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Rising damp, a reoccurring problem in basements – a case study with different attempts to stop the moisture

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KEYWORDS: *Rising damp, basement, microwave moisture measurement, nuclear moisture density gauge, steel plates, capillary suction, renovation*

SUMMARY:

The paper describes how a 2.900 m² basement had to be renovated twice; first to reduce the moisture in the basement, later with focus on stopping the rising damp in the internal brick walls.

The basement had a concrete floor but no effective way to stop capillary suction from the ground. To stop the moisture ingress a double construction was introduced with steel plates as horizontal water barrier in the internal brick walls. At the same time the drainage around the basement was renewed. After a year the internal brick walls were wet; the groundwater level was higher than the level of the steel plates, making the plates inefficient as a moisture barrier as they cannot stand water pressure.

Before a new renovation could start, tests were made on different solutions, mainly to test how a membrane could be placed under the internal brick walls, but also to test if the solution was effective. The latter part involved different in-situ moisture measurements; with nuclear moisture density gauge and microwave moisture measurements, and attempts to dry out the moist internal walls. The paper describes the different attempts to stop the rising damp, the different measurements and the results.

1. Introduction

Basements in Denmark are often damp, especially basements with brick walls. To prevent rising damp above ground level, a moisture barrier on top of the plinth became mandatory in 1871 in multi storey houses in Copenhagen (Engelmark, 1983) and has been widely used in Denmark the last 100 years. Modern basements walls are often concrete walls which reduce the moisture transport, not only above ground level but also into the basement.

Because of stipulations in the Danish Building Regulations basements are normally only used for storage and short stays, normal use is only allowed if the terrain along at least one wall with windows is below the floor level. However, if subjects stored in the basement become mouldy and people feel sick even after short stays in the basement, measures must be taken to reduce the moisture content. The paper describes a case where different approaches were made to reduce water ingress through the basement floor and outer concrete walls, and to reduce rising damp in the internal brick walls.

2. Case description

The subject of this case is the basement of a one storey school building from 1965 with a 2.900 m² basement, with 700 m concrete outer walls and 700 m internal brick walls. Only few rooms were used as practical rooms, the rest were used as storage rooms or for short stays. The basement had concrete floor and drainage around the building.

In 1998 the basement was cleared as it was wet and mould became a severe indoor climate problem. A thorough renovation was necessary, and temporary pavilions were used in compensation for the rooms in the basement during the renovation.

The problems were identified to relate to:

- Defect drainage; blocked by ochre or broken
- Leaky sewage system placed under the basement floor near ground water level
- Capillary suction in the concrete floors
- Rising damp in the internal walls

In general a non-watertight construction was placed in a very wet environment. Pumps were used to reduce the water in the ground, but they were not effective, and water ingress was not stopped.

3. First renovation

To reduce the moisture transport into the basement, different approaches were made. FIG. 1 shows schematically the planned renovation.

- *New floors.* Although the concrete floor was placed on sand, the moisture content, indicating that capillary suction was possible through the sand and concrete. As the ceiling height in the basement was 3.28 m, it was possible to raise the floor and create a double construction by placing a new floor at a higher level. The area between the two floors was drained. To stop rising damp through the floor a liquid membrane was applied on the original floor.
- *Steel plates and injections.* To stop the rising damp in the internal brick walls it was planned to use the liquid membrane, removing 2 courses of the brick wall approximately 1 m at the time. This was difficult and time consuming. Instead the contractor chose to force overlapping steel plates through a horizontal joint where they acted as a capillary suction barrier. Where it was impossible to place steel plates e.g. because of downpipes in the walls, it was planned to inject the area of the wall with a capillary blocking mortar, however, this was never done.
- *Outer walls.* The concrete walls were un-insulated and the drainage defective. Therefore, perimeter drain and 150 mm external insulation (EPS) were added to the walls. Pumps to insure the drainage was effective were also installed. The pumps were provided with an alarm system, telling the caretaker when the system had fall outs.
- *Sewage system.* The sewage system was changed; sewage from upper storeys was placed higher than originally and only outlets from the basement were placed under the new basement floor.

