DOI: 10.5604/01.3001.0010.4586

NONDESTRUCTIVE METHOD TO DETERMINE MOISTURE AREA IN HISTORICAL BUILDING

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Abstract. *This paper presents a nondestructive method of brick wall dampness testing in real building structures. The proposed algorithm was used to determine the moisture of test brick walls on the specially models. The finite element method has been used to solve the forward problem. The algorithm is initialized by using one step methods and topological sensitivity analysis. There was constructed the forward model and solved the inverse for visualization of moisture inside objects.*

Keywords: Inverse Problem, Finite Element Method, Electrical Impedance Tomography, Wall Dampness

IMPLEMENTACJA ALGORYTMÓW NUMERYCZNYCH DO WYZNACZANIA ZAWILGOCONYCH OBSZARÓW W BUDYNKACH HISTORYCZNYCH

Streszczenie*. W artykule przedstawiono nieinwazyjną metodę badania wilgotności w konstrukcjach budowlanych. Rozwiązanie zostało wykorzystane do określenia wilgotności w zamodelowanych murach. Metoda elementów skończonych została wykorzystana do rozwiązania zagadnienia prostego. Proponowany algorytm jest inicjowany za pomocą metod jednokrokowych i topologiczną analizę wrażliwościową. Został skonstruowany model prosty zadania i rozwiązane zagadnienie odwrotne do wizualizacji wilgotności wewnątrz obiektów.*

Słowa kluczowe: zagadnienie odwrotne, metoda elementów skończonych, tomografia impedancyjna, zawilgocenie murów

Introduction

This paper presents the new method examining the brick wall dampness by the electrical tomography [2, 4–9, 12, 13]. There were implemented the new algorithms to identify unknown conductivities. The discussed technique can be applied to the solution of inverse problems in electrical impedance tomography. The purpose of the presented method is obtaining the better image reconstruction than gradient methods. One of the major causes of pathologies in historic buildings all over the world is the presence of moisture, particularly rising damp. The traditional techniques used to deal with this kind of problem show, to be ineffective, justifying the need to find a new approach [3, 10]. Moisture transfer in walls of an old buildings, which are in direct contact with the soil, leads to a migration.

The forward problem solution consists in determining potential distribution inside the region Ω under given boundary conditions and full information about region under consideration, that is in solving Laplace's equation:

$$\operatorname{div}(\boldsymbol{\gamma}\ \text{grad}\ \mathbf{u}) = 0 \tag{1}$$

where $\boldsymbol{\gamma}$ denotes conductivity, symbol $\mathbf{u}$ represents electrical potential.

The objective function is formed following:

$$\mathrm{F} = 0.5 \sum_{i=1}^{n} (\boldsymbol{U} - \boldsymbol{U}_m)^T (\boldsymbol{U} - \boldsymbol{U}_m) \tag{2}$$

where n is a projection angle (the number of measurement sequences: 13 measurements × 8 angle projections = 104 independent measurements), $\mathbf{U}_m$ – the measured voltage, $\mathbf{U}$ – the calculated voltage by solving the equation (1).

The object is a brick wall with damp rising from the ground (Fig. 1 and 2). The test results obtained by the nondestructive impedance tomography method are compared with the results obtained by numerical simulations. There were prepared two prototype measuring systems. First of them contains 16 electrodes for measuring damp brick wall on one side (Fig. 1). Second one is a full EIT system with 32 electrodes for test on both sides of wall (Fig. 2).

1. Models and Results

Geometrical models and image reconstruction were obtained by using the Gauss-Newton method (Fig. 3 and 4). Figure 5 shows exemplary numerical reconstruction of moisture in the damp wall with different values of the noise. Figure 6 shows the image reconstruction obtained by the Gauss Newton one step method with real data: (a) the original measurement object, (b) the reconstructed object with 16 electrodes on one side of the wall, (c) the reconstructed object with 16 electrodes on both sides of the wall. The reason these measurements was the inappropriate selection of the supply voltage frequency (50 kHz). The most accurate results can be obtained for frequency around 1kHz as it shown in Figure 7 (the highest voltage potential on the surface electrodes).

