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Experimental Analysis of Efficiency of Profiled Dimpled Membranes in Terms of Wall Moisture Reduction

HÁJKOVÁ Eva[1, a]

[1]Department of Building Structures, Faculty of Civil Engineering, Czech Technical University in Prague, Czech Republic

[a]eva.hajkova@fsv.cvut.cz

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Abstract. One of the major problems in the reconstruction of existing buildings is an additional protection of substructure against the negative effects associated with increased moisture levels in building structures. Currently, one of the most frequently rehabilitation method is the use of profiled dimpled membranes. The efficiency of this rehabilitation method has not yet been precisely determined. This rehabilitation system is mostly designed based on practical experience and the effect of the proposed measures on the rehabilitated structure may be insufficient. This paper analyses the efficiency of the dimpled membrane in terms of its ability to reduce moisture in the structure compared to a reference model and theoretical calculation models.

Introduction

One of the most important measures ensuring structural lifetime is adequate protection of substructure from negative effects associated with increased moisture in building structures. Increased moisture levels result in changes in mechanical and physical properties [1] (e.g., modulus of elasticity and strength), which may lead to reduced load carrying capacity of masonry structures [2]. There are many types of rehabilitation methods for adequate protection of buildings from effects of groundwater and water rising into walls from below the foundations [3]. One of the most common and most affordable methods is the use of profiled dimpled membranes.

A correct design of an appropriate rehabilitation method requires the efficiency of the proposed measure (including all of its weaknesses), reliability and impacts of marginal conditions on the resulting waterproofing effect. These rehabilitation systems are currently mostly designed based on practical experience. Their efficiency is usually only verified using results originating from field surveys. The disadvantage of these field surveys is the fact that moisture measurement can be done destructively (exactly) before the rehabilitation intervention, which is no longer possible once the rehabilitation measure is taken. Therefore, objective comparison of the resulting measured moisture levels before and after the rehabilitation intervention is impossible. For these reasons, experimental analysis using a model under laboratory conditions is beneficial. This paper analyses a structure that uses a profiled dimpled membrane as a rehabilitation measure against water and moisture. The objective of the experiment is to objectively determine the efficiency of the dimpled membrane in terms of its ability to reduce moisture in the structure compared to a reference model and theoretical calculation models (which can be fed with exact parameters). The advantage of these laboratory tests is the direct comparability under identical conditions (reference model vs. model with rehabilitation method applied) and the ability to carry out destructive tests (more exact measurement).

Profiled Dimpled Membrane

The principle of this rehabilitation method consists in prevention of direct contact of moist earth with the building structure. The dimples in the membrane produce an air gap between the structure and the adjacent earth. The system of air cavities enables ventilation (and evaporation) of water vapour from adjacent building structures [4]. The dimpled membrane has a number of uses in both new construction, where it is used primarily as drainage and mechanical protection for the foundation structure, and renovation projects, where it is used primarily for ventilation and moisture reduction of existing building structures. The use of dimpled membrane for solving the problem of rehabilitation of moist walls has the advantages of very quick installation and monetary savings. However, the actual effect of dimpled membrane on the rehabilitated structure has not been determined exactly.

Experimental Analysis

For the purposes of objective determination of the efficiency of dimpled membrane, we made two laboratory models on a scale of 1 : 2 (Fig. 1). These models simulated a segment of perimeter brick wall of a building with a cellar. Profiled dimpled membrane was applied to one of the models as a protection against water rising into the wall from below the foundation; the other model (reference) was left without any rehabilitation measures.