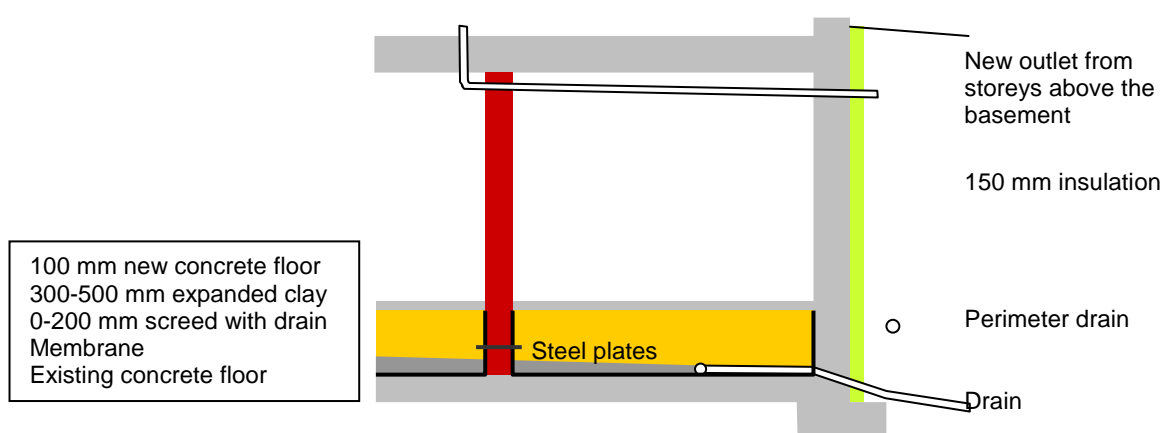


FIG. 1. Schematic drawing of remedies to reduce moisture transport into the basement. Originally the membrane was planned to be continuous e.g. under the internal walls, but this was later changed by the contractor. Instead steel plates were pressed through the walls, and the membrane was continued on the wall.

4. Problems with the first renovation

The renovation was almost finished in 2002; only the finish works on the interior walls were lacking e.g. plasterwork, skirting and new internal doors. Due to several disagreements between the contractor and the building owner, the basement was left unfinished and not used for several years.

As the dispute went on, the internal walls showed signs of high moisture content; the fringe of capillary suction was very visible where the plasterwork was coloured, see FIG. 2 (left), parts of the plasterwork also was loosened by the salt formation at the fringe (efflorescence).

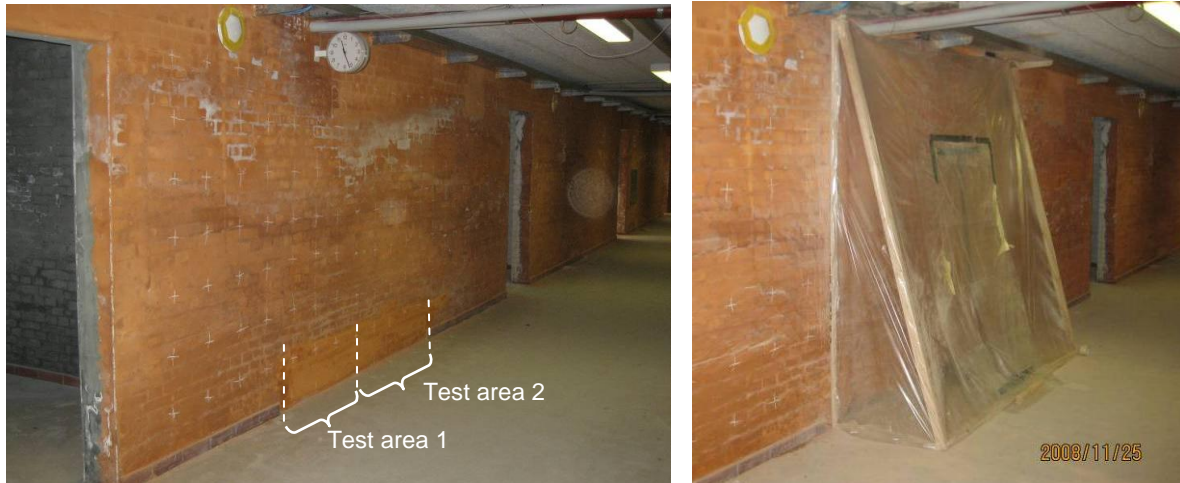


FIG. 2. Examples of moist internal walls in the basement. Left: Visible moisture signs (efflorescence) and the two test areas. Right: Forced drying under a tent.

Therefore, the basement was ventilated and heated to reduce the relative humidity of the air. The development of the moisture content was followed and new renovation proposals tested.