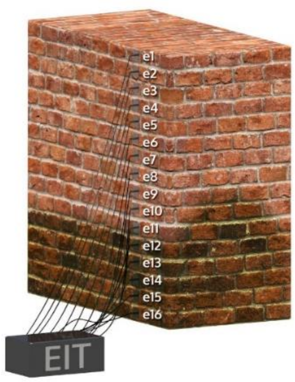


Fig. 1. Measurement EIT systems with 16 electrodes on the damp brick wall

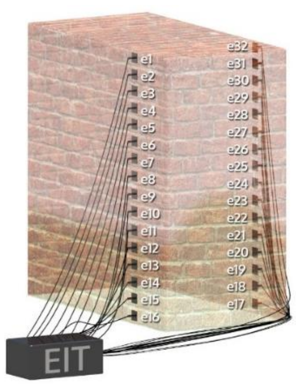


Fig. 2. Measurement EIT systems with 32 electrodes on the damp brick wall

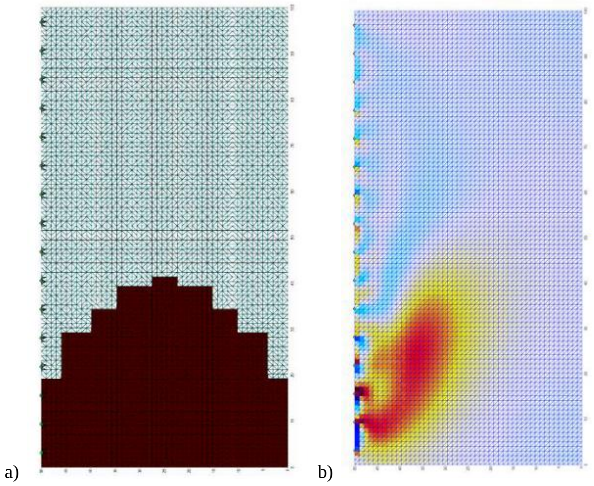


Fig. 3. Geometrical model and image reconstruction of the investigated dumped wall with (a) 16 and (b) 32 electrodes

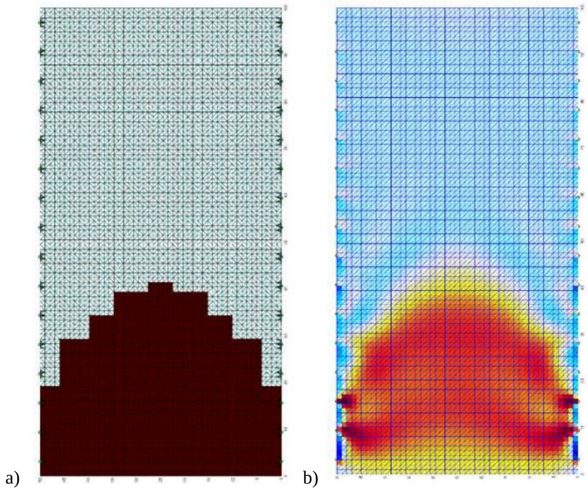


Fig. 4. Geometrical model and image reconstruction of the investigated dumped wall with (a) 16 and (b) 32 electrodes

