = v_x - v_A \tag{4}$$

where:

- a = 288.68.
- b = 1.098°C.
- M = 18.02 kg/kmol.
- n = 8.02.
- R = 8 314,3 J/kmol K.
- v_A = moisture content at air inlet.

B.3. Moisture addition over time
The moisture content at the outlet minus the moisture content at the inlet is the amount of water that is leaving the construction, thanks to the air gap system. In this study, this is called "moisture addition Δv_K" and this parameter is followed over time to estimate the total drying-out over time.

C. Air flow measurements and calculations. The air flow, calculated from the air velocity, is supposed to be the important agent of the Air Gap Method, resulting in a drying out effect and lower *RH* inside a building construction. These measurements were carried out under stable conditions, at one separate occasion, 19 November 2008, when the temperature in the room was 11-12°C. There were also efforts to measure air flow of the major study during summer conditions, but no firm results could be obtained during this period because of the higher ambient temperature prevailing.

The air velocity was measured with a hot wire anemometer from TSI, Finland by the air inlet (see Figure 5 and point 16 in Figure 1). The measurements were recorded in sets and performed in one 55 - cm wide infill space, at ten measurement points A_1-A_{10} side by side with 5 cm in between, five times for "no cable" and ten times for the T-18 cable, in all 150 measurements.

The heating cable was switched on the day before. At time zero the measurements begun, each measurement set starting every 5 minutes. After ten sets the heating cable was switched off, and after 60 minutes another 5 sets were taken. As the floor beams, that measures 0.045 m in thickness and are placed at 0.6 m interval, reduce the horizontal air gap area by 7.5 per cent the calculated air flow will be multiplied by 0.925. The lower detection limit of this anemometer is 5 cm/s. The air flow per metre wall was calculated from air velocity by the equation:

$$Q = u \cdot d_I \cdot l_w \cdot 0.925 \tag{5}$$

where:

$d_{\mathrm{I}} = 0.008$ m; and

$l_{\mathrm{W}} = 1$ m.

The results of the air velocity measurements are shown in Tables AIX and AX (Appendix).

D. Mould growth inside the floor. After the first study the floor was opened, clear tape samples for microscopic investigations of mould and bacteria (Gutarowska and Piotrowska, 2007) were taken from the floor beams that were covered with a suspension of concrete as well as the wooden blocks (see Figure 1 points 18 and 19). In total, there were five samples from the floor beams covered by concrete suspension and nine bare wooden blocks investigated for mould growth. All the sample points were situated under the insulation layer where the *RH* should be higher compared to the air gap above the insulation. Samples were examined concerning mould species and quantity by the respected mould laboratory (Aimex AB).

4. Results

4.1 Studies

A. RH *decrease in slabs on ground.* The *RH* decreases were measured at the "slab measurement points" (Figures 3 and 4). The concrete slabs of the two rooms show different drying out rates. In the ordinary floor construction, the *RH* level has gone down 6 per cent, from 98 to 92 per cent, over a time lapse of 56 days. Reduction for the same period is 12 per cent, from 97 to 85 per cent, in the slab of the air gap system (Figure 6).

A sorption curve is shown in Figure 7 (Nevander and Elmarsson, 1994). This curve is valid for concrete K 40. According to this curve, one cubic metre of concrete contains around 102 kg of water at 92 per cent *RH* and around 89 kg of water at 85 per cent *RH,* see points a and b in Figure 7. As the slabs contain approximately 0.6 m^3, the air gap system succeeds in evaporating around 8 l more during this period, compared to the ordinary built system.

