Experimental Measurements Carried out for the Transport of Humidity in Building Material

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## Abstract

The publication introduces the results of experimental measurements carried out for the transport of humidity in porous steady masses in non-stationary conditions to express the moisture profiles with the help of measuring apparatus working on the non-destructive model of electromagnetic microwave radiation. The aim is to verify the mentioned method of measurement for the description of moisture parameters of the building materials in practice.

## 1 Testing materials samples

We deal with the samples of materials, produced based on the waste products usage. The used samples are marked “R” concrete samples and “H” materials samples. Please check the picture no. 01. The development of such materials is based on the recycle materials (i.e. recycle concrete using the natural aggregate).

Pic. 1 Material samples developed at TSHD FAST VUT Brno – “R” concrete (left), “H” material (middle), “R 0” concrete (right) [4]

Material characteristic is porous structure as well as inert homogenous material. The homogenous material includes aggregate gradation in range 0 up to 8 mm. or possible in range 4 up to 8 mm when used porous gravel. The “H” material represents soft isolative mass with fibrous filling of specific gravity. The usage of the mentioned materials in building activities is based on the material characteristics and attributes. These items are subject for the following examination.

The experimental measurement of the moisture parameters is based on the observation of the liquid moisture transport. It allows us to realize moisture curves, needed for the calculation of the capillary conductivity coefficient using the non-destructive method. We can use measuring instrument built up by experiment. The test results were acquired from the basic samples, see the following tables 01, 02

| „R“ concrete material | | | | |
|---|---|---|---|---|
| Sample no. | Weight | Size | Bulk | Bulk weight |

| | [g] | [mm] | [m3] | [kg.m3] |
|---|---|---|---|---|
| 01 | 356 | 19x58x149 | 0,0001642 | 2168 |
| 02 | 353,2 | 19x58x149 | 0,0001642 | 2151 |
| 03 | 413,9 | 22x59x149 | 0,0001934 | 2140 |
| 04 | 355,7 | 19x59x149 | 0,0001670 | 2129 |
| 05 | 361,9 | 19x59x149 | 0,0001670 | 2167 |
| 06 | 358,7 | 19x59x149 | 0,0001670 | 2147 |
| (Average) | 366,56 | 19,5x59x149 | 0,0001714 | 2150 (2139) |

Table 1 Material samples marked “R” concrete basic parameters

| „H“ material | | | | |
|---|---|---|---|---|
| Sample no. | Weight [g] | Size [mm] | Bulk [m3] | Bulk weight [kg.m3] |
| 01 | 170,95 | 19x60x248 | 0,0002827 | 604,7 |
| 02 | 167,72 | 20x60x248 | 0,0002976 | 593,2 |
| 03 | 163,10 | 19x60x248 | 0,0003192 | 563,6 |
| 04 | 168,66 | 19x60x247 | 0,0002816 | 598,7 |
| 05 | 159,68 | 19x60x247 | 0,0002816 | 567 |
| 06 | 181,44 | 20x60x247 | 0,0002964 | 612,1 |
| (Average) | (168,59) | 19,33x60x247,5 | 0,0002932 | 589 (575) |

Table 2 Material samples marked “H” basic parameters

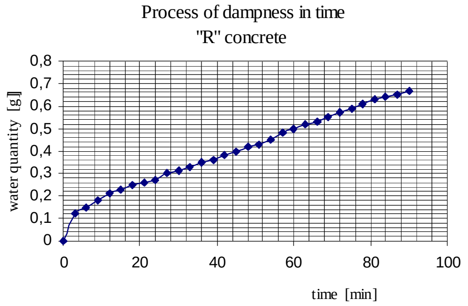
We performed the basic experimental measurement of the above mentioned samples. Our primary aim was to observe the transport of the moisture in order to find out the capillary conductivity coefficient. We used microwave method based on the set methodology. Such measurement is also useful for the testing of the measuring instrument built up by experiment. The measuring instrument is described above. It was developed at the Institute of Building Structures department, FAST VUT Brno.

