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ON THE ACOUSTIC EMISSION IN MOISTED CONCRETS AND THE METHOD OF ITS PRACTICAL APPLICATION

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The paper presents an attempt to explain mechanism of acoustic emission apperance due to water infiltration into the concrete. Experimental procedure of the *V* tests concerning this phenomenon is presented and obtained results are suported. Practical applications of the presented tests in civil engineering is also discussed.

Przedstawiono próbę wyjaśnienia mechanizmu pojawiania się emisji akustycznej pod wpływem procesu wsiąkania wody w beton. Zaprezentowano i omówiono wyniki badań doświadczalnych nad tym zjawiskiem oraz możliwości ich praktycznego wykorzystania do celów kontrolnych w budownictwie.

1. Introduction

Problems connected with obtaining sufficiently high tightness of buildings constructed nowadays oblige us to look for a new concepts and technologies applicable there. New research project conducted in Kielce branch of the IFTR is a part of this main trend. Investigations are concentrated on new technologies of joints, couplings and barriers together with their application in constructed structers. Experiments considering practical benefits obtained by their application are also conducted on the proper control stand.

Method signalizing water infiltration throughout poor tightenings is needed for this investigations.

Recent experiments as weell as years of observations showed that water infiltration into the concrete is accompanied by excitement of mechanical vibrations in a wide range of frequencies. These vibrations exhibit all the features of acoustic emission and can be applied as a source of information considering appearance and development of the water leaking from concrete precasts into the structure. Special investigations conducted as a project of the general 02.21 research program have been devoted to this problem. This paper presents their description and results.

2. Hypothetical mechanism of the acoustic emission appearance due to the water infiltration into the concrete

According to the commonly used definition, acoustic emission appears when the continuity of the structure of deformed material is destroyed. For this reason it should be examined in which way the water infiltration into the concrete can change its structure.

Professional literature considering technology of concrete its properties and applications does not pay too many attention to the processes taking place in the nature concrete due to its saturation with moisture. Such phenomenon as swelling of concrete, its shrinkage and corrosion are only generaly presented. The most information considering these processes can be found in the paper by Neville [8].

Water adsorption by a cement gel is the reason of concrete swelling. Water makes efforts to separate molecules of concrete evoking pressure of the extending nature. Water infiltration into the decomposed aggregate can be treated as another reason of concrete swelling. Magnitude of swelling mainly depends on the composition of concrete and its degree of moistness hightweighted concrets swell more than dense concrets. In concrete placed for good in the water swelling process is of continuous and long-lasting nature. It begins just after concrete is plunged in the water.

It is probable that the process of microcracks development within the cement building agent is one of the visible consequences of concrete swelling [2, 3, 9–11].

Drying of moistured concrete is accompanied by its shrinkage developing gradually from limit surfaces to interior of the object. Magnitude of shrinkage can varry with its propagation into the concrete mix. The so called heterogeneous shrinkage then takes place. It causes concrete cracking more often than usual shrinkage. Cracking of drying and shrinking concrete is a very slow process [6].

Concrete corrosion under the influence of water mainly consists in leaching and draining off outside components of binding material and in evoking chemical reactions leading to destruction of the concrete structure. Corrosion type phenomena mentioned above can disturb equilibrium of the hardened concrete and cause cracking. Nature and degree of concrete damage depend on the chemical constitution of water and the degree of its purity. Soft water without dissolved mineral salts has a great ability to leach calcium compounds [1, 4, 7].

Concrete strains briefly described above can disturb continuity of its texture and excite vibrations of the acoustic emission in the indirect way. On the other hand, when the basic aims of this paper formulates at the beginning are taken into account, swelling phenomenon seems to be of the greatest importance here. This phenomenon initiates just after water infiltration into the concrete begins and then reflects progress of this process. Suppositions presented herein concerned causes evoking acoustic emission of meistured concrets have their experimental confirmation.