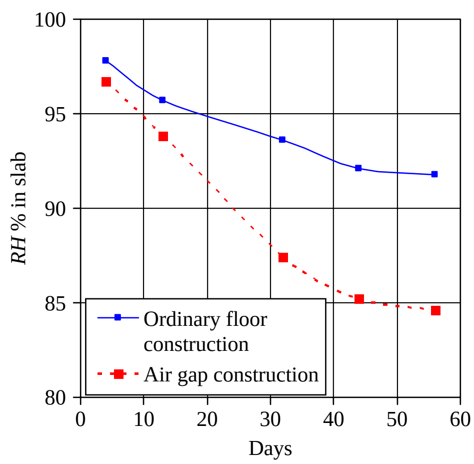
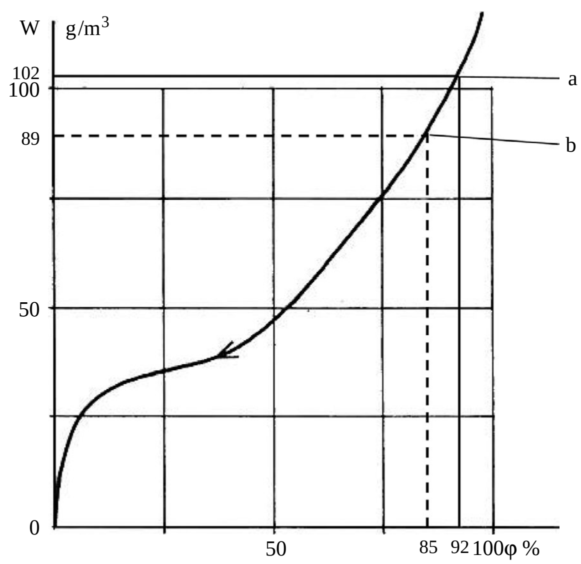


Figure 6.
RH decrease in slabs on ground



Notes: The points "a" and "b" refer to the drying out level reached by the ordinary floor and air gap system, respectively, after 56 days

Figure 7.
Sorption curve of concrete K 40

B. RH *and vapour concentration in construction air.*

B.1. *RH* levels in air gap construction compared to ordinary construction. The *RH* levels below the two floor constructions over time are shown in Figure 8, together with the *RH* levels of the two rooms. The measurement points are shown in Figure 3 (point D) and Figure 4. The chart shows that the ordinary construction has significantly higher *RH* levels compared to the air gap system. The reference floor values exceed 75 per cent for more than 20 days, and this limit of 75 per cent *RH* is considered to be a critical level

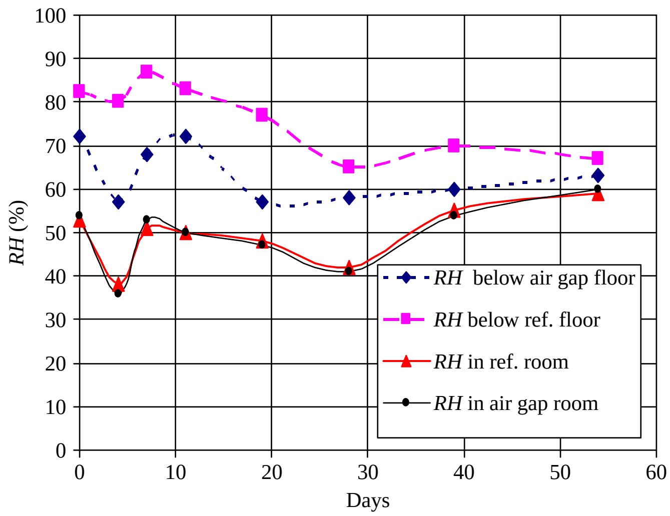


Figure 8.
RH levels inside ordinary floor construction upon slab, inside air gap construction upon slab and in room air

for mould growth (Sedlbauer, 2001; Viitanen, 2002; BBR, 2006). The *RH* level in the air gap floor is less than 75 per cent for all the period.

B.2. Distribution of vapour concentration in the air gap system. All results of *RH* and temperature measurements together with the calculated vapour concentrations are displayed in Tables AI-AVIII (Appendix).

