

Heating and Drying of Autoclaved Aerated Concrete Blocks for Defects of Buildings by Application of Microwave Radiation

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Abstract. Experiments of heating and drying of autoclaved aerated concrete blocks were divided into several areas, in which the depth of heating in relation to irradiation time intervals was checked. The impact of individual heating phases on the distribution of the irradiated field and comparison of drying rate at different lengths of the cycle “heating-cooling”. Theoretical potential of construction materials rehabilitation with the use of microwave radiation has been known for many years. This technique has been used by a number of companies in the construction practice. However, obtaining accurate information on suitable devices, procedures of their use, remedial action technique, positives and negatives and potential risks when using microwave radiation is very demanding since the findings obtained from practice are protected by individual companies for their own needs. It is understood that it is part of their “know-how”. The long-term research based on close cooperation between Civil Engineering Faculty, BUT Brno, and S. P. UNI company, tries to make accessible enough information on potential and suitable use of the microwave technology in practice, based on laboratory and in-situ experiments.

1. Introduction

Microwaves is a term given to a part of electromagnetic irradiation characterized by wavelength ranging from 1 cm to 1 m. Microwaves spread into space from a source in the form of waves. Worldwide, a frequency of 2.45 GHz with a corresponding wavelength of 12.2 cm has been designated for industrial purposes [1, 2].

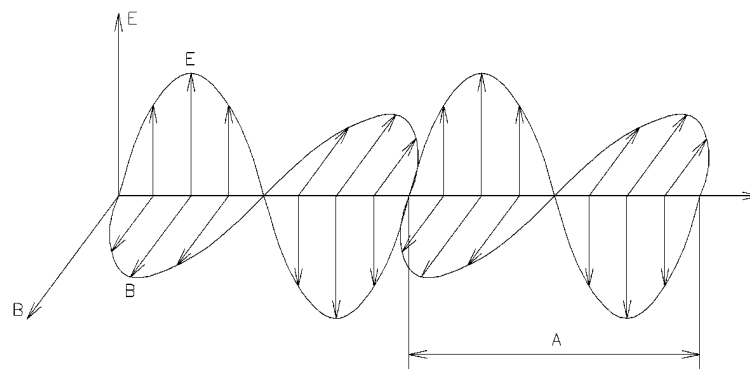


Figure 1. Electromagnetic wave with length λ – electric (E) and magnetic (B) components of the wave [3].



2. Drying by EMW irradiation

Despite having a bi-polar character, water molecules are electrically neutral. Therefore, in an electric field each and every water molecule is oriented by polarity (positive to negative and negative to positive), especially if the polarity alternates. This is precisely the case of microwave irradiation. The polarity of the electromagnetic field varies depending on frequency F , where the frequency can be higher than 10^9 times per second [1,2, 4].

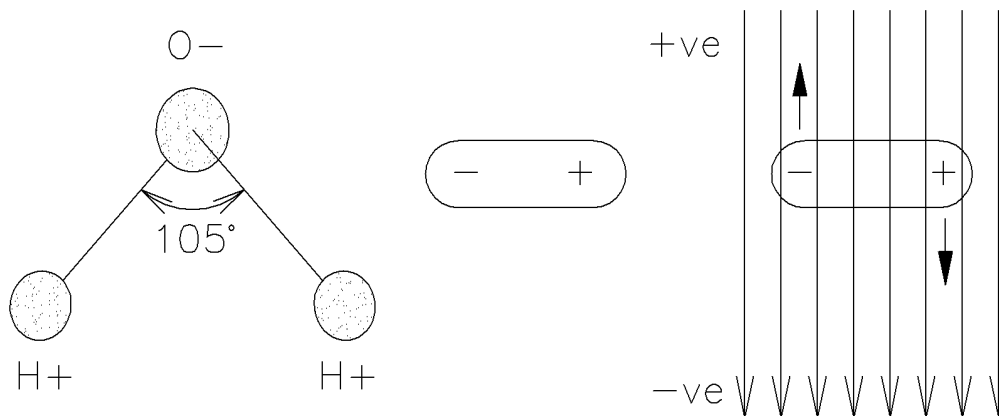


Figure 2. Water molecule and its orientation in electric field [6].

Heat is produced at high frequencies of radiation (i.e. oscillating vibration) and the subsequent change in orientation of molecules of loosely bound water. The thermal energy is produced by friction of molecules. This phenomenon is called polar rotation or polar friction [2]. In a simple manner it can be described as follows: the entry of microwaves into structures causes a rapid change in polarity of molecules of loosely bound water, causing their rapid movement in the material. Because of this movement particles themselves collide into each other, hence producing thermal energy. This process results in a conversion of water from liquid state into gaseous form, and its subsequent evaporation from the structure [2, 5].

3. Principle of drying variant

Two identical blocks with dimensions of 600 x 150 x 250 mm were used. The blocks were freely laid in a testing area of BUT Brno. After soaking the blocks were being dried. A different time interval of the heating-cooling cycle was selected for each block. However, total heating time was the same.