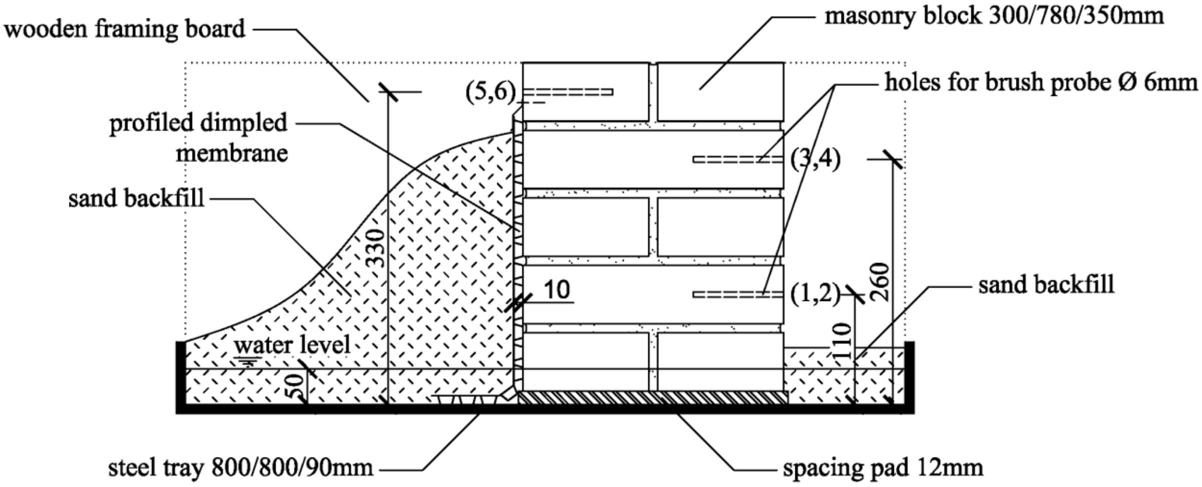

Fig. 1 Scheme of a laboratory model with profiled dimpled membrane in a scale of 1:2

The test models were bricked in steel trays, in which a constant water level was maintained throughout the experiment duration. The laboratory models were built of solid fired bricks with dimensions of 290 x 140 x 65 mm. Lime mortar was used as the binder. To achieve efficient saturation of the brickwork with water, the masonry blocks were built on spacing pads 12 mm high. The moisture measurements were made using a resistance moisture meter. That was why holes for the device brush electrodes 6 mm in diameter had to be drilled in the brickwork. Each masonry model contained 6 measuring points. Each measuring point consisted of two holes for electrodes. The location of measuring points can be seen in Figure 2. The brush probes up to 100 mm in depth were used for the measurement. The length of the probes was sufficient in this case. It is assumed that the highest moisture values due to capillary attraction are achieved at the centre of the brickwork [5]. To be able to compare the results obtained from the laboratory measurements and the results of the numerical simulation, the brickwork segment model had to comply with the parameters of the 2D problem. For this reason, the masonry blocks were wrapped in impermeable film on the lateral sides and additionally were covered with wooden boards. The boards were used as framing for the sand backfill, simulating the surrounding earth adjacent to the brickwork.

Fig. 2 Designation of measuring points on the laboratory model

Measuring Devices. The moisture measurements of the brickwork used an advanced Greisinger GMH 3810 electrical resistivity moisture meter. After the experiment was completed, the gravimetric method was employed to verify the results measured with the resistance device. Control samples were collected from the points where the measuring end of the brush probe had been located during the measurement.

Laboratory Testing. In the first phase of the experiment, the models were left in the laboratories for a period of 3 months, during which the moisture of the brickwork was not measured. In this period, the masonry structure was saturated with rising water. Moisture measurements of brickwork were made in each measuring point during the next ten months. The measuring interval was 1 month. The bulk moisture of masonry materials is also influenced by the relative humidity of the air in the area where they are located. Therefore, the relative air humidity and the air temperature were measured in the laboratory. Both models were in the same environment, exposed to identical conditions. The influence of the salts was not considered in this laboratory experiment. Salts may negatively affect the masonry surface structure in the course of evaporation of salt-containing water.

Results and Discussion. The efficiency of the dimpled membrane type used was determined based on the moisture readings. The efficiency was calculated based on differences between the moisture readings at individual points of both models and is expressed as a percentage reduction in the mass moisture in the brick block with the dimpled membrane compared to the reference model. The following charts show the values of the moisture readings w [% weight] at individual measuring points during a period of 10 months. Thus, the charts show the rate of moisture decrease in the individual measuring points (Fig. 3).