The drainage from under the floor and the perimeter drainage were connected but without anti-flood valve, heavy rain could result in flooding of the area under the new floor. One Easter holiday there was a power failure, which meant that the pumps ensuring the drainage stopped, unfortunately, no one reacted on the alarm, and after the holidays there was visible water in the basement. This enhanced the moisture content in the basement, and blurred the general image of the problem.

Before the first renovation started the groundwater level was 6 - 76 cm under the planned new ground level of the basement, after the first renovation the groundwater level was 1-3 cm above the new ground level. As the groundwater had risen above the original floor level, there was water pressure in the internal brick walls. The steel plates could only hinder capillary suction not withstand water pressure, as the plates were only overlapping and therefore not a watertight barrier.

5. Test renovations

Before initiating renovation of all the internal walls, different pilot projects were performed with the triple purpose of testing work methods, effect and costs of the renovation.

5.1 Blocking rising damp

First priority of the renovation methods was to block the rising damp. As steel plates had not been effective under the new concrete floor, a second try with steel plates was not made, although these might had worked higher up, where there was no water pressure. Instead tests with a liquid membrane

were performed. Different solutions were tried; the first was regarded more safe than the second but also more expensive. Both solutions are presented in FIG. 3.

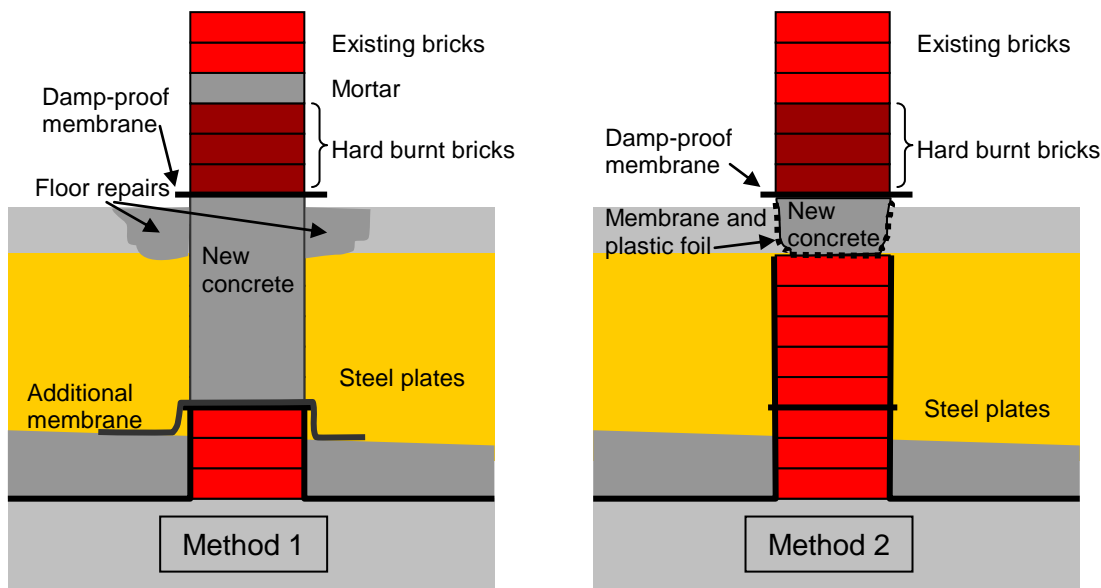


FIG. 3. First method to avoid moisture transport in internal walls, ten courses of bricks had to be replaced in this solution (left). In the second method the concrete floor was untouched and only five courses had to be removed (right).

As both methods included removal of bricks, it was not possible to renovate the whole wall at once, but the wall had to be divided in bits, making it possible to have a gap of maximum 1 m and solid wall on both sides of the gap. Theoretically every other meter of wall could be renovated at the same time. When the gap was closed, the adjacent wall piece could be renovated. However, a part of the wall had to be left open between the two similar work processes, as the liquid membrane had to overlap.

5.2 Other possibilities

The tested methods were very work intensive and time consuming. As the basement was under a school, noisy work could only be performed during summer holiday. To renovate the whole basement in six weeks would require approximately 40 workers at the same time in the basement. This would not only be crowded but also expensive. Therefore, other possibilities were explored as well.

- *Lowering the groundwater level by continuous pumping of water from the area.* This solution was rejected for environmental reasons and because of high running costs; the ground water in the area has a high content of ochre, which would mean high costs for filters and cleaning of pipes. Finally there is a levy on water pumped from construction sites.
- *Injections with water repelling mortar.* The contractor had planned to use steel plates supplemented by injections with water repelling mortar around downpipes. Injections could be used as a new moisture barrier in the whole wall. However, since the first renovation, tests had shown that the effect of injections could not be confirmed (Brandt & Hansen, 2004) and this solution was not pursued any further.