3.1. Course of experiment

Experiment procedure:

- weighing and marking of samples,
- weighing of samples with absorbed air humidity,
- immersion of blocks into a waterbath for 60 minutes,
- removal from water, 30-minute stabilization of absorbed moisture, packed in a foil for 22 hours,
- weighing of blocks after soaking,
- drying after time cycles,
- measurements of surface temperatures at the front and back side after heating cycles,
- another cycle of heating,
- measurements of surface temperatures after individual heating phases,
- weighing for 18 hours after the last heating phase [1, 2].



Figure 3. Weight of dry autoclaved aerated concrete sample V1, V2 before soaking.

3.2. Division of testing blocks

Block No. V1

- Soaked for 60 minutes in water, 60-minute stabilization of absorbed water, heating 4 x 15 minutes, a 15-minute break between heating cycles,

Block No. V2

- Soaked for 60 minutes in water, 60-minute stabilization of absorbed water, heating 2 x 30 minutes, a 15-minute break between heating cycles.

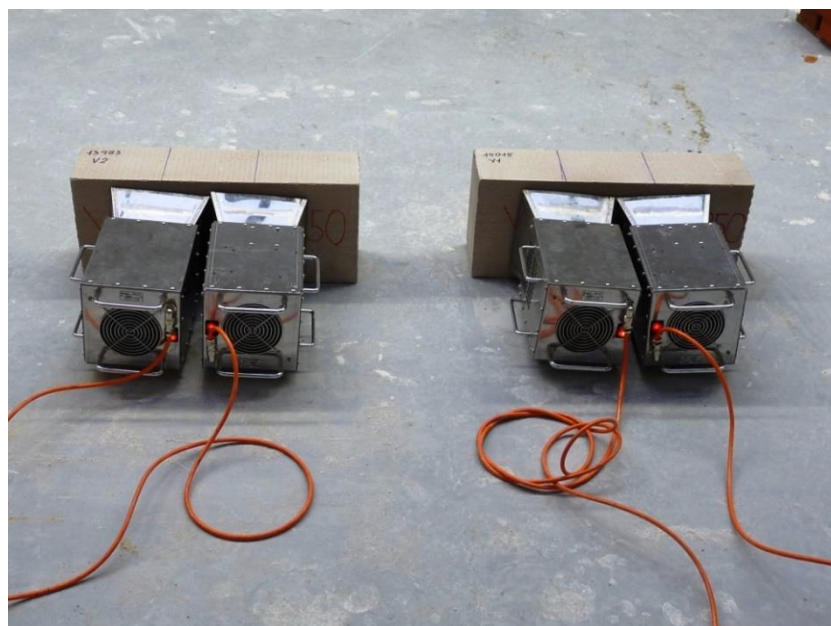


Figure 4. Heating of samples V1, V2 by microwave generators MG electronic MB.

The values of surface temperatures measured in autoclaved aerated concrete blocks are shown in Table 1 and Table 2. They were identical cross sections of blocks, which were each exposed to different irradiation times (4 x 15 minutes, 2 x 30 minutes). Surface temperatures were measured at the front as well as at the back sides of blocks.

3.3. Partial experiment results

Table 1. Temperatures of samples V1 after heating intervals.

| Block No. V1 | Heating No. 1 | Heating No. 2 | Heating No. 3 | Heating No. 4 |
|--------------|---------------|---------------|---------------|---------------|
| Front side | 80.9 °C | 83.5 °C | 91.9 °C | 92.3 °C |
| Back side | 32.1 °C | 50.5 °C | 59.4 °C | 71.4 °C |

Table 2. Temperatures of samples V2 after heating intervals.

| Block No. V2 | Heating No. 1 | Heating No. 2 |
|--------------|---------------|---------------|
| Front side | 83.1 °C | 88.8 °C |
| Back side | 38.4 °C | 61.1 °C |

Table 3 shows decrease in weights of autoclaved aerated concrete blocks in “dry” condition, after soaking, and after 18-hour stabilization after final heating cycles. The weight decrease is almost identical for both blocks. The irradiation of these blocks revealed that shorter times of irradiation with a higher number of repeated cycles is much more effective.

Table 3. Weight decrease of autoclaved aerated concrete blocks after different heating intervals.

| Block No. | Initial weight | Weight after soaking | Weight 18 hours after drying | Weight decrease |
|-----------|----------------|----------------------|------------------------------|-----------------|
| V1 | 12.510 g | 14.015 g | 12.717 g | 1.298 g |
| V2 | 12.512 g | 13.983 g | 12.837 g | 1.146 g |

Figure 5 graphically displays initial weights, weights after soaking, after stabilization, and total decrease in weight of autoclaved aerated concrete blocks. It is obvious that the measured values of both autoclaved aerated concrete blocks are comparable.

