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ACOUSTIC EMISSION IN MOISTENED BRICKS AND WOOD

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Initial investigations were carried out concerning an occurrence of acoustic emission in different kinds of bricks and woods under moistening. The results are presented and discussed of these investigations and possibilities of their practical applications for finding out water leakages in places difficult of access in buildings made of bricks and wood.

1. Introduction

Successful results of the experiments, which were carried out in the years from 1987 to 1990, indicated practical possibilities of applications of acoustic emission (AE) caused by water permeation into concrete. It has induced an interest in this kind of investigations for other materials used in building industry, such as bricks and wood.

2. Measurements of AE parameters for the samples of moistened bricks

2.1. Procedure of measurements

For experiments, 5 specimens (without cracks) of each kind of the following types of bricks were chosen:

common cavity brick
common solid brick
cement solid white brick
clinker solid brick

Each specimen was placed on the corrugated bottom of a laboratory dish in this manner that the largest surface of the brick was in contact with the bottom. This dish was supplied with water (0.25 l/h), which had been de-aerated. Owing to the corrugated bottom, water was able to contact with the almost whole lower surface of the brick and permeate from the brick bottom. The accelometer which was the receiver of AE signals was glued to the upper surface of the brick. Few minutes before turning the water supply on, the measurement equipment was switched on and the natural level of AE was measured for the tested brick. According to that, the sensitivity level of the equipment was adjusted to eliminate unnecessary signals. Subsequently, after turning the water supply on, the densities of events N_e and energy E_s in 10-second intervals were measured during period of time longer than one hour and recorded by *Y-t* plotter. Every ten minutes, the fundamental frequency f_p of received signals of AE was also measured (at random).

To check whether the phenomenon of AE occurs in the moistened bricks some samples were immersed in 10 mm layer of water (the water supply was turned off) during 24 hours. After that, the measurements of $\dot{N}_e$, E_s and f_p were continued.

Repeatability of this phenomenon was also tested, by measurements of the same AE parameters as previously, for the bricks that were totally dried after first experiment and subsequently again exposed to the influence of water.

To carry out the above mentioned measurements, the setup, which is schematically presented in Fig. 1, was applied *1* denotes the accelometer KD32 made in GDR, *2*— the preamplifier of the AE signals type EA 233-5, Unipan, *3* — the band amplifier 232 B, Unipan, *4* — the apparatus (own construction) for measurements of $\dot{N}_e$ and E_s, *5* — the analog plotter *Y-t* B72BP, made in Japan, *6* — digital oscilloscope 2230, Tektronix, *7*— the sample of tested material.

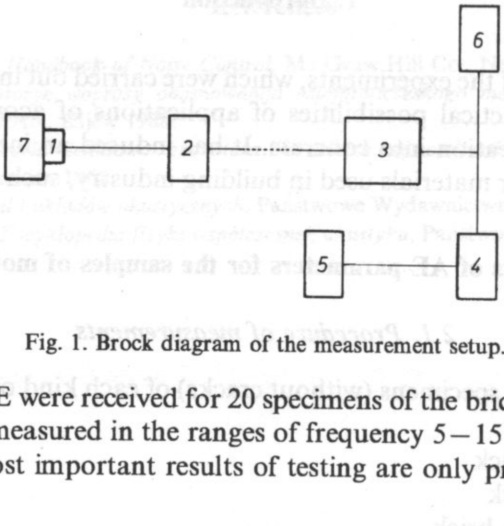

Fig. 1. Brock diagram of the measurement setup.

The signals of AE were received for 20 specimens of the bricks and the parameters of the signals were measured in the ranges of frequency 5 – 15 kHz and 15 – 50 khZ.

To avoid the most important results of testing are only presented.