3. Experiments

Formulation of relations between the water infiltration into the concrete and nature as well as intensity of the acoustic emission accompanying to this process have been the basic aim of the conducted experiments. Rectangular prism specimens 200×220 mm cross-section and different length, Fig. 1 of lightweight and dense

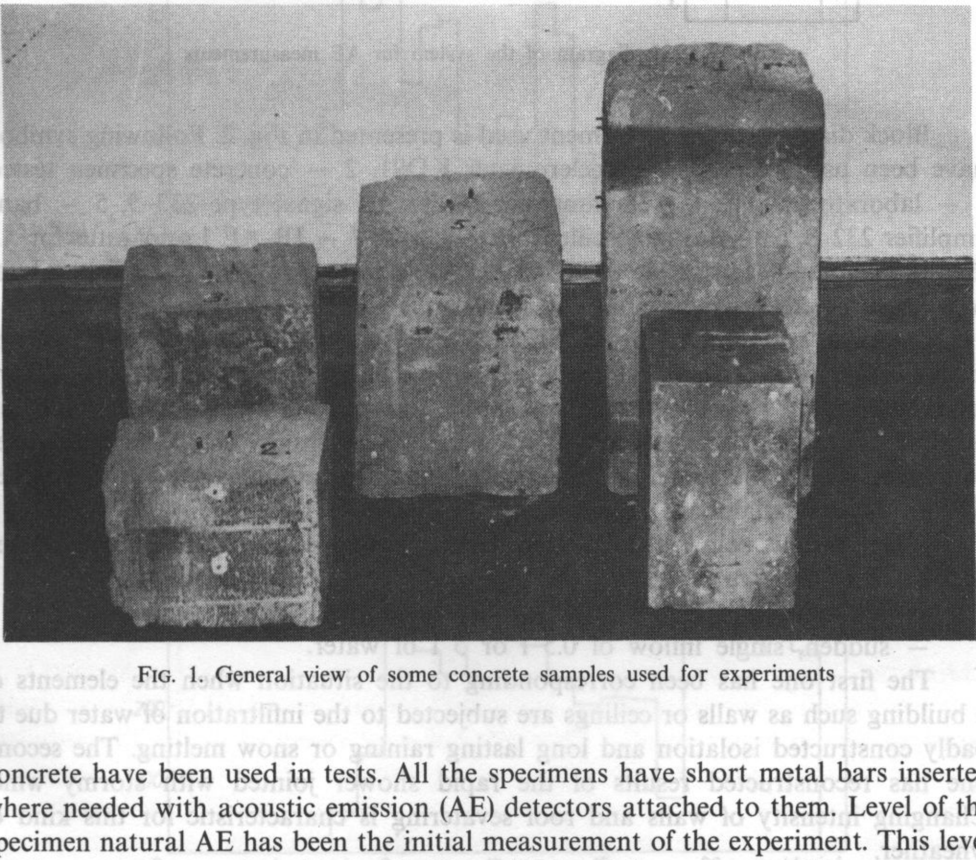

FIG. 1. General view of some concrete samples used for experiments

concrete have been used in tests. All the specimens have short metal bars inserted where needed with acoustic emission (AE) detectors attached to them. Level of the specimen natural AE has been the initial measurement of the experiment. This level has been compensated by the threshold sensitivity of the apparatus. Then specimens have been put in turn in the laboratory tank. Water inflowing the tank has been deaerated and its inflow has been under controll. Simultaneously event rate that is number of AE signals detected in a unit of time has been measured. Maximal amplitude of the signal in a unit of time has been also measured when circumstances allowed. Pictures of the selected AE signals have been photographed. Acoustic emission in the frequency range 15–100 kHz has been used in experiments. Necessity of environment disturbances elimination defined lower value of this band whereas the upper one has been imposed as the AE receiver transmitted band [5].

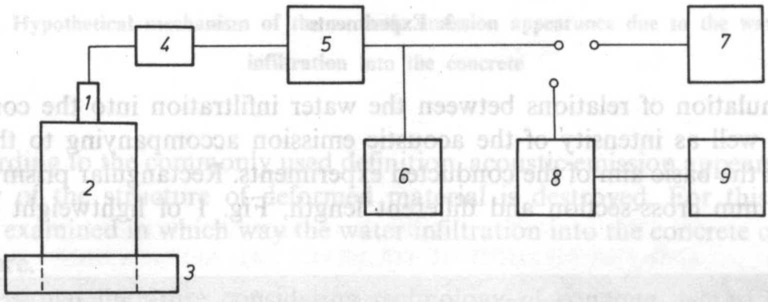

FIG. 2. Block diagram of the system for AE measurements

Block diagram of the equipment used is presented in Fig. 2. Following symbols have been used there: 1 – accelerometer KD91, 2 – concrete specimen tested, 3 – laboratory tank, 4 – preamplifier of the AE signal type 233–5, 5 – band amplifier 232 B, 6 – storage oscilloscope KR7401, 7 – IB–AE 1 apparatus for AE measurement and registration (own original construction), 8 – AE–3 apparatus for AE measurement (own original construction), 9 – B 72 BP analogue plotter.