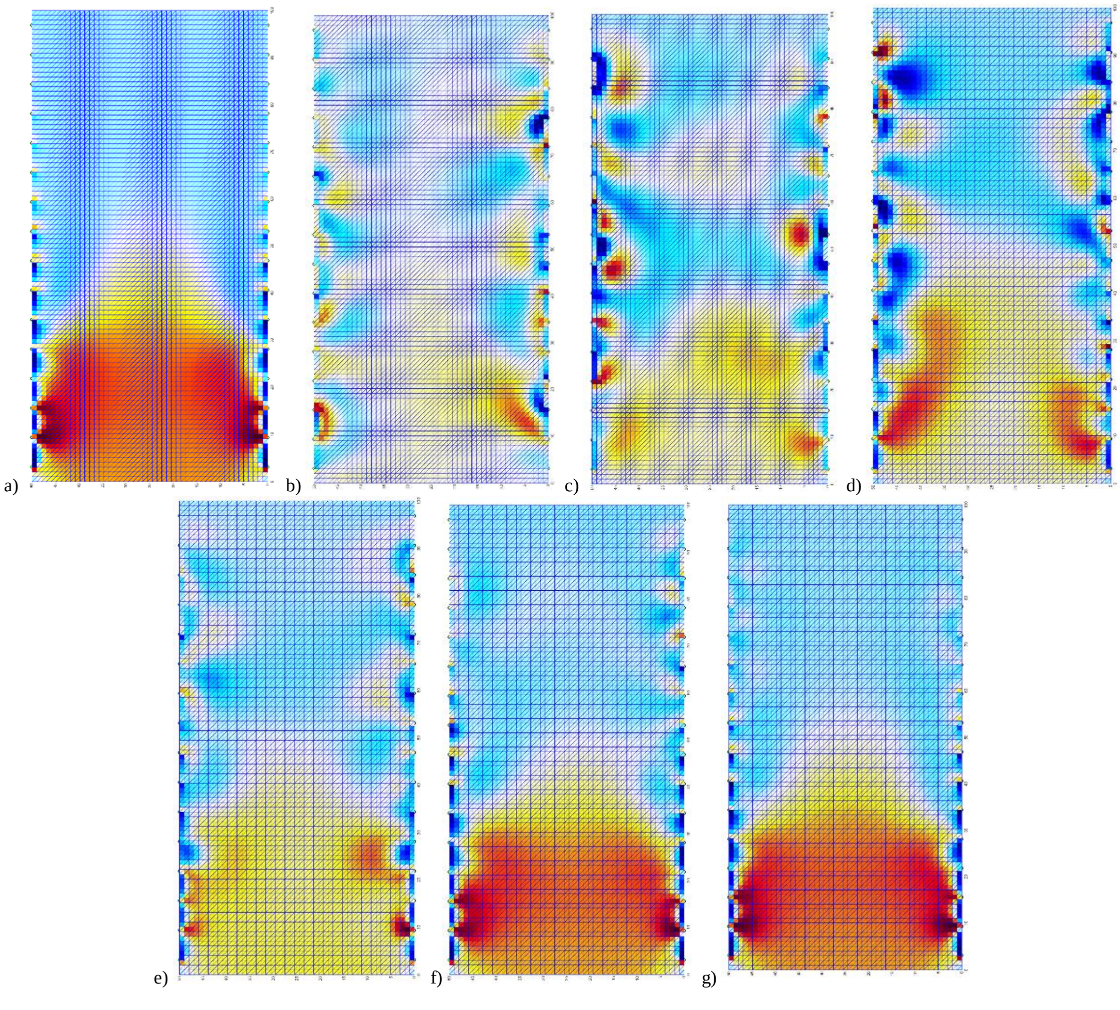


Fig. 5. Numerical reconstruction of moisture in the damp wall with different values of the noise: a) without noise, b) 6 dB, c) 9 dB, d) 12 dB, e) 20 dB, f) 24 dB, g) 30 dB

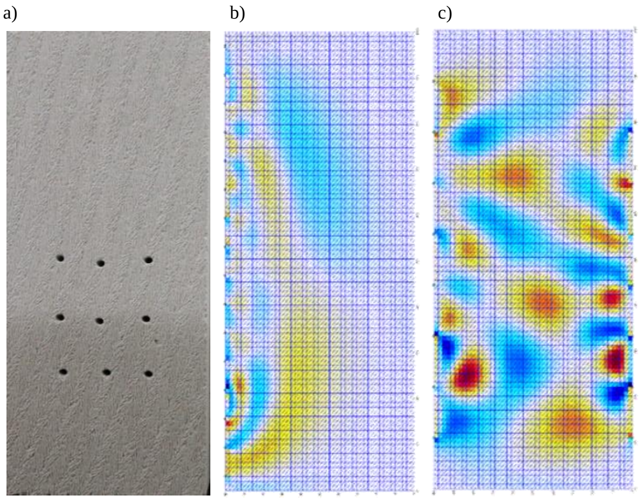


Fig. 6. The image reconstruction obtained by the Gauss Newton one step method: (a) the original measurement object, (b) the reconstructed object with 16 electrodes on one side of the wall, (c) the reconstructed object with 16 electrodes on both sides of the wall

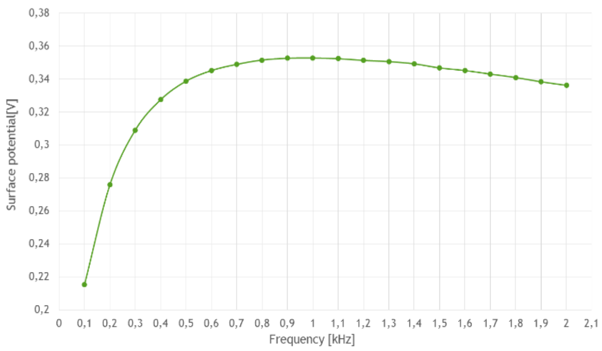


Fig. 7. Voltage level on surface electrodes in dependence of supply voltage frequency