6. Moisture measurements

During the first renovation, the internal walls were dried, but later the internal walls showed signs of being wet. The moisture content was not measured until several years after the second test renovation was finished, as the signs were regarded as very clear, see FIG. 2.

6.1 Drying the wall

After the test renovations were performed, the wall was left to dry naturally, but with heating and enhanced ventilation in the basement. Approximately four years after the second test was performed the moisture content in the wall was measured by a nuclear moisture density gauge, see FIG. 4. As the measurements showed very little difference to moisture content in the parts of the walls where no test renovations were performed, forced drying was installed. To reduce the drying costs the two test areas were covered by a small tent, see FIG. 2. Moisture measurements were continued after the forced drying was stopped.

Before starting the forced drying the test area was separated from the untreated part of the wall by milling a groove on both sides of the test area to prevent horizontal capillary suction from the untreated walls to the test area.

6.2 Measure methods

The moisture content in the walls was measured with two methods, both independent of the salt content in the wall. To get an exact measurement of the moisture content both methods have to be calibrated with measurements of wet and dry weight of the material.

- *Nuclear moisture density gauge.* Neutron radiation beams are reflected by the hydrogen atoms in the material. The strength of the reflected beams expresses the moisture content (Brandt, 2009). In this case a nuclear moisture density gauge from Troxler was used.
- *Microwave moisture measurements.* These measurements are based on the dielectric properties of water. The dielectric constant of water is 10-20 times higher than of most building materials. This means that when microwaves are emitted, molecules will vibrate, but the energy loss when hitting water molecules will be significant, and the reduced strength of the reflected microwaves expresses the moisture content (Brandt, 2009). In this case the microwave moisture measurements were done with an instrument from hf-sensor.

7. Results

The moisture content in the wall above the two test areas was measured several times in the period from December 2007 to August 2009, see FIG 4. This also included few determinations of moisture content based on weighing and drying of specimens from the wall.

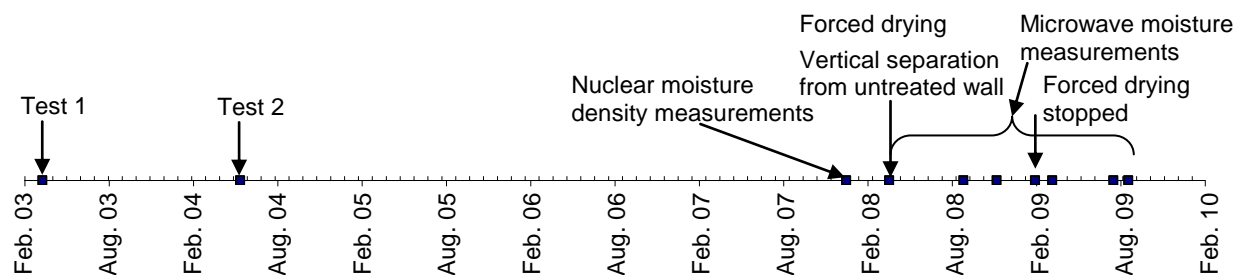


FIG. 4. Timeline of the tests and following moisture measurements.

Measurements with nuclear moisture density gauge are shown in FIG. 5. The measurements are shown as numbers that resembles the moisture content; high numbers indicates high moisture content. The measurements were performed in December 2007, 4½ years after the two tests were performed; e.g. rising damp was blocked horizontally but not vertically. The basement was heated and ventilated during this period. Moisture content in brick and mortar was determined by weight to 21 % in brick and 6 % in mortar in an area where the nuclear moisture density gauge showed high moisture content.

The microwave moisture measurements were introduced when the test areas were separated from the untreated wall and the drying was forced. The results are shown in FIG. 5.

The salt content in the brick and mortar was less than 0.27 weigh-%.

The perimeter drainage and drainage from the area under the new floor were separated from each other. Inspections of the drainage under the new floor showed heavy sediment of ochre, it was necessary to add extra inspection chambers to ensure effective drain in the future.

Moisture content in bricks and mortar was determined by weighing during and after the forced drying. After the drying the moisture content in bricks was less than 0.6 weigh-% and less than 0.4 weigh-% in mortar.