IB–AE 1 apparatus equiped with IBICO type recorder allowed long-lasting measurement of the AE event rates. Measurement have been carried out in time intervals equal to 1 min, 10 min or 1 hour. Results have been printed. Measurements of short duration of event rate and maximal amplitude of events have been conducted for 10 s time intervals using AE-3 apparatus. Results have been registered by two-channel analogous recorder.

Water inflow below the concrete specimens used in experiments has been accomplished by two ways:

– constant, slow inflow 0.25 l or 1 per hour,

– sudden, single inflow of 0.5 l or 5 l of water.

The first one has been corresponding to the situation when the elements of a building such as walls or ceilings are subjected to the infiltration of water due to badly constructed isolation and long lasting raining or snow melting. The second one has reconstructed results of the rapid shower jointed with stormy wind. Changing intensity of walls and roof sevatering is characteristic for this kind of wheather.

4. Experimental results

Examples of the $\dot{N}_e$ event rate changes registered by the IBAE 1 apparatus for 1 minute time intervals in 1 l/h constant water inflow below the dense concrete sample of small porosity and lightweight concrere sample of high porosity are shown in figures 3 and 4. AE level is significantly lower for the inflow equal to 0.25 l/h. This fact is presented in Figs. 5 and 6 by curves plotted for lightweight and dense concrete.

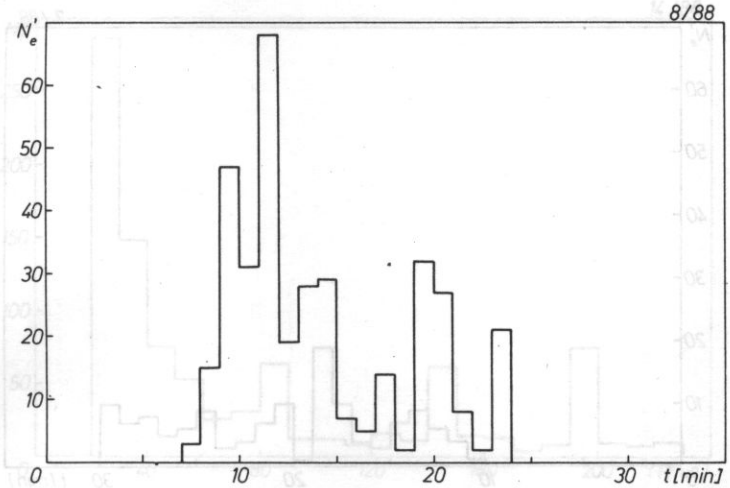

FIG. 3. Results of the measurement of $\dot{N}_e$ event rate conducted for dense concrete of low porosity with water influx equal 1 l/h per hour

FIG. 4. Results of $\dot{N}_e$ measurements for light concrete of high porosity for water influx equal 1 l per hour

Examples of the results of the $\dot{N}_e$ measurements presented above concern the observations conducted in 30 minutes time periods. Observation time has been so short here because the basic aim of these experiments was to proof that acoustic emission appears soon after water begins to infiltrate into the concrete. Durability and course of this phenomenon in time has been investigated by measurements carried in a few hours, see Fig. 7, for time interval equal to 10 min.

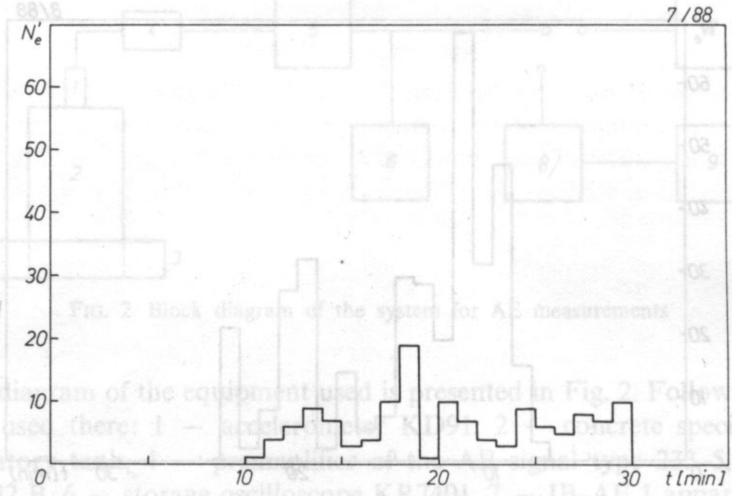

FIG. 5. Results of $\dot{N}_e$ measurement for dense concrete of low porosity for water influx equal 0.25 l per hour