2.2. *Discussion of the measurement results*

In Figure 2 examples of the records of changes N_e and E_s are presented for the common cavity brick. They began after compensation the natural level of AE and were continued during about one hour after turning water supply on. The zero level of the record corresponds to the time of water flowing up to the tested sample. After that flowing up, AE appeared immediately. The AE parameters, N_e and E_s, increase with the icreasing contact surface between the sample and water increases due to the

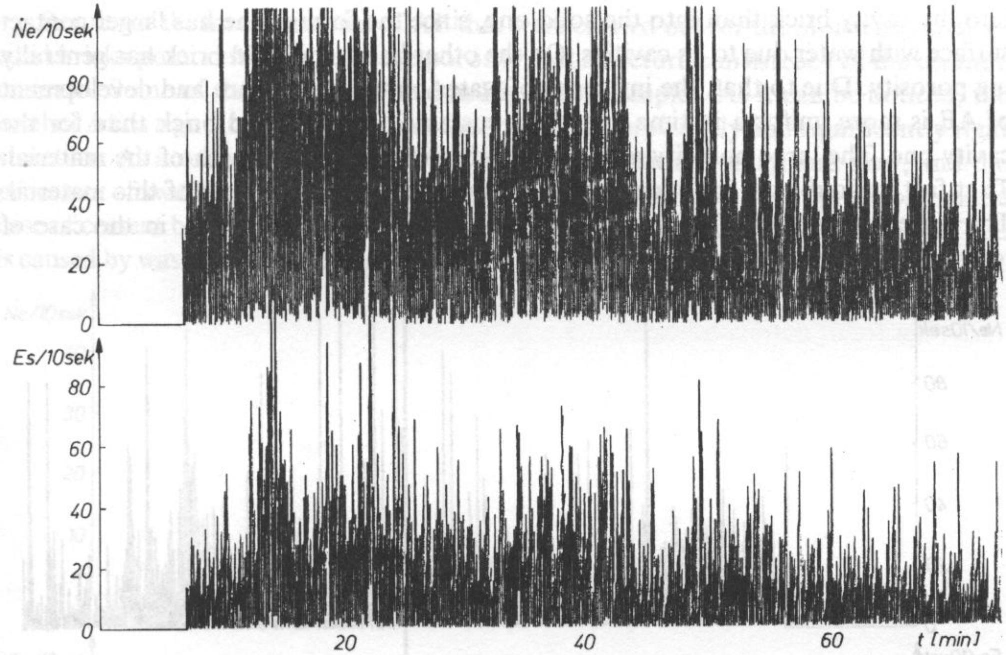

Fig. 2. Results of measurements of $\dot{N}_e$ and E_s in the moistened common cavity brick.

increase of water level. However, after about 60 minutes, the mean level of AE began to decrease slowly, but it remained large even after 24 hours, despite of turning water supply off. The randomly measured fundamental frequencies of AE signals were changed from about 5 kHz to about 75 kHz (see Fig. 3).

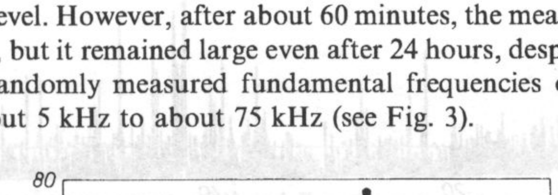

Fig. 3. Results of measurements of f_p in the moistened common cavity brick.

Exemplary results of measurements $\dot{N}_e$ and E_s are shown in Fig. 4 for the common solid bricks under moistening. In this case the mean level of AE is lower than that of the cavity brick but it decreases only slightly after 24 hours of the water influence. Most probably, the origin of this difference is the more intensive water permeation into the cavity brick than into the solid one, since the former one has larger contact surface with water due to its cavities. On the other hand, the solid brick has generally big porosity. Due to that, the influence of water on the occurrence and development of AE is more uniform in time and more sustained for the solid brick than for the cavity one. The large porosity also reduces the rigidity and strength of the material. That fact undoubtedly influences on the course of sweeling process of this material. The large fluctuation of values of the AE parameters confirm that, in the case of longer moistening in particular.