As an example, the results from day 28 are also shown in Figure 9. In these tables, the moisture addition, Δv_x, is introduced as the vapour concentration from one measurement point A-M (Figure 3) minus the vapour concentration at the inlet, point A.

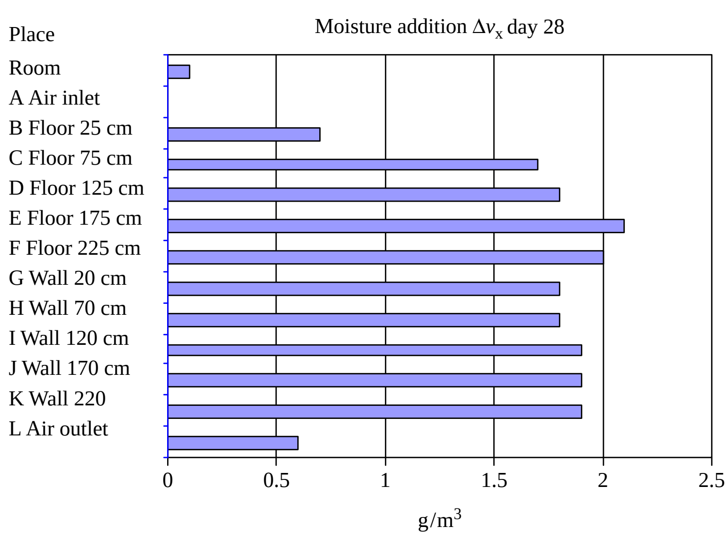


Figure 9.
The moisture addition Δv_x at every measurement point during day 28

Figure 9 shows that there is a gradual increase in moisture addition Δv_x in the floor from the air inlet at "A" to point "F". This moisture addition remains at this level up to point "K" in the wall. The lower value at the air outlet "L" is explained by the process of mixing between air from the room and air from the air gap. The damp concrete slab is the only source for moisture in the construction.

B.3. Moisture addition over time. Figure 10 shows how the moisture addition at point "K", Δv_K in the outlet air varies over time. The average value for 54 days is 1.3 g/m^3 air, which means that 1.3 g of water leaves, the construction for each cubic metre of air. It is also shown that the reduction goes down to zero at 54 days, when the moisture content was the same beneath the floor as above the floor.

C. Air flow measurements and calculations. The results from the air velocity measurements are displayed in Tables AIX and AX (Appendix) and the values lie within the measuring range of the anemometer.

According to Tables AIX and AX, the average air flow for each position A_1-A_{10} calculated by equation (5) varies between 9×10^{-4} and 11×10^{-4} m^3/s. Assuming that the air flow goes in the same direction when the heating cable is switched off, the zero value, which is 1×10^{-4} m^3/s, must be deducted from the measured values. This will lead to an air flow caused by the heating cable between 8×10^{-4} and 10×10^{-4} m^3/s.

D. Mould growth inside the floor. The mould was investigated concerning species, growth and occurrence of mould by Aimex AB and the results are shown in Table I.