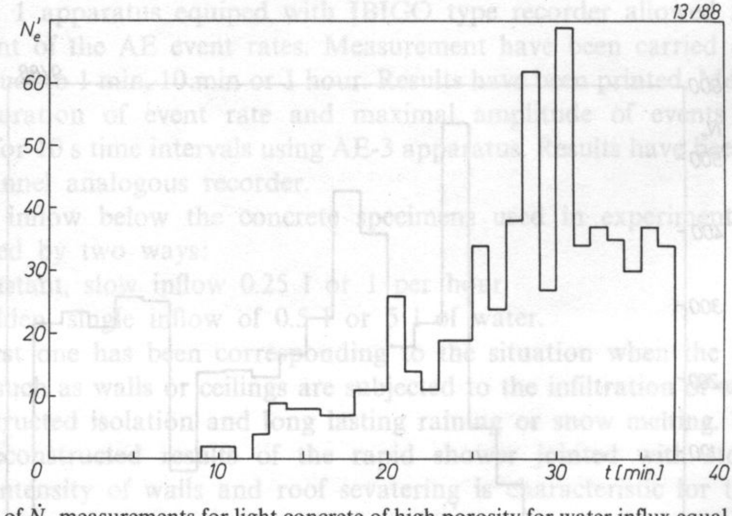

FIG. 6. Results of $\dot{N}_e$ measurements for light concrete of high porosity for water influx equal 0.25 l per hour

In the case of constant slow inflow of water into the concrete, level of AE grows rapidly from the moment of its initiation the seaches maximum and next significantly falls down to be of a variable nature in the end. Peak of the AE level mentioned here can be caused by air pushing out from the concrete subsurface pores by water. Time in which acoustic emission apears and rate of its growth depends on the quantity of water supplied and on porosity of concrete.

Changes of the AE level are completly different in the case of sudden, single water inflow to the concrete. Example is presented in Fig. 8. This figure presents analogous $\dot{N}_e$ record as well as record of AM maximal amplitude measured by AE–3

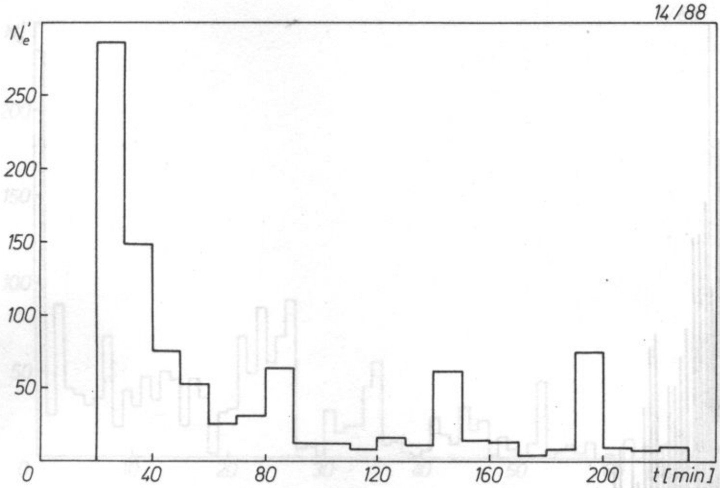

FIG. 7. Results of $\dot{N}_e$ measurements for light concrete after single influx of 1.5 l of water

apparatus for 10 s time intervals. Measurements have been done after single inflow of 5 l of water to lightweight concrete. Initial significant increase of the AE level is caused by percussive excitement of concrete vibrations by water impact and water pushing up from near the surface situated void. After approximate time of 2 to 3 min mean value of the AE level now caused only by concrete swelling gradually decreases together with water infiltration and evaporation. This process is rather long what can be seen in Fig. 9 an another $\dot{N}_e$ measurement result. This measurement has been done by IB–AE 1 apparatus just after single inflow of 5 l of water to the dense concrete. It can be seen that after 1 hour acoustic emission level is still allowed to be experimentally observed.