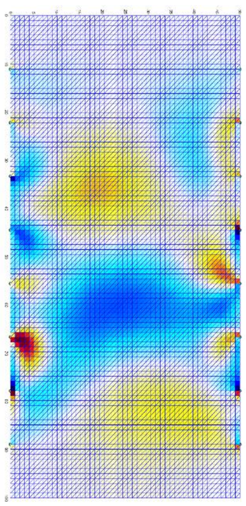


Fig. 8. The image reconstruction obtained by the Gauss Newton one step method - the reconstructed object with 16 electrodes on both sides of the wall (frequency 1kHz)

After finding the most suitable power supply voltage frequency (1 kHz) we repeated measurements with electrodes on both sides of the airbrick. The results were beater then lower frequency, but still unsatisfactory and differ from simulation. Figure 8 shows the image reconstruction obtained by the Gauss-Newton one step method.

Figure 9 shows two exemplary models with square electrodes place on both sides and different number of elements. Distribution of equipotential lines for the first couple of measurement was shown in Figure 10. The model of the wall with the inserted one object and image reconstruction was presented in Figure 11.

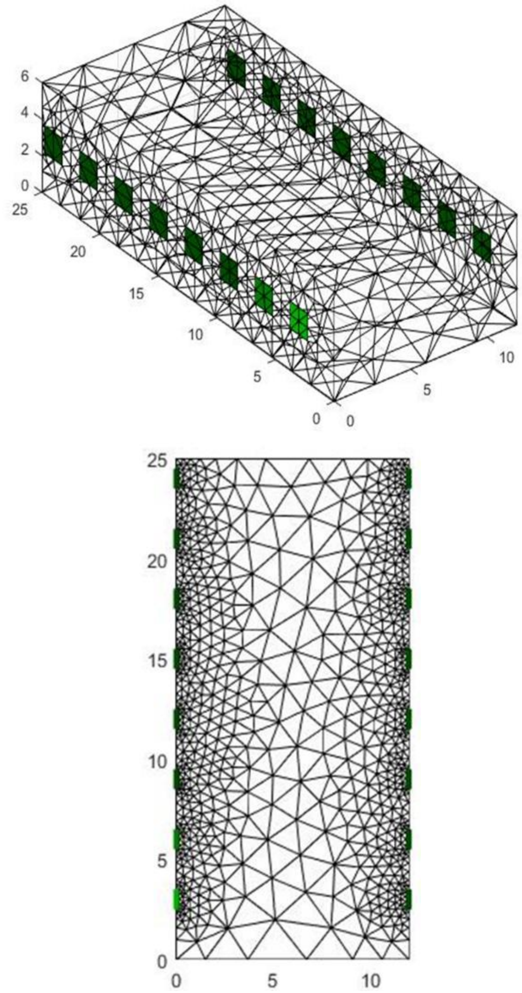


Fig. 9. Geometrical models of the investigated dumped wall with square electrodes

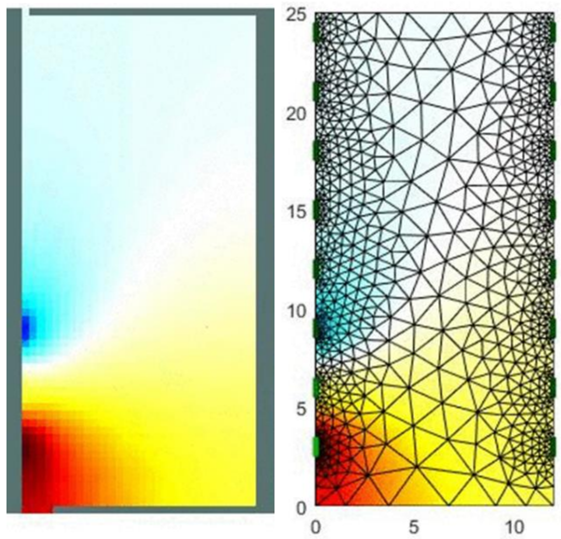
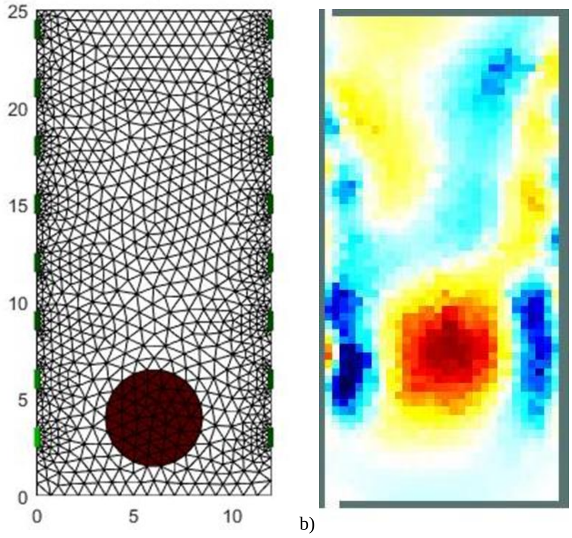