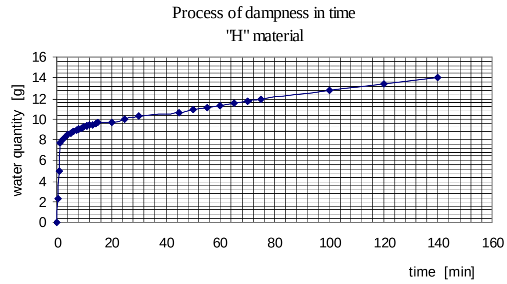
## 2 Moisture behavior

For the testing of the mentioned behavior was used measuring instrument built up by experiment. We tested time behavior of moisturize by observing water intake through samples imbibitions. The sample dimension was 60 x 20 mm. The process of imbibitions was done by close contact of lower sample’s surface with the liquid area. This behavior was tested in the time line (see the picture 02). As a source for the measurement were used objective samples of the new developed materials, marked as “R” concrete samples and “H” materials samples.

Pic. 2 Position of the “R” concrete, “H” materials and “R 0” concrete samples during moisture behavior monitoring

Graphical expression of the time line for the moisture can find on the picture 03. This is base to set right time period to calculate profile of the moisture front coordinates.




Pic. 3 “R” concrete, “H” materials and “R 0” concrete samples moisture time line

We can see clear discrepancy as for the absorbability of the tested materials ability (see the picture 03). This feature is specified by its structure. We will use this information to set right time period to calculate absorption of moisture curves during non-stationary absorption of moisture state.

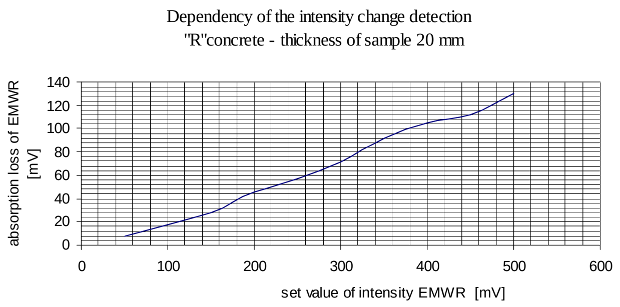
## 3 Dependency of EMWZ permeability based on the set intensity

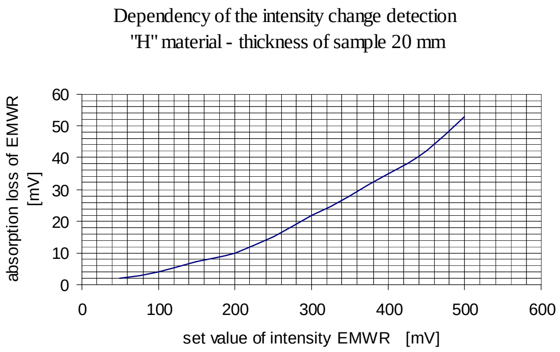
Dependency of intensity changes of material permeability on electromagnetic MW radiation and its graphical expression is base to set intensity of the radiation. We set function of intensity changes dependency according to the specific moisture as well as detect the moisture front profile. Picture 04 includes results of the above mentioned measurement of the MW radiation.

Table 3 Electromagnetic MW radiation absorption according the intensity level

| | „H“ material | „R“ concrete | „R 0“ |
|---|---|---|---|
| Set level [ mV] | EMW radiation intensity change [mV] from amount 450 mV | | |
| 500 | 482 | 151 | 402 |
| 450 | 430 | 112 | 387 |
| 400 | 393 | 105 | 363 |
| 350 | 322 | 92 | 333 |
| 300 | 291 | 71 | 276 |
| 250 | 239 | 57 | 228 |
| 200 | 192 | 45 | 195 |
| 150 | 145 | 28 | 150 |
| 100 | 96 | 17 | 95 |
| 50 | 46 | 8 | 47 |

Table 03 includes figures of the used MW radiation depending up the intensity set. There are mentioned also figures measured through “R 0” material samples. Therefore, we can compare the results from the different samples.