Concrete arying can be accompanied by its shrinkage which can also initiate AE vibrations. It must be added that for conducted experiments such effects have not been observed. It can be justify by a fact that such a phenomenon usually appears when swelling stops and this happened after the time measurement has been done.

Independently of the way of water inflow to the concrete level of the acoustic emission does not change gradually but is subjected to fluctuations in changing, although mean value of AE exhibits decreasing tendency as a function of time. It can be understood as evidence of irregularity of swelling process of the binding agent, and forming microcracks in that. Intensity of this process decreases with extending of the moistured zone. The increase of the AE signal is not a problem here because AE sources are aproachingthe receiver with extending of the moistured zone so the AE level should grow.

Except of the information considering leakage appearence acquaintance of the range of moistured region is the second important information of practical value. Information concerning situation of this zone with respect to the position of observation is peculiarly helpful here.

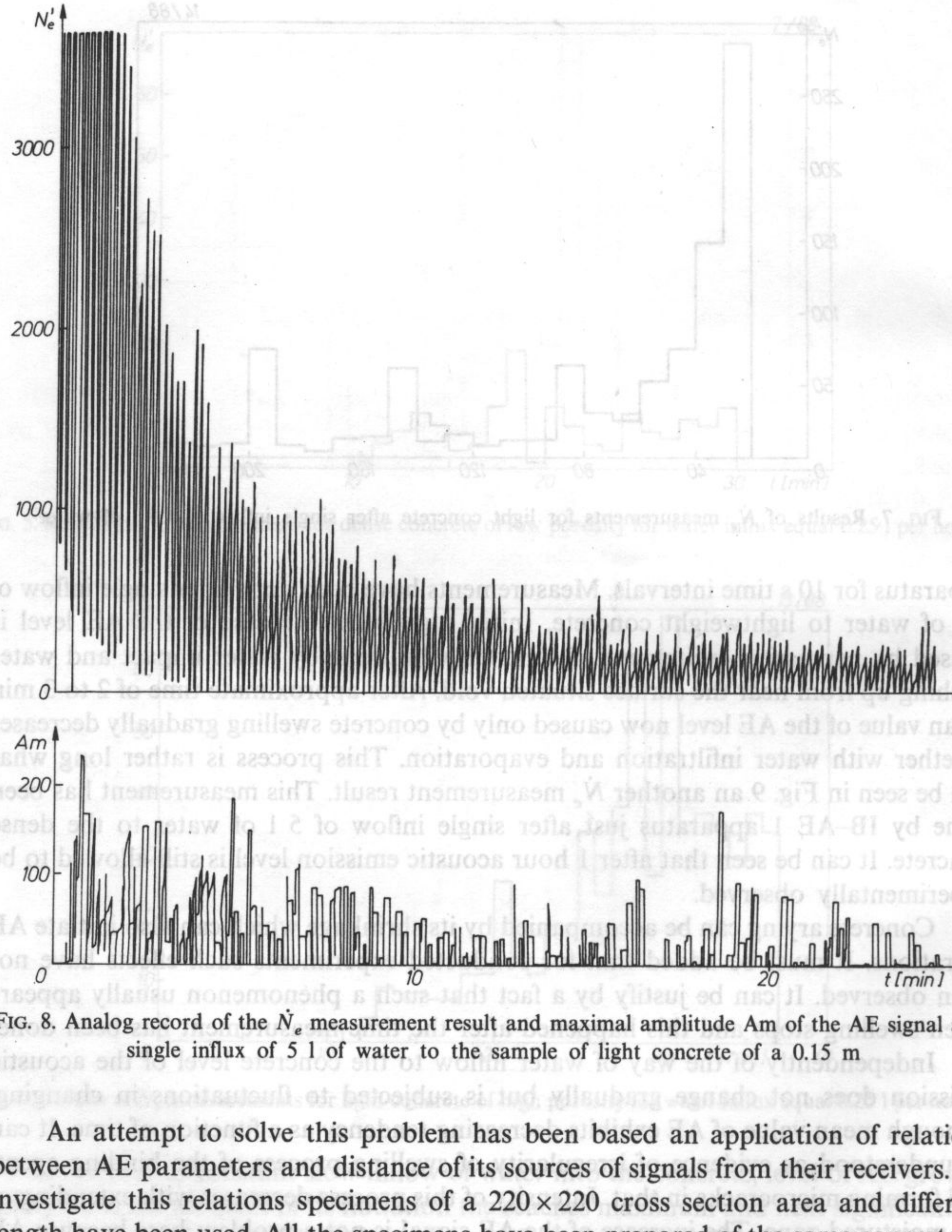

FIG. 8. Analog record of the $\dot{N}_e$ measurement result and maximal amplitude Am of the AE signal after single influx of 5 l of water to the sample of light concrete of a 0.15 m