Fig. 10. Distribution of equipotential lines for the first couple of measurement

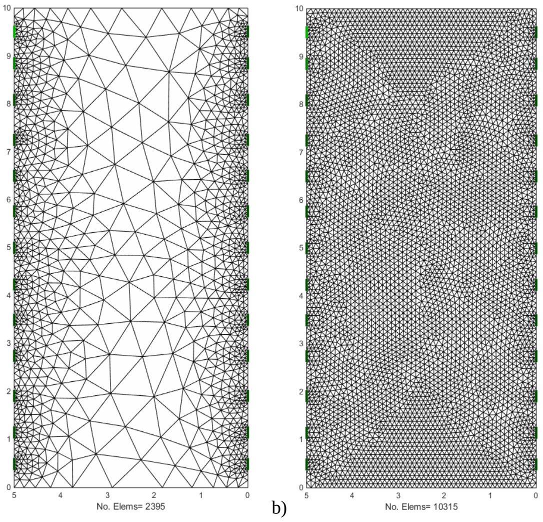
The next step to improve quality of the reconstruction there was generated more complex model with larger number of elements and electrodes on both sides of damps wall [1, 11]. Figure 12 shows two exemplary models with 26 electrodes place on both sides and different number of elements.

New models with larger number of electrodes provided us to beater reconstruction results. Contribution of moisture in damp wall both brick and air brick seems to be more complex in compared to the results obtained from than the simulations. Figure 13 shows image reconstruction obtained by the Gauss-Newton one step method from the original measurement object with 26 electrodes. It is clear that more measurements should be taken and new algorithms should be prepared for determine moisture areas in damps walls.



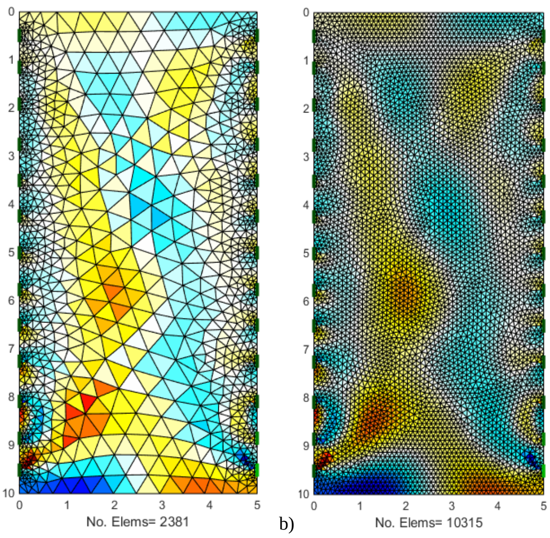
a) b)

Fig. 11. The model of the wall with the inserted one object: a) model, b) reconstruction



a) b)

Fig. 12. Geometrical models of the investigated dumped wall with 23 electrodes and: (a) 2395 and (b) 10315 elements



a) b)

Fig. 13. The image reconstruction obtained in EIDORS by the Gauss Newton one step method from the original measurement object with 26 electrodes: (a) 2395 and (b) 10315 elements

2. Conclusion

The nondestructive method of the brick wall dampness was tested by electrical impedance tomography. The proposed algorithm was used to determine the moisture of the test wall on a specially built model. Numerical methods were based on the gradient techniques. An efficient algorithm for solving the forward and inverse problems would also improve a lot of the numerical performances of the proposed methods. The presented algorithms have been applied successfully in the reconstruction of measured data of the model wall. These approaches based on sensitivity approach include the area design of the elastic interface. There are used the one step methods and iterative algorithms base on Gauss-Newton model where the examined objects there were detected.

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otrzymano/received: 20.09.2016 *przyjęto do druku/accepted: 15.02.2017*