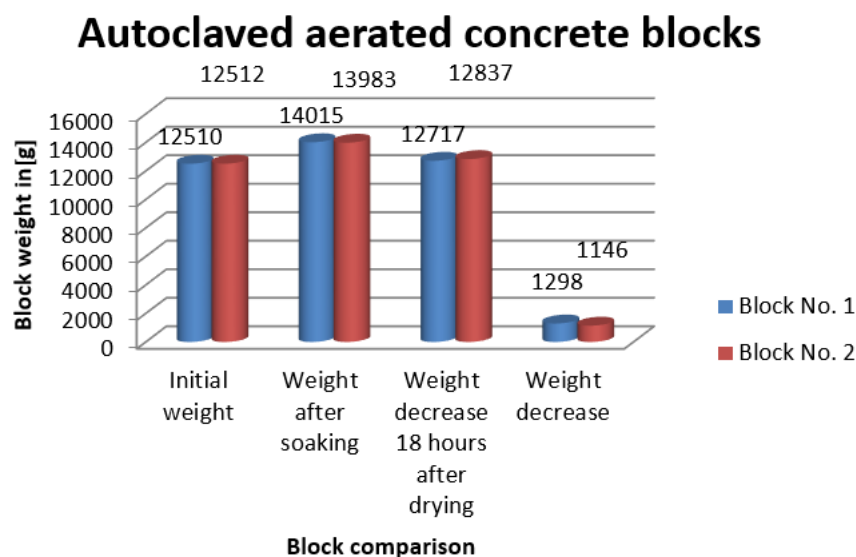


Figure 5. Illustrative block weight decreases after different heating intervals.

4. Experiment assessment

The experiment aimed to check the drying speed of autoclaved aerated concrete blocks in two different time cycles “heating-cooling”. Total time of heating was the same for both blocks – 60 minutes. In the first case the cycles were divided into 4x15 minutes, in the other into 2x30 minutes. The measurement of surface temperatures at the front and back side, which was performed straight after the end of each heating proved that higher temperatures were reached with sample V1 (at the same time of active heating) than with sample V2. Regarding weight, higher decrease was found with sample V1; both in absolute values as well as in terms of percentage. The factor that affects this is the second phase of the cooling cycle. In this phase intensive moisture evaporation occurs from the surface layers, and thus conditions for deeper penetration of microwave radiation is created. This would apply for drying of all similar construction materials [6-8].

5. Conclusion

When irradiating, heating and drying all materials that were used within individual experiments, the frequently published opinion that the irradiated material is heated in depth from the very beginning was not confirmed. Moreover, it would contradict basic physical laws. The penetration depth of microwaves through the material depends on its moisture and distribution of moisture in the whole cross section. In cases when higher and evenly distributed moisture is concerned, microwave energy absorption occurs by surface layers first. Only afterwards, when moisture from these layers is reduced, the microwaves penetrate deeper. Therefore, during longer, uninterrupted, irradiation of a single spot, an undesirable gradient may occur between the front part temperature and temperatures in different cross section depths which may thus lead to uneven drying of individual layers. Consequently, undesirable stress of the heated and dried material or structure may occur, and a risk of shape deformations, or even destruction, may appear [3, 4].

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References

- [1] J. Sobotka, and R. Smolka “The temperature distribution during the microwave drying of wooden elements for structural defects in buildings,” *MATEC Web of Conferences*, vol. 146, 03008, 2018.
- [2] D. Bečkovský, L. Vacková, T. Bečkovská, J. Sobotka, J. Pěňčík, and M. Lavický “Analysis of the diffusional properties of Peripheral walls of wooden houses during Emw radiation exposure,” *WOOD RESEARCH*, vol. 61, pp. 627-636, 2016.
- [3] J. Plachý, “The analysis of implementation options of transverse joints of bitumen sheets,” *MATEC Web of Conferences*, vol. 93, 02006, 2017.
- [4] R. Smolka, and J. Sobotka, “Application of Recycled Plastic in Flat Roofs,” *MATEC Web of Conferences*, vol. 146, 02009, 2018.
- [5] M. Novotný, K. Šuhajda, J. Sobotka, J. Gintar, E.S. Dová, M. Mádl and Z. Jiroušek, “Use of microwave radiation in building industry through application of wood element drying,” *WOOD RESEARCH*, vol. 59, issue 3, pp. 389-400, 2014.
- [6] J. Sobotka, and R. Kolář, “Drying of the Basement Spaces of the Faculty of Arts in Brno,” *Applied Mechanics and Materials*, vol. 861, pp.295-302, 2016.
- [7] M. Procházka, and J. Sobotka, “Spreading of temperature field caused by microwave radiation,” *Applied Mechanics and Materials*, vol. 824, pp.355-362, 2016.
- [8] J. Sobotka, and R. Smolka, “Use of EMW radiation in the building industry at defects in buildings,” *MATEC Web of Conferences*, vol. 93, 01008, 2017.