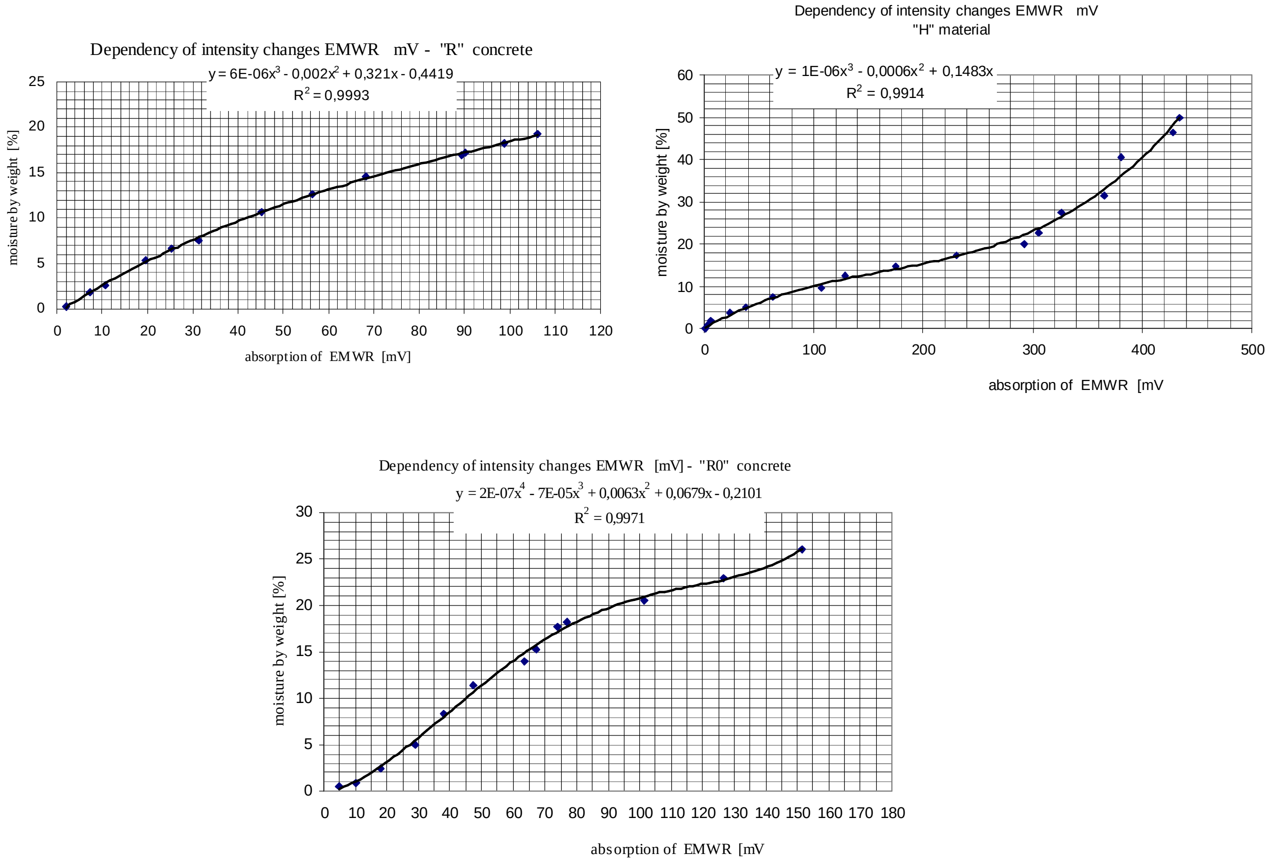




Pic. 4 Dependency of the intensity change detection according the level of electromagnetic MW radiation (dry state material) [4]

We can see the picture 04 (functional dependency of the tested sample materials) has linear course. This confirms presumption, mentioned in the part 1 (set of the capillary conductivity coefficient).

## 4 Function of intensity changes dependency EMWZ according to the specific moisture

We conducted the experiment using gravimetric survey. There were measured level of the radiation through the sample based on the specific samples’ moisture. The aim of the experiment was determination as for the function dependency of intensity changes on electromagnetic MW radiation, which affects mass moisture (picture 06).




Pic. 5 Graphical output - function of electromagnetic MW radiation (mV) intensity change dependency according to the specific moisture of the material sample “R” concrete, “H” material and “R 0” material [4]

The table 05 covers function of intensity changes (absorption) dependency according to the specific moisture of the tested materials.

Pic. 06 “R” concrete and “H” material during measurement to assess function dependency for EMW radiation (mV) intensity change according to the specific moisture.