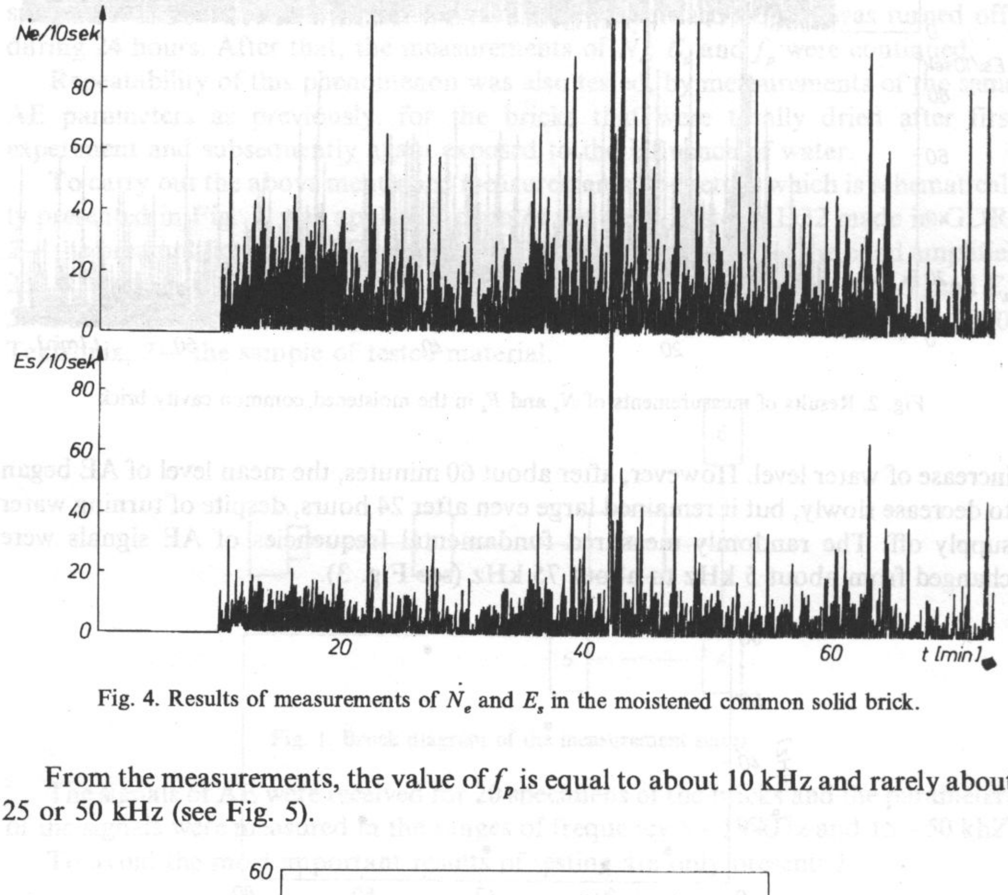

Fig. 4. Results of measurements of $\dot{N}_e$ and E_s in the moistened common solid brick.

From the measurements, the value of f_p is equal to about 10 kHz and rarely about 25 or 50 kHz (see Fig. 5).

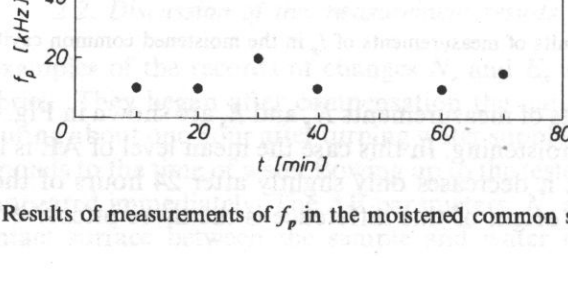

Fig. 5. Results of measurements of f_p in the moistened common solid brick.

Results of the measurements of AE that were carried out for the moistened cement solid bricks point out the role of the porosity and structure consistency of the ceramic material. Some of them are presented in Fig. 6 as examples. As it can be noticed, the level of AE is significantly lower than that measured previously and significantly rigid structure. As a consequence of that, the water permeation is small and slow, and the processes of swelling and cracking of the material are impeded. Most probably, in the case of cement bricks, the initial and momentary, but rapid increase of the level of AE is caused by washing out a cement dust from the pores near the surface of this brick [3].

