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Evaluation of microwave drying effects on historical brickwork and modern building materials

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Abstract. One of the most common reasons for any construction work requirements is an increased humidity of the building. Increased humidity does not affect only buildings with basement, but also buildings without it, which were not properly hydro-isolated or the hydro isolation was damaged due to aging or to adverse environmental effects. Such situations are solved with designing suitable remediation measures, which necessarily includes drying of damp masonry as well. This almost always includes historical buildings, where protection against groundwater was never planned. Such buildings are usually very sensitive to any physical intervention into construction itself and destructive methods of revitalization are very often completely out of the question, therefore it is necessary to develop methods, which can be used particularly for historical buildings. This article focuses on evaluating effects of microwave drying historical brickwork as well as modern building materials. First, the method of microwave drying is described in general, then we cover the experiment, which was performed at the Faculty of Civil Engineering at Brno University of Technology. The experiment was applied on two pillars made of historical brickwork. Those samples were being thoroughly analysed during the drying process and final outcomes were compared to already existing experiments on modern materials. The goal of this work is to find out, if the method of microwave drying is more suitable for described conditions and also to set such process of drying, which would provide the highest effectivity.

1. Introduction

In the long-term high humidity of building materials, which, in addition, degrades building materials and structures. Excessive humidity can cause volume changes as well as deterioration of mechanical and physical properties of building materials and structures. Other negative effects include a deterioration in the thermal properties of the objects. There are currently several ways to artificially reduce excess moisture in building structures. One of these options is microwave drying, which so far seems to be a relatively quick and cheap solution. The knowledge gained so far in the field of microwave drying will now be applied and developed for research on historical objects. With excessive dampness constructions and building materials can change in volume and their mechanical and physical properties can worsen. Among other negative effects is degradation of thermo-technical properties of given objects. Currently we know more options how to artificially reduce content of excessive dampness in building structures. One of these options is microwave desiccation, which currently appears as relatively fast and inexpensive solution. So far collected knowledge in the area of microwave desiccation will be now applied on and evolved in the research focused on historical buildings.



2. Overview of the problematic

Followed by a theoretical reason for the issue of increased humidity of building structures and its reduction by microwave drying. Following is theoretical introduction of the problematic of excessive dampness of building structures and its reduction using microwave desiccation.

2.1. Water and moisture in building structures

In every building material there is a certain amount of free water, which we call equilibrium moisture content. Moisture enters the building materials already during their production, then it is practically incorporated into the building structures and is created by usage of already completed buildings as well. Each building has to be evaluated separately in terms of moisture, as many factors influence the final moisture of the structure. For historical buildings, it is especially important to evaluate all the input parameters and to suggest an optimal solution [1].

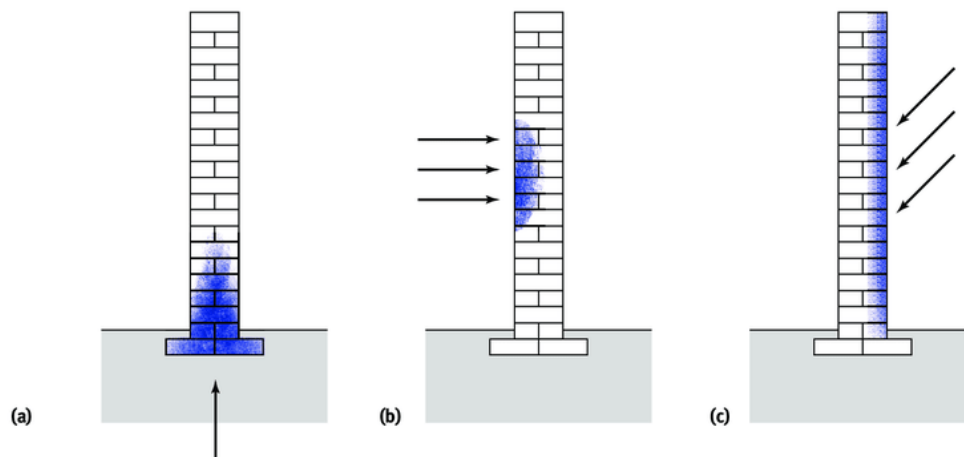


Figure 1. Water distribution in masonry depending on the moisture.

The amount of water in the porous material is expressed as volume or mass moisture. The definitions are based on the names given above, where the density is determined as the volume of water to the solid of the sample ratio, as shown in Equation (1), and mass moisture is defined as the weight of water to the solid of the sample ratio (2).

$$w_v = \frac{V_w}{V_d} \times 100, [\%] \quad (1)$$

where V_w is volume of free water in m^3 and V_d is volume of dry material in m^3 .

$$w_h = \frac{m_w - m_d}{m_d} \times 100, [\%] \quad (2)$$

where m_w is weight of wet material in kg and m_d is weight of dry material in kg.