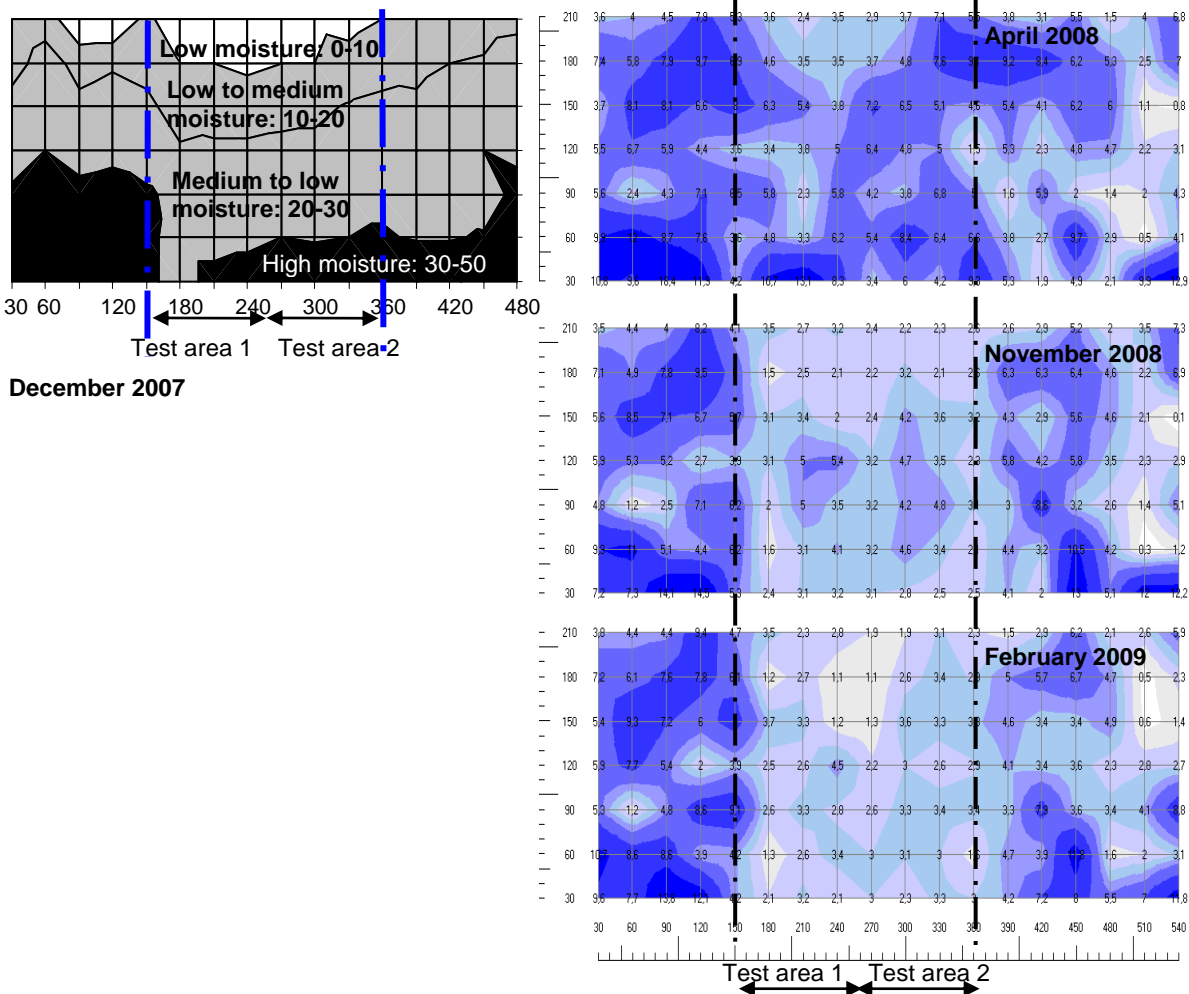


FIG. 5. Moisture measurements with nuclear moisture density gauge with numbers resembling the moisture content (left). Microwave moisture measurements (in weight % of bricks) (right); when the test areas were separated from the rest of the wall and forced drying activated (April 2008) and after (November 2008 and February 2009). The measurements after the forced drying was stopped (February 2009) did not show significant changes and were similar to those from February 2009.