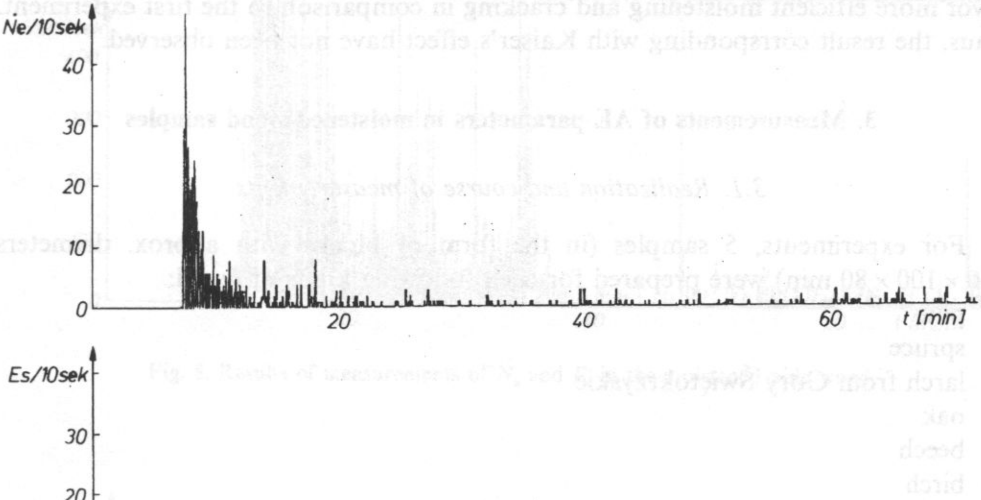

Fig. 6. Results of measurements of N_e and E_s in the moistened cement solid brick.

Changes of the fundamental frequency f_p of the AE signals, received for the cement brick, are shown in Fig. 7. Domination of higher frequencies in the end of experiment informs us about the formation of the significantly smaller cracks of the

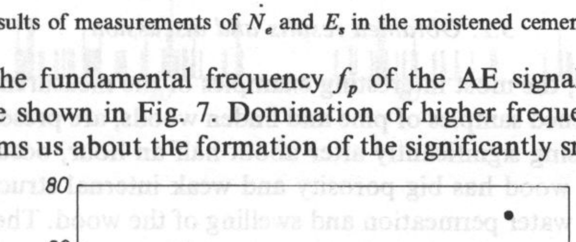

Fig. 5. Results of measurements of f_p in the moistened cement solid brick.

material in this period than the first stage of moistening. It is caused undoubtedly by the slow water permeation, and the large rigidity and structure consistency of this brick. All of them result in the microcracks appeared after 40–50 minutes from the start of sweeling.

After drying the bricks used in the first experiment, their repeated moistening produces higher level of AE than previously [3]. This increase of AE level, particularly large for the solid bricks, is caused by the changes destruction in the material structure, the destruction being caused by the first swell. These structure changes favor more efficient moistening and cracking in comparison to the first experiment. Thus, the result corrsponding with Kaiser's effect have not been observed.

3. Measurements of AE parameters in moistened wood samples

3.1. Realization and course of measurements

For experiments, 5 samples (in the form of blocks with approx. diameters 150 × 100 × 80 mm) were prepared for each following kinds of wood:

pine
spruce
larch from Góry Świętokrzyskie
oak
beech
birch
linden.

Range of the experiment, their realization and experimental equipment remained the same as those described in Section 2.1.

3.2. Obtained results and discussion

In Figs. 8 and 9, the most interesting examples of the measurement results of $\dot{N}_e$ and E_s in the moistened samples of pine and linden woods, are presented. The highest level of AE, decreasing significantly after about half an hour, occurred for the pine wood, because this wood has big porosity and weak internal structure. This causes rapid and intensive water permeation and swelling of the wood. The swelling process is two stage. The first stage is relatively short about 30 min. and contains the intensive swelling of the material in the beginning, with rapid decrease after complete water saturation of the wood. In the second one, which is long, the residual swelling remains with small fluctuations.

The small densities of $\dot{N}_e$ and E_s occur in linden (Fig. 9). This is connected with the low porosity, consistency and rigidity of this kind of wood. These features of the linden wood cause so low permeability and swelling.

Intermediate results for the measurements of $\dot{N}_e$ and E_s have been obtained for the moistened spruce, beech and birch woods.