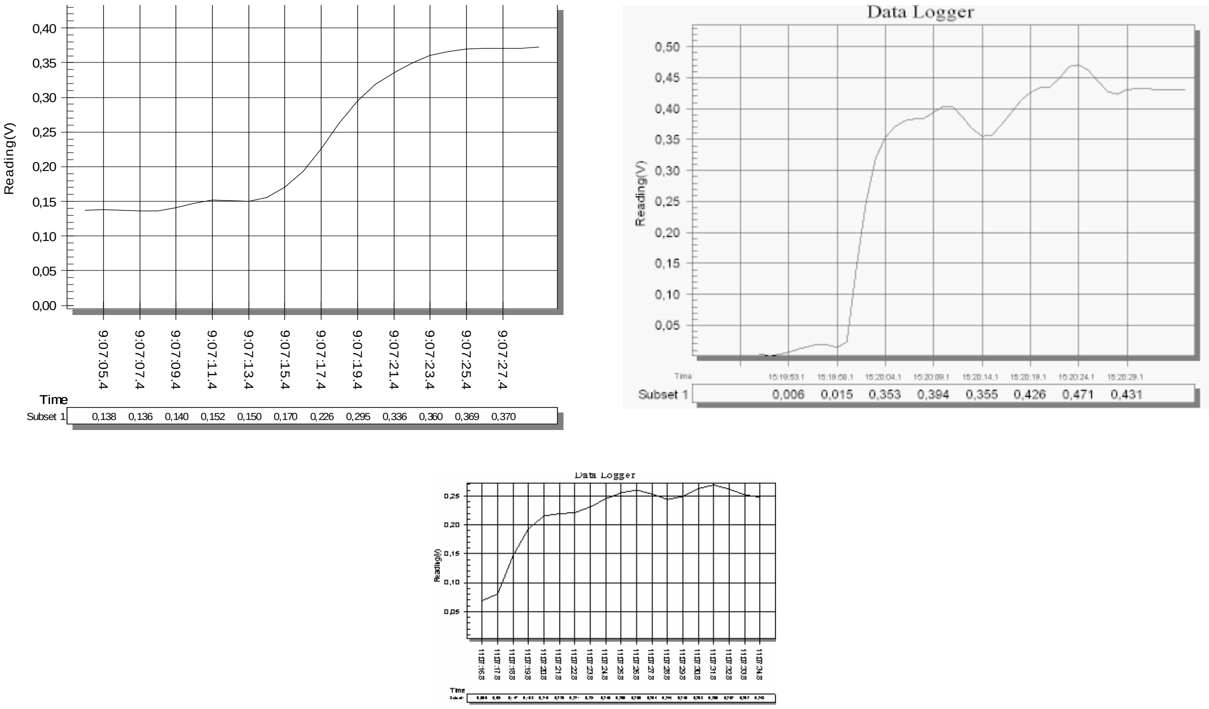
## 5 Moisture transport

There were used “R” concrete samples and “H” materials samples to record moisture front profile position (picture 01).
Sample size 150 x 19x 60 mm, specific gravity 2150 kg/m$^3$.

There was captured position of the moisture front profile in the particular time period thanks to the change of intensity changes on electromagnetic MW radiation. We used traversing of the waveguide through the tested material's sample (picture 09)

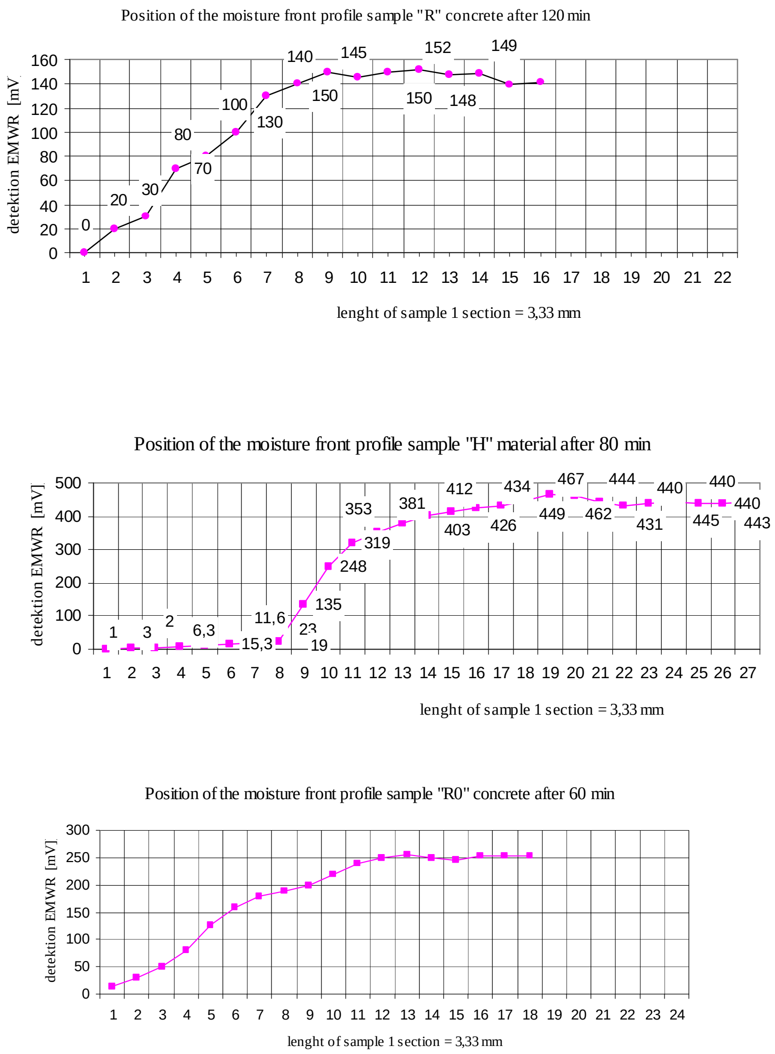
Picture 09 "R" concrete and "H" material samples during recording of the moisture front profile position