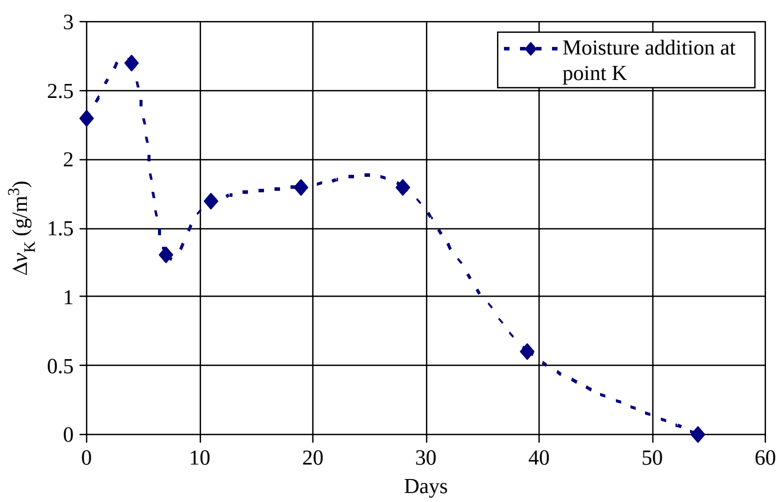


Figure 10. The moisture addition, Δv_K, at point K over time

Experiment	Unprotected block	Beam covered with concrete
Growth	Yes on 1/3 of the spots	Nowhere
Occurrence of spores and hyphas	Moderate on 2/3 of the spots, sparse on 1/3 of the spots	Moderate on 1/5 of the spots, sparse on 4/5 of the spots
Species mould	Acremonium sp. Altenaria sp.	No species growing

Table I. Occurrence and fouling of bacteria and mould on block and beams

Mould did not grow upon the beams that were covered with concrete as expected. This implies further investigation of the retard mechanisms of the mould growth.

5. Discussion

5.1 Air flow estimations

Calculations of the moisture addition transport. The results from *RH* studies of a "slab on ground" construction indicate that eight extra litres of water has disappeared from the "air gap" concrete slab in 56 days compared to the reference slab. No air flow was registered during this period, but the results (Figure 9 and Tables AI-AVIII) indicate that the moisture finds its way towards the air outlet. As seen in these tables, the moisture content measurements in the air gap wall and in the air gap floor correspond very well, which indicate that there are only small air leakages in this system.

The average moisture addition, Δv_K (Figure 10) for the period was 1.3 g/m^3 air, around 8 l disappeared during this period and this will imply that around 6,000 m^3 has ventilated through the system during 54 days (equal to 4,665,600 seconds). This would imply an air flow of 1.3 l/s. As the wall is 2.25 - m long, the air flow will be approximately 0.6 l/s/m.

Air flow measurements. The air velocity has also been measured separately when the room temperature was rather (low 11-12°C) when it was possible to obtain steady results and from those measurements, the air flow has been calculated to be between 0.8 and 1.1 l/s m wall. This could be compared with the expected air flow needed to remove water from the construction, which is 0.6 l/s m wall. This is definitely of the same magnitude and it seems that lower room temperature gives a higher air velocity. This is in line with the statement by the cable manufacturer: "If the air is colder it takes more power to reach the maximum temperature of the cable". More power results in higher air flow, which will be detectable by the anemometer.

These air flows may be compared to the air flow registered in af Klintberg and Björk (2008) that measured flows of 1.3-1.7 l/s/m for the same cable for a single wall construction. The results are of the same magnitude and it is reasonable to believe that the air flow should be lower in a combined wall and floor system compared to a sole wall system. The air gap is more than twice as long in the combined wall and floor construction, and the air flow is assumed to meet stronger friction in this case.

As the floor area of the room is 6 m^2 and the air flow is 1.3 l/s, it will lead us to an air flow of 0.2 l of ventilating air per m^2/s, which is of the same magnitude as the air flow in a Nivell floor (Section 1.3).

As the volume between the floor and the concrete slab is 1.5 m^3, it will lead us to an air change rate around three times per hour. This could be compared with a normal air change rate for a room which would be about 0.5 times per hour.

5.2 Reduced RH *values gives less fragility*

If water has entered into a building construction it is important that the dampness can get out. It is also important that the *RH* inside the construction is kept at a low level in order to avoid mould growth.

The results displayed in Figure 8 show that the *RH* level below the floor in the air gap construction never exceeds 75 per cent. This is a rather big difference compared with the reference floor, especially at the beginning of the study when the water was just added.

The low-*RH* values also imply that there ought to be no mould growth on the under side of the floor. As the major investigation was performed during summertime, it may be considered that the circumstances to avoid mould growth would be even better during the rest of the year.