8. Discussion

There are several reasons why the first renovation did not solve the problem with rising damp:

- *Groundwater level.* Before the renovation groundwater was pumped from the area. After the renovation this stopped and the groundwater level rose, resulting in a higher water pressure in the internal walls.
- *Steel plates to stop rising damp.* Normally steel plates are effective in blocking rising damp, but as they only overlap they are not watertight, which a membrane would have been. As a result water under pressure could pass the steel plates. The problem was increased by the higher groundwater level. Where downpipes had made it impossible to press steel plates through the internal walls, injections were used, these might have been ineffective.
- *Drainage.* The perimeter drain was connected to the drain from the area between new and old floor, but there was no anti-flood valve, heavy rain could therefore result in flooding the area between the two floors. The drain was blocked by ochre; as a result water would not be drained from the area between the two floors.

The groundwater level is probably a secondary groundwater level and changes therefore with the season; however, the result was a wet basement. In the future this problem might become more general; if climate changes lead to heavier rain, and consequently higher groundwater levels, the amount of damp basements will increase, as moisture barriers that were effective to capillary suction no longer will be sufficient, as they will have to be watertight.

8.1 Moisture measurements

Moisture determination by weighing the material when moist and after drying is considered as the most exact method, the other methods are therefore compared to the weighing results. Placing several dowels or electronic relative humidity sensors in cavities in the wall would have been another way to compare the methods for measuring moisture. However, such equipment would probably have affected the other methods, and were omitted.

The measurements with nuclear moisture density gauge were only calibrated by weighing pieces of mortar and brick in an area, where the moisture content was considered to be high. The weighing of materials from this area confirmed high moisture content. As measurements with the instrument on homogenous walls normally indicate the moisture distribution in the wall (Simonsen et al. 2007), the measurements were considered to be valid. However, the measurements also showed that the bricks in the test area were still wet, more wet than could be explained by hygroscopic moisture uptake (Hansen 1986). Therefore, capillary suction was still possible. The pattern showed that the moisture content was highest in the lowest part of the wall.

Like the measurements with nuclear moisture density gauge the first microwave moisture measurements showed that there was only little difference in the moisture distribution in test area compared to the untreated parts. The lower parts were moister than the upper parts although the image was more blurred, with some wet areas higher up in the wall. It seems more likely that the walls are moister at the bottom than at the top, as the measurements with nuclear moisture density gauge showed (FIG. 5 left), than a random distribution as the microwave moisture measurements showed (FIG. 5 right).

The results of the weighed specimens did not correlate very well with the measured moisture content determined by microwave moisture measurements (not shown).

However, the general picture of decreasing moisture content over time, which was seen in the weight measurements, is recognisable in FIG. 5. The microwave moisture measurements may not give exact information on the moisture content in a particular point but can be useful as a picture of how the moisture distribution changes over time.

8.2 Effectiveness of test solutions

The two solutions did not show significant differences in effectiveness, and will therefore be treated as one. The main principle in the solutions was to stop rising damp also if the water was under pressure, due to a high groundwater level.

After more than four years the test area was still wet, indicating that the rising damp was not stopped. However, the moisture could come from the untreated parts of the wall; therefore, horizontal capillary suction was stopped by milling a groove at both sides of the test area. At the same time the wall was dried forcefully.

After the moisture content in the test area had stabilised (after less than a year, cf. FIG. 5), the forced drying was stopped, and microwave moisture measurements continued. The moisture distribution did not change after the forced drying had stopped. Therefore, rising damp in the internal walls had stopped; the tests were successful. As a result the second test solution is now being applied to all the internal walls. After a drying period the moisture content will be checked with microwave moisture measurements combined with moisture measurements by weight.

9. Conclusions

Double constructions where water can be drained from the layer between two concrete shells are in general safe solutions. However, if they are built in as part of a renovation, this case shows some pitfalls:

- The groundwater level should be checked; if the level is likely to be higher than where the blocking of capillary suction is planned, the blocking should be watertight, e.g. not steel plates
- Drainage from the area between the concrete floors must be effective and have a high water valve to prevent flooding

To determine the moisture content in the walls before, during and after renovation solutions were tested, two non-destructive measure methods were used as an alternative to the destructive method of weighing and drying cut out pieces; the nuclear moisture density gauge and microwave moisture measurements. The first showed a realistic moisture distribution but is cumbersome to use, where as the latter did not seem to give exact measurements in a specific location but is easier to use.

In this case microwave moisture measurements were very useful to show how the wall dried and to determine if the tested solutions were effective. The results seemed realistic and corresponded with the overall picture of the moisture content.

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