2.2. Electromagnetic microwave radiation

Electromagnetic microwave radiation is in fact electromagnetic waves with a frequency in the range from 300 MHz to 300 GHz. In free space microwave radiation spreads from the source in the form of waves at the speed of light. The most often used frequency in construction is 2450 MHz [2].

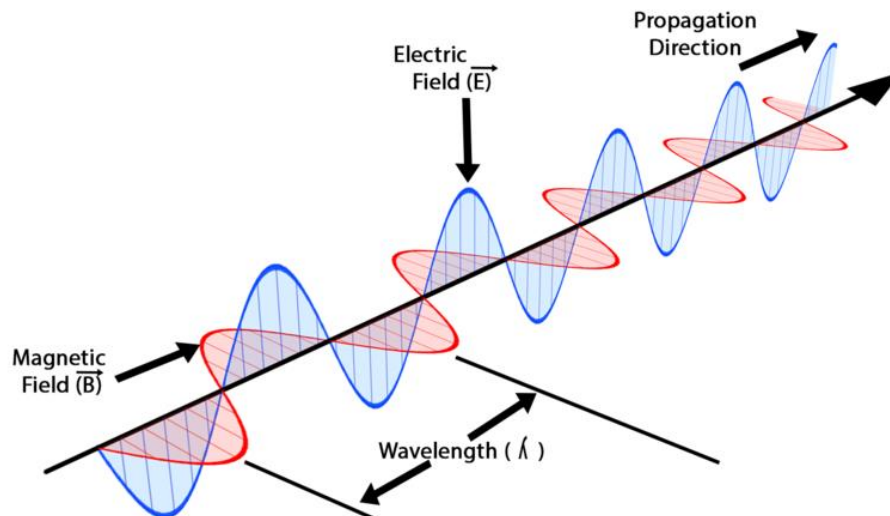


Figure 2. Electromagnetic waves.

2.3. Drying-out of building structures using microwave radiation

The use of microwave masonry desiccation usually requires synergy with other measures, since remediation is generally the summary of activities and measures that eliminate existing moisture, and also prevent the penetration of additional moisture. The principle of microwave drying-out is the ability to vibrate water molecules in the masonry mass and the subsequent generation of heat, which is created by their movement and friction, causes their conversion into water vapour. The water vapour thus converted is then only vented from the structure. The water temperature is higher than the temperature of the building material itself and it has been found that the heating increases from the centre of the material. The heated area then spreads so the moisture already removed allows the radiation to extend its effectiveness [3], [4].

3. Experimental measurement

This is one of the experiments carried out at the Faculty of Civil Engineering in Brno. The aim was to obtain input information on the reaction of historical masonry to microwave drying-out and to compare the results of measurements with already performed experiments on selected building materials.

3.1. Description of the experiment

The experiment was carried out on two sets of three pillars made of historical brickwork. These pillars were made of a brick tripod with age reaching 350 years. Walling up of the individual pillars was done on cement lime mortar. The samples were then left for 30 days in constant laboratory conditions. The first set of samples was prepared for drying-out using a microwave rod antenna by drilling holes in the pillars to fit the antenna. The diameter of the drill holes was set to 24 mm. The holes were designed so that the dried area was evenly distributed over the width of the test pillar. The second set of samples was prepared for drying-out using a microwave funnel antenna, such desiccated pillars do not need any special treatment. Initially, the samples thus prepared were weighed on digital scales and the approximate equilibrium initial humidity of each given sample was determined as well. Afterwards, these samples were left for one week in a soaking tub with water, where the water level reached height of approximately 150 mm. In the next phase the samples were removed from the water and weighed individually, so their moisture was determined by gravimetric method.

3.2. Microwave drying process

A 650 W microwave drying device was used for this experiment. Desiccation of samples was done in cycles. The length of each cycle was 20 minutes, with 17 minutes of drying, and the remaining 3 minutes was a break between drying to avoid overheating of the samples. Individual samples were weighed

during these pauses. In total, 12 drying cycles were performed on each sample. During the experiment three basic characteristics were observed - the weight of individual pillars, the weight loss of moisture at the time of drying and the weight moisture - using the gravimetric method.

4. Results and discussion

The experiment was carried out on two sets of samples, each set consisting of 3 pillars, and from the individual results from each set the average of measured values was calculated for better results' clarity. The weight loss of individual samples at the time of desiccation is shown below table 1. A set of samples dried using a microwave device with a plug-in antenna has a number 1 and a set of samples numbered 2 represents piles dried by a microwave device with a funnel antenna.