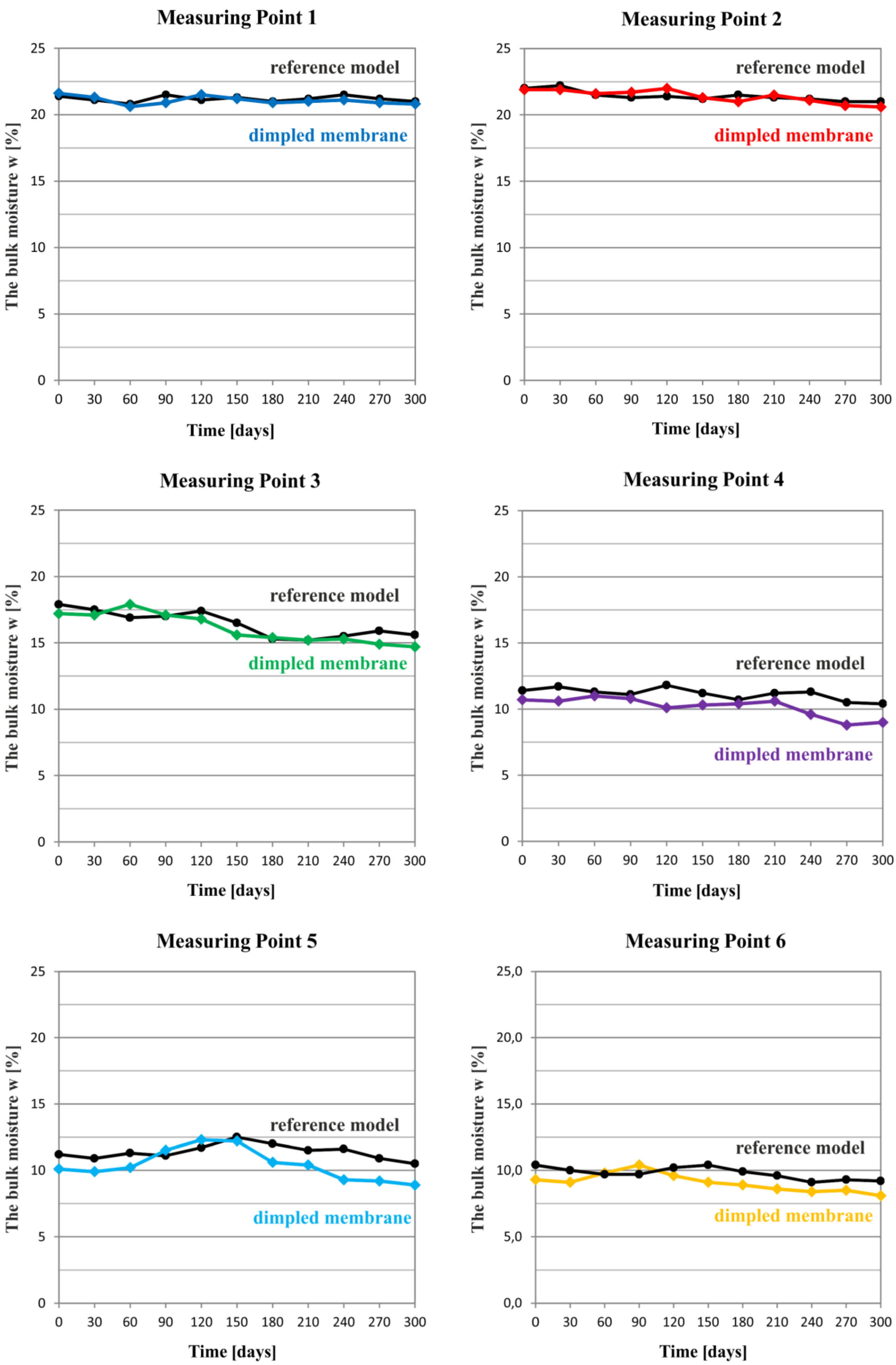

Fig. 3 The measured values of moisture in the individual measurement points

Based on the measured moisture values, it can be concluded that the efficiency of the dimpled membrane is very limited. Values of the moisture in the model with dimpled membrane are almost identical compared to the reference model. Depending on differences season, slight fluctuations of moisture values are evident (increase moisture values in the summer months). However, the bulk moisture of the brickwork does not decrease significantly.

The final bar charts summarize the average values of moisture measured w [% weight] at individual points for the reference model and the model with dimpled membrane. The first chart shows the initial moisture values in the masonry blocks after saturation with rising water for a period of 3 months (Fig. 4). The second chart shows the final values of moisture after 10 months from the beginning of measurement (Fig. 5). The results of laboratory testing showed that the moisture in the masonry had decreased considerably for both models due to the evaporation of moisture from the structure. The moisture in the wall with dimpled membrane was reduced by 8% on average compared to the reference model.