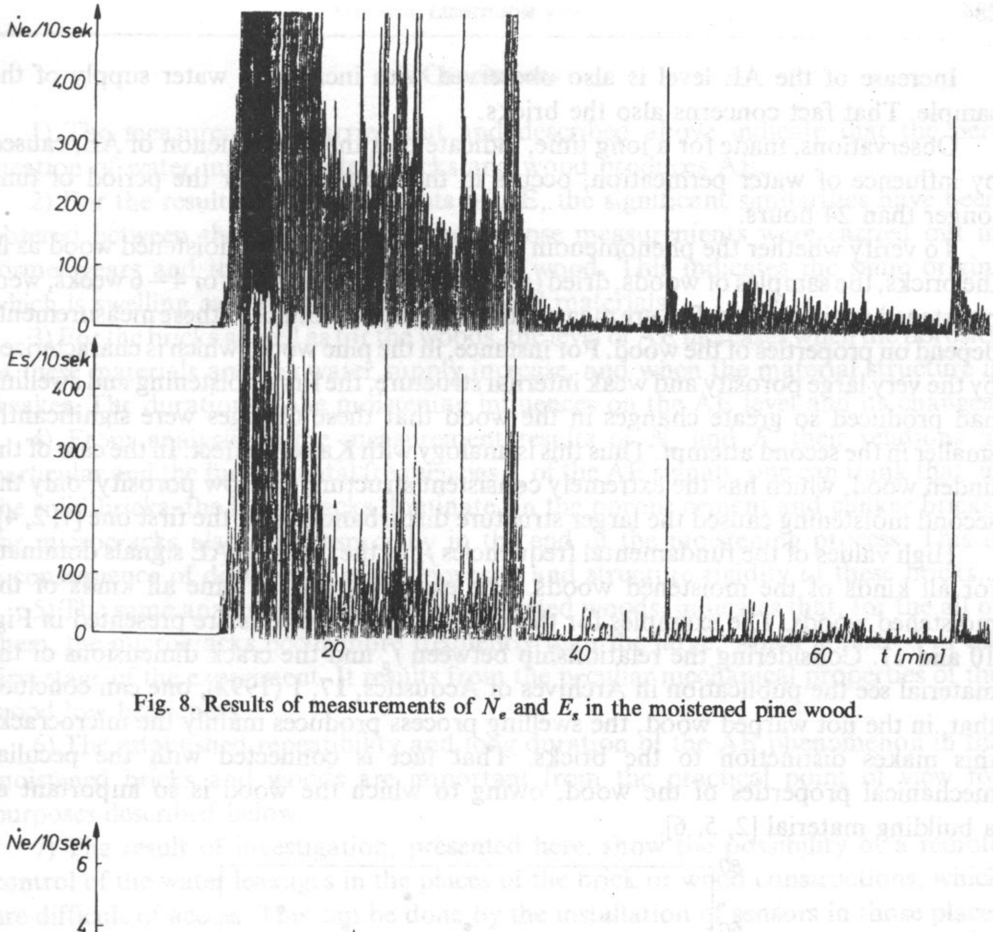

Fig. 8. Results of measurements of N_e and E_s in the moistened pine wood.

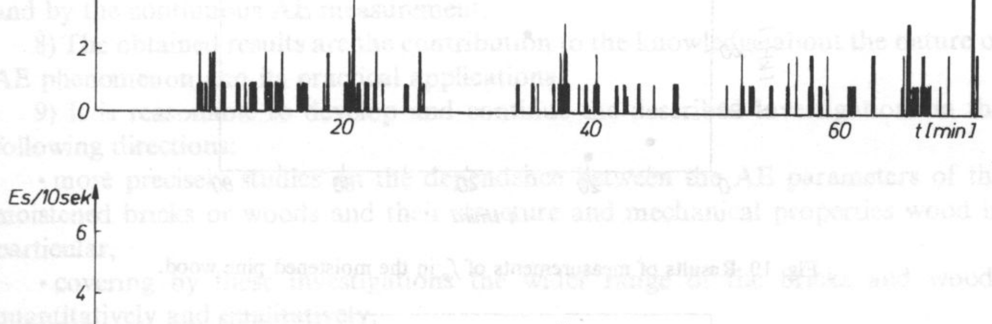

Fig. 8. Results of measurements of N_e and E_s in the moistened linden wood.

Increase of the AE level is also obeserved with increasing water supply of the sample. That fact concerns also the bricks.

Observations, made for a long time, indicate that the phenomenon of AE, caused by influence of water permeation, occurs in the wood even for the period of time longer than 24 hours.