Concrete suspension. The mould study shows that a suspension of concrete seems to hinder mould from growing on the timber beams inside the floor. This should be further investigated.

6. Conclusion

This work is useful because it provides better understanding of the mechanism of RH inside a building construction and how this parameter could be lowered. This is of general interest, because mould growth is hindered when *RH* is kept at low levels.

This work is also useful in the context of renovating water damaged small detached houses built by the risky method of construction used in the last decades of the twentieth century. The Air Gap Method provides a possibility of drying out such damage without a prolonged drying period. A family could therefore be able to use a renovated water damaged kitchen 6-8 weeks earlier compared to ordinary building concepts.

This study has shown that:

- The Air Gap Method managed to dry out water from a concrete slab. This has been researched both by measuring the actual amount of water that has disappeared from the slab and also by measuring the humidity transport.
- The result of this study is that the air gap system managed to reduce the *RH* in the slab by seven extra percentage points. Approximately, eight extra litres of water were removed in 56 days.
- The air gap system managed to reduce *RH* in the air below the floor in a significant way, minimizing the growth of mould.
- The air change rate between the floor and the concrete slab, inside a "slab on ground" construction, is around three times per hour.

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Appendix

Table AI.
RH, temperature, vapour concentration and the moisture addition Δv_x of air gap air in wall, floor and by inlet and outlet at day zero, one hour after the experimental start

Place	*RH* (%)	Temperature (C)	v_x (g/m^3)	Δv_x (g/m^3)
A. Air inlet	53.9	15.5	7.1	0
B. Floor 25 cm	59.3	14.6	7.4	0.3
C. Floor 75 cm	71.8	14.2	8.8	1.7
D. Floor 125 cm	68.0	14.6	8.5	1.4
E. Floor 175 cm	70.8	15.5	9.4	2.3
F. Floor 225 cm	69.0	15.6	9.2	2.1
G. Wall 20 cm	54.3	17.3	8.0	0.9
H. Wall 70 cm	55.4	16.0	7.5	0.4
I. Wall 120 cm	56.0	15.9	7.6	0.5
J. Wall 170 cm	56.0	15.9	7.6	0.5
K. Wall 220 cm	54.8	15.8	7.4	0.3
L. Air outlet	53.6	16.6	7.6	0.5
M. Room	52.1	16.1	7.2	0.1

Place	RH (%)	Temperature (C)	v_x (g/m^3)	Δv_x (g/m^3)
A. Air inlet	36.4	15.1	4.7	0
B. Floor 25 cm	41.5	13.9	5.0	0.3
C. Floor 75 cm	48.4	13.7	5.7	1.0
D. Floor 125 cm	53.0	14.0	6.4	1.7
E. Floor 175 cm	57.2	14.2	7.0	2.3
F. Floor 225 cm	55.9	14.4	6.9	2.2
G. Wall 20 cm	51.1	16.8	7.3	2.6
H. Wall 70 cm	54.3	15.8	7.3	2.6
I. Wall 120 cm	55.1	15.7	7.4	2.7
J. Wall 170 cm	55.0	15.7	7.4	2.7
K. Wall 220 cm	54.5	15.9	7.4	2.7
L. Air outlet	48.1	16.3	6.7	2.0
M. Room	36.6	15.4	4.8	0.1

Table AII.
RH, temperature, vapour concentration and the moisture addition Δv_x of air gap air in wall, floor and by inlet and outlet at day 4

Place	RH (%)	Temperature (C)	v_x (g/m^3)	Δv_x (g/m^3)
A. Air inlet	52.8	12.1	5.7	0
B. Floor 25 cm	57.5	11.7	6.0	0.3
C. Floor 75 cm	62.5	11.5	6.5	0.8
D. Floor 125 cm	64.4	11.6	6.7	1.0
E. Floor 175 cm	67.2	11.7	7.0	1.3
F. Floor 225 cm	68.1	11.9	7.2	1.5
G. Wall 20 cm	58.0	14.3	7.1	1.4
H. Wall 70 cm	60.8	13.0	6.9	1.2
I. Wall 120 cm	61.9	12.8	6.9	1.2
J. Wall 170 cm	62.4	12.7	7.0	1.3
K. Wall 220 cm	62.3	12.8	7.0	1.3
L. Air outlet	55.0	13.2	6.3	0.6
M. Room	55.1	12.2	5.8	0.1