You can see the graphical output of the measurement at the picture no. 10. There is captured position of the moisture front profile in the particular time period from the start of the imbibitions. The process of imbibitions was done by close contact of lower sample's surface (placed in the measuring equipment) with the liquid area.
The electromagnetic MW radiation intensity changes according the either time dependency or speed of the waveguide shift is covered in the following graph.




Picture 10 Graphical output - "R" concrete and "H" material samples during non-stationary state for recording of the moisture front profile position

Data taken from the graph 10 are set as an input data to determine position of the moisture front profile during the sample moisturize of "H" material. The following step is the calculation of the obtained figures covering intensity EMWZ changes dependency according to the specific moisture during the waveguide shift through the observed material's sample using the software Linregrese Excel (see the picture 11).




Pic. 11 Time information from the sample length “R” concrete, “H” material and “R 0” concrete settlement

Based on the above mentioned measurements, we are able to express moisture curves (according to the methodology) as a base to calculate capillary conductivity coefficient.

# 6 Conclusion

The verification of the electromagnetic microwave radiation usage to detect moisture movement into the porous mass, using the measuring instrument built up by experiment, will give us the assumption for the next material characteristic information. Such non-destructive way to define moisture position allow us obtain continuous figures of the continual measurement. We can process the results of the measurement using the well-known mathematical operations.

We have to express the dependency between the two quantities by function. The required function should intersect the set pieces (measured figures). We have to take in the account that measured figures are influenced by the measurement error. Therefore, it is recommended to respect dependency characteristic of the two quantities in order for keep the approximation error as low as possible.

It is reasonable to use software Maple for the calculation from the measured figures. There are several advantages, i.e. user friendly interface, easy way to define functional dependency as well as displaying of the curves or numeric methods calculation to mention some of them.
There were measured tested samples of the material to obtain moisture parameters based on the theoretical hypothesis. We deal with the absorption of moisture. The results of the measurement should help us to define the capillary conductivity coefficient, one of the material specific quantities.

The output from the above mentioned when using the obtained results of the measurements for mathematical expression of the construction materials moisture characteristic using the EMWZ. The measured items were basic material's moisture parameters, tested sample moisture behavior, functional dependency of specific moisture, level of the moisture through the particular time intervals.

There are the following outputs from the work:

- application for the utilization of the measurement methodology to obtain moisture transport. This can be used also for the expression of the moisture curves for review of the secondary building raw materials.
- verification of the mathematical solution for the outputs of the moisture measurement during non-stationary state.
- the utilization of the integral method is considered in the current time. The integral method allows to give precision for the figures measured through the EMWZ.

Next planned steps:

a) Evaluation of the obtained building materials moisture characteristic. There must be taken account on the real requirements, functionality in the building construction and database construction.
b) Judgment of the most optimal mathematical method to be used in the real situation. Such method should allow us to process outputs from moisture characteristic of the materials using non-destructive measurements.
c) Detection of the material's moisture quantities dependency on the material structure as well as verification of the possibilities to assess volume moisture using EMWZ. As a source we use figures from microwave radiation absorption.

## Acknowledgement

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## Literature

1 Kutílek M.: *Porous material moisture,* SNTL, 1992
2 Mrlík F: *Builidng materials and construction moisture problems,* Alfa Bratislava, 1985.
3 Horák Z.Kupka F. *Technical universities physics,* SNTL /ALFA, Praha 1976
4 Škramlik J: *Report to Experimental program MSM0021630511, University of Technology, Faculty of Civil Engineering, Czech Republic, 2007*