To verify whether the phenomenoin of AE is reatable in the moistened wood as in the bricks, the samples of woods, dried (after the first experiment) for 4 – 6 weeks, were moistened again. N_e and E_s were measured. As fromerly, results of these measurements depend on properties of the wood. For instance, in the pine wood, which is characterized by the very large porosity and weak internal structure, the first moistening and swelling had produced so greate changes in the wood that these changes were significantly smaller in the second attempt. Thus this is analogy with Kaiser's effect. In the case of the linden wood, which has the extremely consistent structure and low porosity, only the second moistening caused the larger structure disturbances than the first one [1, 2, 4].

High values of the fundamental frequencies f_p of the received AE signals dominate for all kinds of the moistened woods. The examples for the pine all kinds of the moistened woods. The examples for the pine and linden woods are presented in Fig. 10 and 11. Considering the relationship between f_p and the crack dimensions of the material see the publication in Archives of Acoustics, 17, 1 (1992), one can conclude that, in the not warped wood, the swelling process produces mainly the microcracks this makes distinction to the bricks. That fact is connected with the peculiar mechanical properties of the wood, owing to which the wood is so important as a building material [2, 5, 6].

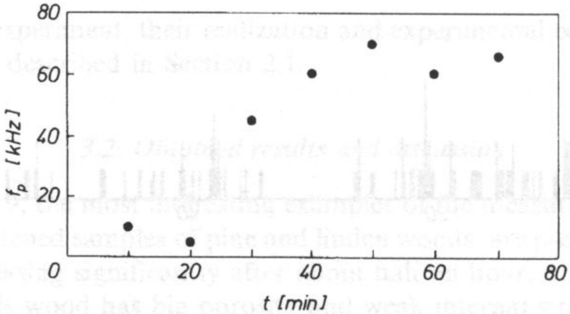

Fig. 10. Results of measurements of f_p in the moistened pine wood.

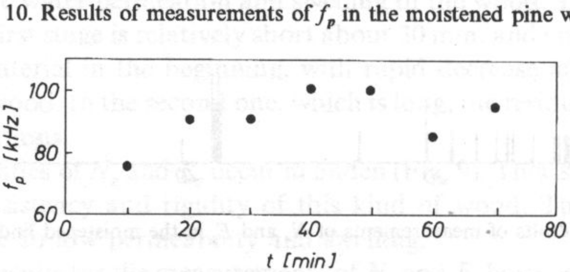

Fig. 11. Results of measurements of f_p in the moistened linden wood.

Conclusions

1) The measurements carried out and described above indicate that the permeation of water into the tested bricks and wood produces AE.

2) For the results of measurements of AE, the significant similarities have been observd between the moistened concrete those measurements were carried out in former years and the moistened bricks and wood. This indicates the same origin, which is swelling causing AE in all mentioned materials.

3) For the bricks as well as for the woods, the level of AE increases when the porosity of these materials and the water supply increase, and when the material structure is weaker. The duration of the moistening influences on the AE level and its changes.

4) From analysis of the measurement results of $\dot{N}_e$ and E_s their relations in particular and the fundamental frequencies f_p of the AE signals, one can think that, in the solid bricks, the large cracks dominate. In the porous cement and clinker bricks, the microcracks also exist, especially in the end of the moistening process. This is a consequence of differences of the porosity and structure rigidity of these bricks.

5) The same analysis performed for the tested woods, indicates that, for the all of them, the microcracks occur more frequently than the large, which appeared in the first stage of the experiment. It results from the peculiar mechanical properties of the wood low brittleness.

6) The established repeatibility and long duration of the AE phenomenon in the moistened bricks and woods are important from the practical point of view for purposes described below.

7) The result of investigation, presented here, show the possibility of a remote control of the water leakages in the places of the brick or wood constructions, which are difficult of access. This can be done by the installation of sensors in those places and by the continuous AE measurement.

8) The obtained results are the contribution to the knowledge about the nature of AE phenomenon and its practical applications.

9) It is reasonable to develop and continue the described investigations in the following directions:

• more precisely studies on the dependence between the AE parameters of the moistened bricks or woods and their structure and mechanical properties wood in particular,

• covering by these investigations the wider range of the bricks and woods quantitatively and qualitatively,

• introducing the continuous measurement of f_p (instead of every 10 min.) and the spectrum analysis of that frequency.

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