An attempt to solve this problem has been based an application of relations between AE parameters and distance of its sources of signals from their receivers. To investigate this relations specimens of a 220×220 cross section area and different length have been used. All the specimens have been prepared of the same concrete. It has been assumed that sources of acoustic emission are activated when wall of the specimen contacts with water and within a few minutes time after it. Activation process takes place only in nearest part of the moistured zone that is near this wall. Such an assumption has been practically verified. If AE receiver is placed on the opposite wall of the specimen then the specimen length equals to the distance between sources of AE signals and their receiver.

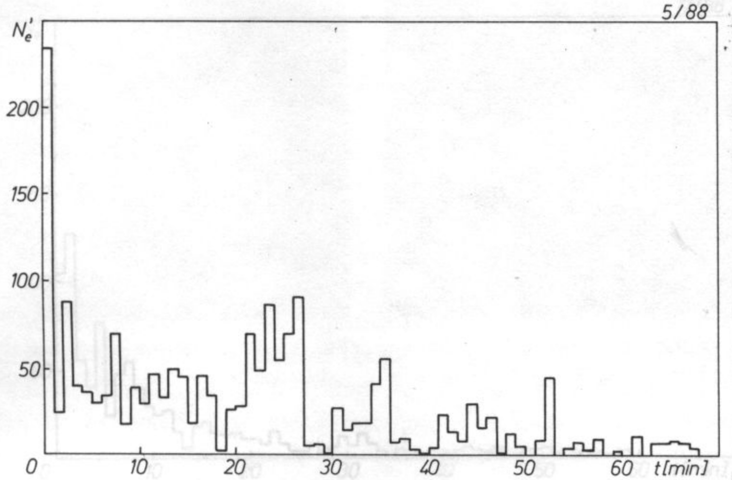

FIG. 9. Result of the $\dot{N}_e$ measurement after single influx of 5 l of water to the sample of dense concrete of a length 0.15 m

N_e and Am measurements have been conducted for analogous testing conditions for samples of growing length when their wall contact with water. Image of the received AE signals have been photographed. Results of measurements are presented in Figs. 8, 10, 11, 12 and 13. First three of them concern. light concrete specimens of a length equal to 0.15, 0.31 and 0.85 m whereas additional two – dense concrete specimens of a length 0.35 and 0.85 m. The increase of AE attenuation with the increasing of the way of the acoustic wave can be seen. It can b supposed that AE signals coming from sources sittuated in distance greater than 1 m of the receiver cannot be registered. In this way AE level can indicate how long is a distance between the place of observation and boundary of moistured zone.

Energy of the AE signal diminishes when the length of its way grows. Spectrum and fundamental frequency of this signal is not constant but changes with this length. It happens due to filtering properties of concrete. Images of two typical AE signals obtained for moistured dense concrete can be seen in Figs. 14 and 15. First signal has been received from the distance of 0.15 m whereas the second one – 0.85 m. Images of three additional typical AE signals but obtained for light weight concrete and received from the distance of 0.15 m, 0.31 m and 0.85 m are shown in Fig. 16, 17 and 18. In the case of dense concrete, increasing length of the way causes change fundamental frequency of AE signal from 30 kHz to 15 kHz. For lightweight concrete corresponding change is from 25 kHz to 7.5 kHz. It must be added here that frequencies lower below than 15 kHz are damped by the apparatus. Apart of this fundamental frequency of the AE signal and, after all, its spectrum can be treated as information concerning the situation of a moistured region boundary with respect to the place of AE reception.