Table 1. Table of average weight loss of individual samples at the time of desiccation.

| Drying cycle | Marking of fittings | KC1 | KC2 |
|--------------|-----------------------|---------|---------|
| | Starting weight [g] | 15626.0 | 15791.0 |
| | Moistened pattern [g] | 17752.5 | 17826.0 |
| 1 | 20 | 17635.0 | 17710.5 |
| 2 | 40 | 17503.5 | 17590.0 |
| 3 | 60 | 17366.5 | 17465.0 |
| 4 | 80 | 17232.5 | 17336.0 |
| 5 | 100 | 17101.5 | 17203.0 |
| 6 | 120 | 16971.5 | 17067.5 |
| 7 | 140 | 16843.0 | 16931.0 |
| 8 | 160 | 16716.5 | 16798.5 |
| 9 | 180 | 16591.5 | 16664.5 |
| 10 | 200 | 16466.0 | 16528.0 |
| 11 | 220 | 16341.0 | 16398.5 |
| 12 | 240 | 16218.0 | 16267.5 |

Referring to above table, following figure 3 is shown, which is a diagram of the average weight loss on each set of samples at the time of drying.

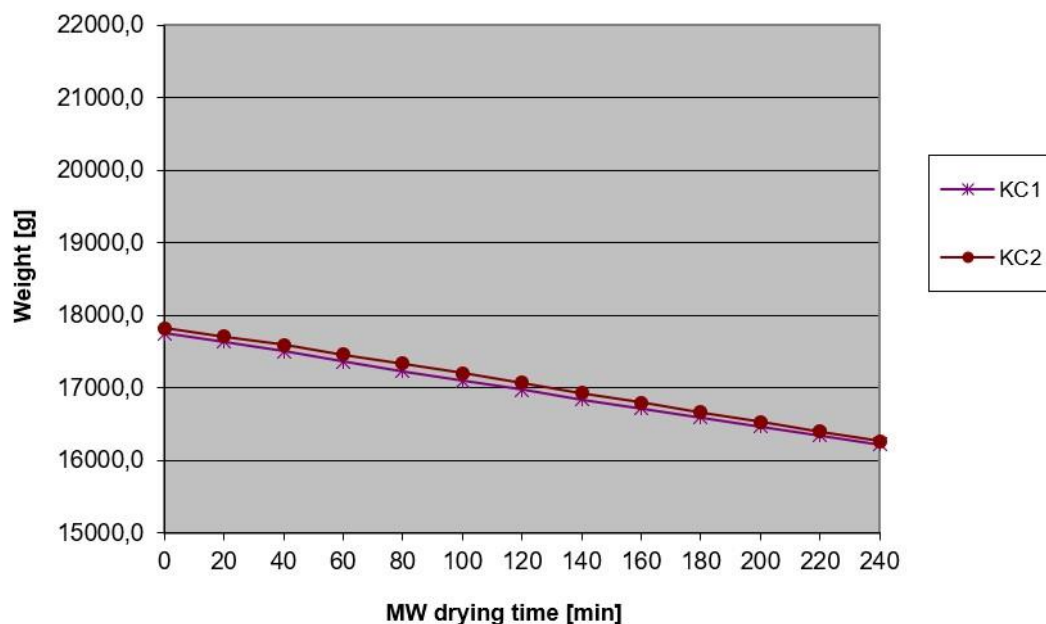


Figure 3. Graph of average weight loss of individual samples at the time of desiccation.

It can be seen from the figure 3 that the desiccation using the attachable funnel antenna, or the plug-in antenna was approximately the same, or to be exact - the moisture losses were comparable. We also monitored the weight loss of moisture at the time of drying on the individual samples and according to the type of drying device, that is using a plug-in antenna and a funnel antenna. This is shown in table 2.

Table 2. Table of average weight loss of moisture at the time of drying on the individual samples and according to the type of drying device.

| Drying cycle | Marking of fittings Amount of moisture [g] | KC1 2126.5 | KC2 2035.0 |
|--|---|---------------|---------------|
| 1 | 20 | 117.5 | 115.5 |
| 2 | 40 | 131.5 | 120.5 |
| 3 | 60 | 137.0 | 125.0 |
| 4 | 80 | 134.0 | 129.0 |
| 5 | 100 | 131.0 | 133.0 |
| 6 | 120 | 130.0 | 135.5 |
| 7 | 140 | 128.5 | 136.5 |
| 8 | 160 | 126.5 | 132.5 |
| 9 | 180 | 125.0 | 134.0 |
| 10 | 200 | 125.5 | 136.5 |
| 11 | 220 | 125.0 | 129.5 |
| 12 | 240 | 123.0 | 131.0 |
| Total weight loss [g] | | 1534.5 | 1558.5 |
| Residual moisture after MW drying [g] | | 592.0 | 476.5 |

Again, the above table 2 is supplemented with figure 4, which is a diagram of the weight loss of moisture in individual sets at the time of drying using two types of antennas.