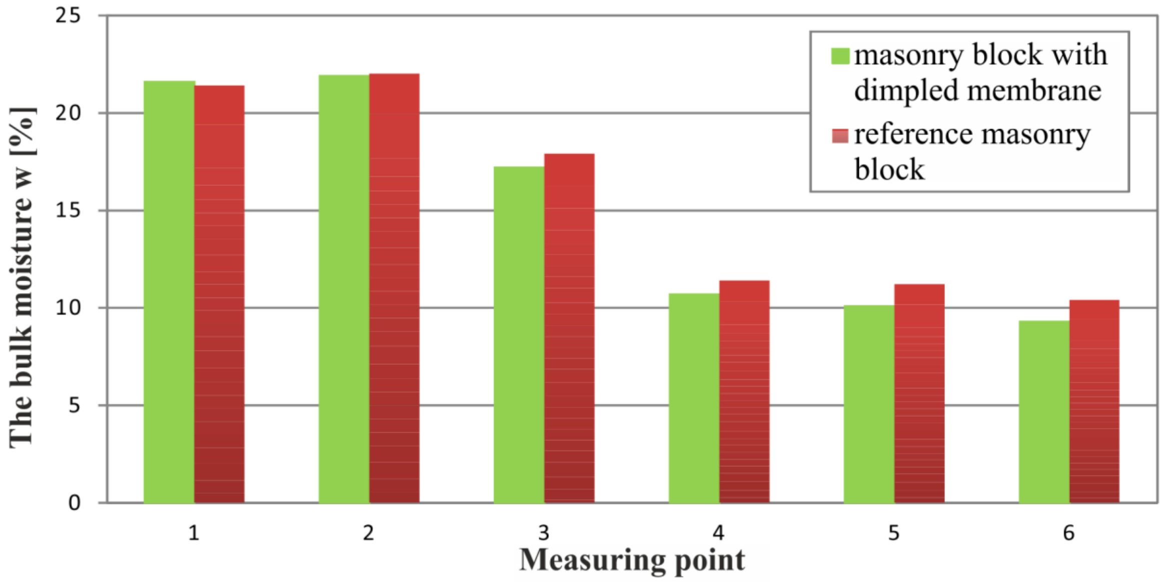

Fig. 4 The measured values of moisture at the beginning of measurement

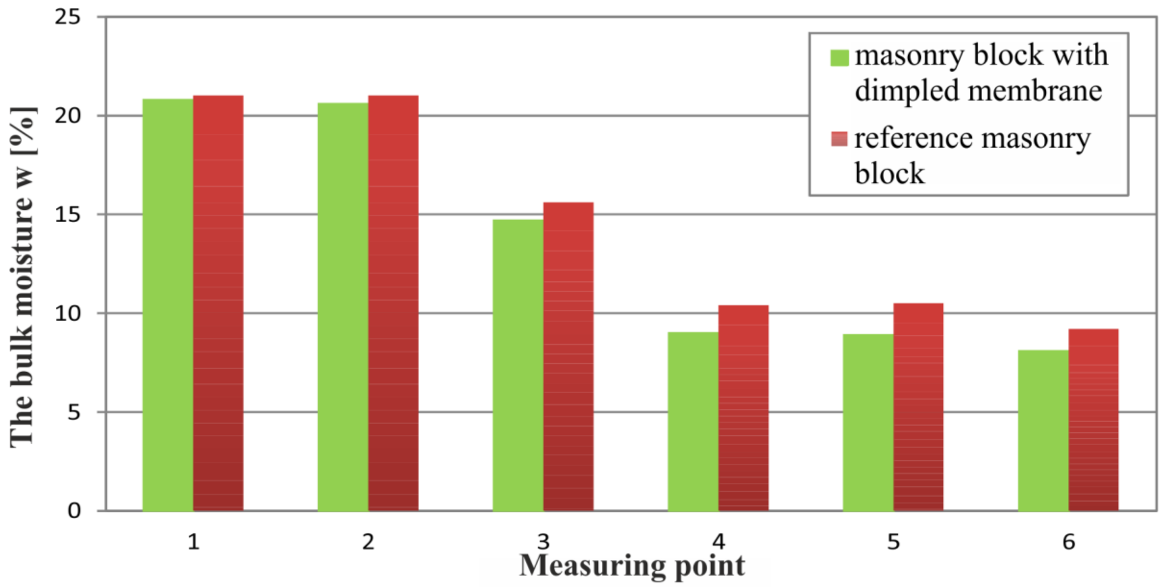

Fig. 5 The final values of moisture after 10 months from the beginning of measurement