Table AIII.
RH, temperature, vapour concentration and the moisture addition Δv_x of air gap air in wall, floor and by inlet and outlet at day 7

Place	RH (%)	Temperature (C)	v_x (g/m^3)	Δv_x (g/m^3)
A. Air inlet	54.1	10.4	5.2	0
B. Floor 25 cm	59.9	9.4	5.4	0.2
C. Floor 75 cm	63.2	9.6	5.8	0.6
D. Floor 125 cm	66.6	10.0	6.3	1.1
E. Floor 175 cm	71.7	10.2	6.8	1.6
F. Floor 225 cm	71.3	10.4	6.9	1.7
G. Wall 20 cm	61.6	12.9	6.9	1.7
H. Wall 70 cm	66.8	11.6	7.0	1.8
I. Wall 120 cm	67.4	11.6	7.0	1.8
J. Wall 170 cm	67.1	11.5	6.9	1.7
K. Wall 220 cm	66.8	11.6	6.9	1.7
L. Air outlet	62.5	12.0	6.7	1.5
M. Room	49.8	11.8	5.3	0.1

Table AIV.
RH, temperature, vapour concentration and the moisture addition Δv_x of air gap air in wall, floor and by inlet and outlet at day 11

Table AV.
RH, temperature, vapour concentration and the moisture addition Δv_x of air gap air in wall, floor and by inlet and outlet at day 19

Place	*RH* (%)	Temperature (C)	v_x (g/m^3)	Δv_x (g/m^3)
A. Air inlet	46.6	14.5	5.8	0
B. Floor 25 cm	46.4	14.4	5.7	−0.1
C. Floor 75 cm	48.4	13.9	5.8	0
D. Floor 125 cm	53.9	13.8	6.4	0.6
E. Floor 175 cm	53.5	14.1	6.5	0.7
F. Floor 225 cm	56.7	14.2	7.0	1.2
G. Wall 20 cm	53.4	16.4	7.5	1.7
H. Wall 70 cm	56.5	15.6	7.5	1.7
I. Wall 120 cm	56.8	15.9	7.7	1.9
J. Wall 170 cm	57.3	15.6	7.6	1.8
K. Wall 220 cm	58.3	15.3	7.6	1.8
L. Air outlet	49.6	15.4	6.5	0.7
M. Room	46.6	14.5	7.1	0

Table AVI.
RH, temperature, vapour concentration and the moisture addition Δv_x of air gap air in wall, floor and by inlet and outlet at day 28

Place	*RH* (%)	Temperature (C)	v_x (g/m^3)	Δv_x (g/m^3)
A. Air inlet	43.6	18.8	7.0	0
B. Floor 25 cm	49.7	18.1	7.7	0.7
C. Floor 75 cm	55.4	18.4	8.7	1.7
D. Floor 125 cm	56.2	18.3	8.8	1.8
E. Floor 175 cm	58.2	18.3	9.1	2.1
F. Floor 225 cm	57.5	18.4	9.0	2.0
G. Wall 20 cm	46.8	21.5	8.8	1.8
H. Wall 70 cm	51.0	20.0	8.8	1.8
I. Wall 120 cm	51.5	19.9	8.8	1.9
J. Wall 170 cm	52.0	19.8	8.9	1.9
K. Wall 220 cm	52.2	19.7	8.9	1.9
L. Air outlet	43.5	20.0	7.6	0.9
M. Room	40.7	20.0	7.1	0.1