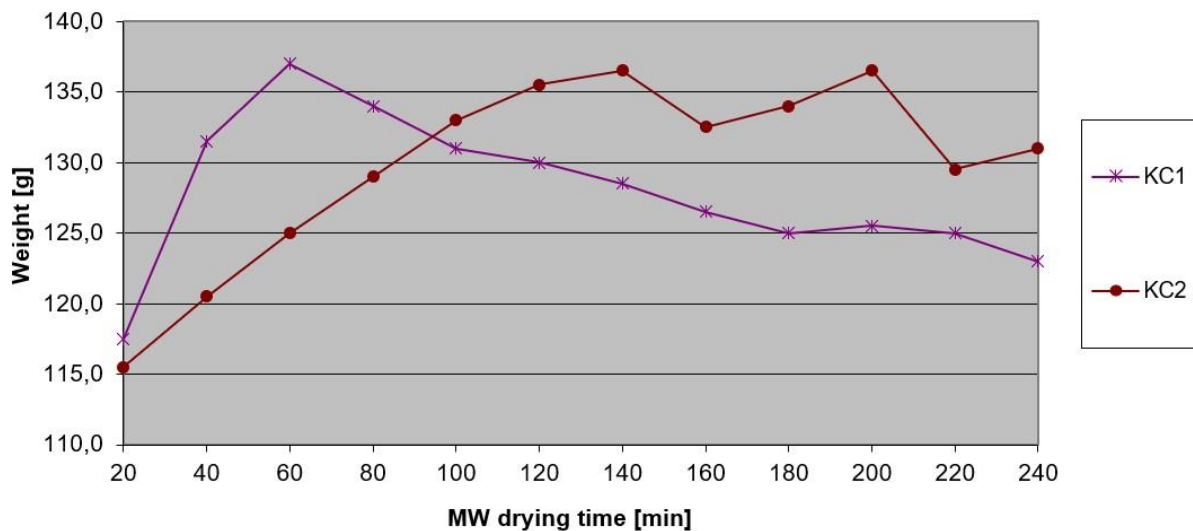


Figure 4. Graph of the weight loss of moisture in individual sets at the time of drying using two types of antennas.

Furthermore, the mass moisture of the samples was monitored, respectively its decrease during the drying time. The course of weight humidity decrease is shown in the following table 3. This table is also supplemented by the results of a similar experiment, which was performed on other types of masonry. These were samples of ceramic blocks of the Therm type with the KT designation and samples of air-entrained concrete blocks with the PT designation, while the numerical designation again indicates the

type of drying device. This way it is possible to monitor the drying results using two different devices on different types of masonry with different structure and age.

Table 3. The course of weight humidity decrease.

| Marking of fittings | KT1 | KT2 | PT1 | PT2 | KC1 | KC2 |
|------------------------------|------|------|------|------|------|------|
| Equilibrium humidity [%] | 2.5 | 2.3 | 3.8 | 4.1 | 2.9 | 2.7 |
| Moisture after dampening [%] | 24.3 | 24.5 | 52.9 | 54.5 | 16.1 | 15.4 |
| Moisture after drying [%] | 11.7 | 12.5 | 25.1 | 24.9 | 5.8 | 5.2 |
| Residual moisture [%] | 12.6 | 11.8 | 27.8 | 29.6 | 10.3 | 10.2 |

5. Conclusion

It was found that the weight loss was almost the same when either desiccated with the plug-in rod antenna or the attachable funnel antenna. According to table 3, this is true for all types of masonry, but for historical brick pillars, the weight loss of moisture was almost identical for both types of drying antennas used.

Generally, it can be said that the weight loss when drying-out with the plug-in rod antenna starts to rise more slowly, up to a certain maximum value of the weight loss. From this limit on, the weight loss again decreases slowly until the value of the moisture weight loss value fluctuates around zero. The course of the moisture loss during desiccation using a funnel antenna shows a steeper increase in the weight loss values, that are even during the drying time approximately constant or fluctuate around same value. According to table 3, the efficiency of microwave drying was best reflected in samples of historical full burnt clay bricks, so it can be concluded that historical masonry reacts well to microwave desiccation and this experiment can be the foundation for further research.

6. References

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