Numerical Simulation

Simulation Program used and Validation. The experimental study was afterwards verified using a numerical simulation made in the WUFI 2D software. This software was developed at the Fraunhofer Institute for Building Physics in Germany based on the thesis of H. M. Künzel [6]. WUFI 2D enables to create a model of dynamic two-dimensional heat and moisture transfer in structures and materials depending on the boundary conditions [7]. It is also necessary to know the thermal and moisture-related properties of the materials used. In this case, we used the thermal and moisture-related material properties determined experimentally in the laboratory study. Boundary conditions entering into the computation as e.g. the test duration, the relative air humidity and air temperature in the laboratory were the same as in the laboratory experiment. The numerical simulation was made for a reference model and a model with dimpled membrane.

Simulation Results and Discussion. The results of the numerical simulation confirmed the results obtained from the laboratory measurements. Figure 6 shows the total content of water in the masonry block with dimpled membrane and in the reference masonry block at the end of the simulation. Compared to the reference model, the total content of water in the model with dimpled membrane was fractionally lower. We can therefore conclude that the numerical simulation confirmed the behavior of test blocks determined by experimental measurement.

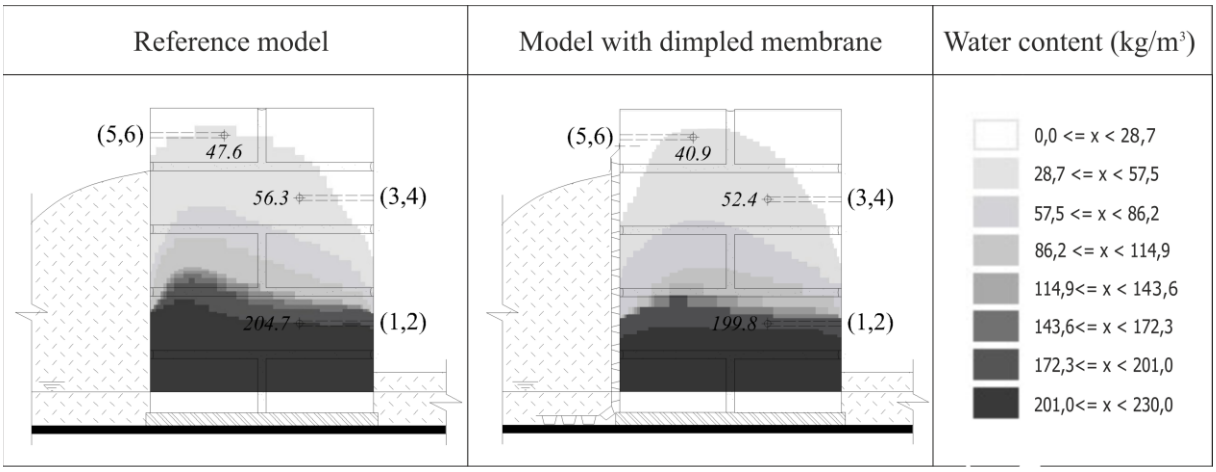

Fig. 6 The results of the numerical simulation – water content in reference model and model with dimpled membrane (created in WUFI 2D)

Conclusion

Based on the results of the laboratory tests, it can be concluded that the efficiency of this measure is very limited. According to data from the manufacturers' data sheets, dimpled membrane is suitable for removing moisture from building walls and permits air circulation as well. The laboratory experiment demonstrated that the moisture in the wall with dimpled membrane was reduced by 8% on average compared to the reference model. Obviously, no air circulation occurs without provision of air inflow and exhaust. Dimpled membrane is only suitable as protection against water entering the walls from the sides and water that flows down freely. As can be seen from the results, it is not effective against water rising into the wall from below the foundations by itself; it has to be accompanied by an additional rehabilitation measure. The results of the numerical simulation showed agreement with the data obtained from the laboratory measurements: like in the laboratory experiment, the total content of water in the brick block with the dimpled membrane was lower. The partial results of the experiment verification will be presented in this article and at a conference.

Acknowledgement

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