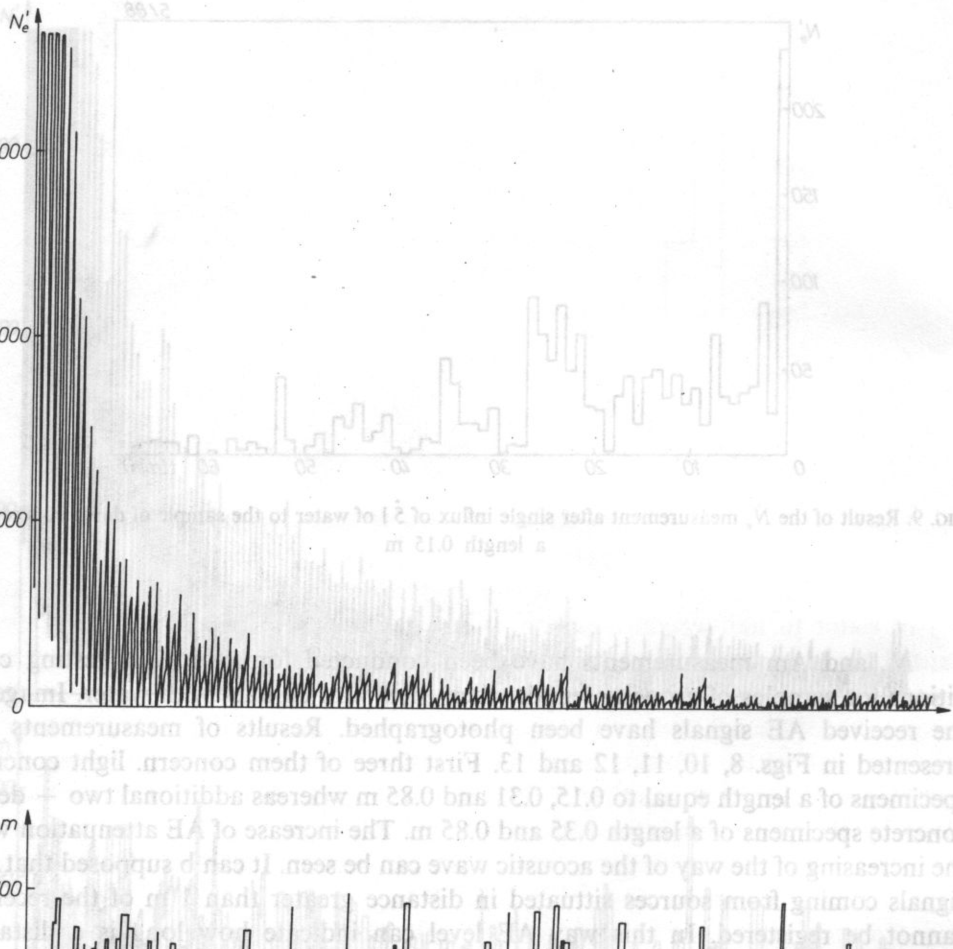

FIG. 10. Analog record of the $\dot{N}_e$ measurement result and Am for the sample of light concrete of a length 0.31 m

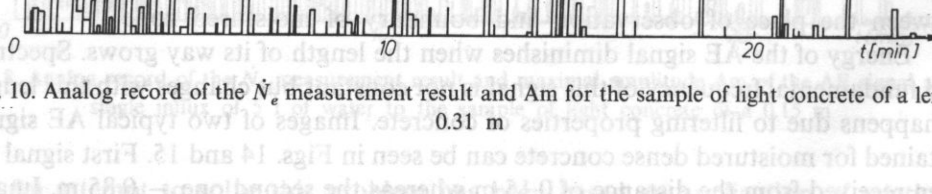

FIG. 11. Analog record of the $\dot{N}_e$ measurement result for a sample of light concrete of a length 0.85 m

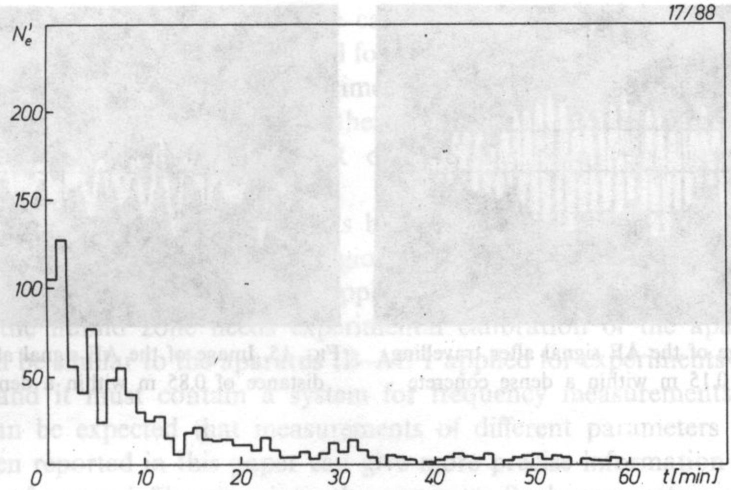

FIG. 12. Results of $\dot{N}_e$ measurement for a sample of dense concrete of a length 0.35 m