Table AVII.
RH, temperature, vapour concentration and the moisture addition Δv_x of air gap air in wall, floor and by inlet and outlet at day 39

Place	*RH* (%)	Temperature (C)	v_x (g/m^3)	Δv_x (g/m^3)
A. Air inlet	54.8	16.9	7.8	0
B. Floor 25 cm	57.2	16.1	7.9	0.1
C. Floor 75 cm	60.3	16.1	8.3	0.5
D. Floor 125 cm	59.4	16.1	8.2	0.4
E. Floor 175 cm	60.0	16.2	8.3	0.5
F. Floor 225 cm	60.4	16.3	8.4	0.6
G. Wall 20 cm	53.3	18.4	8.3	0.5
H. Wall 70 cm	55.0	17.8	8.4	0.6
I. Wall 120 cm	56.9	17.2	8.4	0.6
J. Wall 170 cm	57.3	17.1	8.4	0.6
K. Wall 220 cm	57.8	17.0	8.4	0.6
L. Air outlet	59.4	17.5	8.9	1.1
M. Room	53.5	16.9	7.9	0.1

Place	RH (%)	Temperaute (C)	v_x (g/m^3)	Δv_x (g/m^3)
A. Air inlet	58.8	19.9	10.0	0
B. Floor 25 cm	62.1	19.0	10.0	0
C. Floor 75 cm	63.0	18.8	10.0	0
D. Floor 125 cm	62.4	18.9	10.0	0
E. Floor 175 cm	62.3	18.9	10.0	0
F. Floor 225 cm	62.1	19.0	10.0	0
G. Wall 20 cm	56.0	21.1	10.0	0
H. Wall 70 cm	59.4	20.0	10.0	0
I. Wall 120 cm	59.2	20.0	10.0	0
J. Wall 170 cm	59.3	20.0	10.0	0
K. Wall 220 cm	59.3	20.0	10.0	0
L. Air outlet	59.3	20.0	10.0	0
M. Room	60.5	19.4	10.0	0

Table AVIII. *RH*, temperature, vapour concentration and the moisture addition Δv_x of air gap air in wall, floor and by inlet and outlet at day 54

Measurement	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	Av.
1. T-18	15	17	12	13	14	13	15	12	13	10	13.4
2. T-18	13	15	15	13	13	15	12	11	12	11	13.0
3. T-18	14	16	13	12	15	12	13	17	10	10	13.2
4. T-18	15	13	15	13	13	16	13	15	12	11	13.6
5. T-18	15	14	12	11	13	12	11	15	11	13	12.7
6. T-18	16	13	13	15	12	13	12	14	11	16	13.5
7. T-18	14	16	13	13	10	9	7	12	18	16	12.7
8. T-18	13	12	15	12	13	15	16	10	12	10	12.8
9. T-18	14	13	17	13	15	13	16	13	15	12	14.1
10. T-18	13	13	13	12	10	12	15	13	12	10	12.4
Av. T-18	14.2	14.2	13.8	12.7	12.7	13.0	13.1	13.2	12.9	11.9	*13.2*

Table AIX. Air velocity at measurement points A_1-A_{10} during separate occasion in November, when the heating cable T-18 is switched on

Measurement	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	Av.
1. No C	0	4	1	0	0	2	3	0	0	0	1.0
2. No C	0	3	1	0	1	6	1	1	0	0	1.2
3. No C	0	1	2	0	0	3	2	0	0	0	0.8
4. No C	0	2	1	0	0	4	3	2	2	1	1.5
5. No C	0	2	1	0	1	2	3	0	0	0	0.9
Av. No C	0	2.4	1.2	0	0.4	3.4	2.4	0.6	0.4	0.2	*1.1*

Table AX. Air velocity at measurement points A_1-A_{10} during separate occasion in November, when no heating cable is switched on

Corresponding author
Tord af Klintberg can be contacted at: tord.klintberg@byv.kth.se