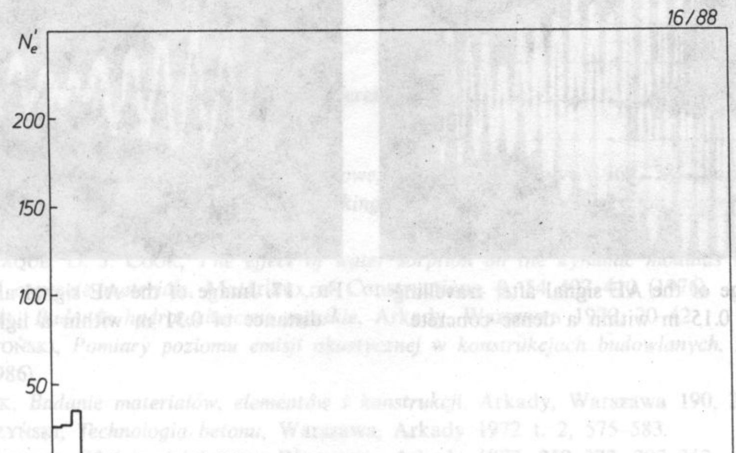

FIG. 13. Results of $\dot{N}_e$ measurement for a sample of dense concrete of a length 0.85 m

5. Conclusions

1. Performed experiments gave evidence supporting assumption presented at the beginning of this paper that acoustic emission accompanying water infiltration into the concrete is caused by its swelling. Fact, that the both acoustic emission and swelling appear with initiation of water infiltration and grow with concrete porosity and its humidity (see Sec. 2) is the reason of this statement.

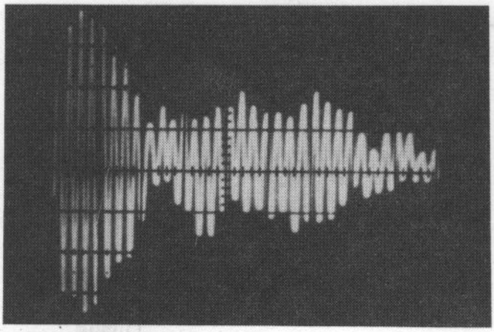

FIG. 14. Image of the AE signal after travelling distance of 0.15 m within a dense concrete

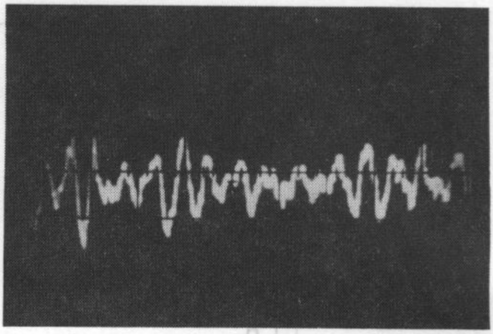

FIG. 15. Image of the AE signal after travelling distance of 0.85 m within a dense concrete

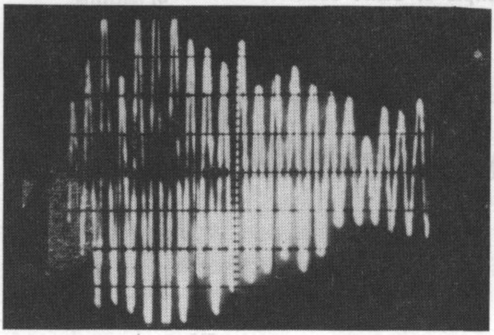

FIG. 16. Image of the AE signal after travelling distance of 0.15 m within a dense concrete

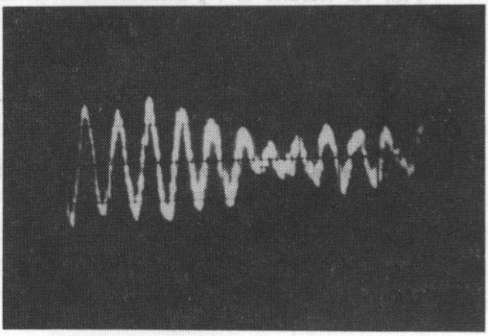

FIG. 17. Image of the AE signal after travelling distance of 0.31 m within a light concrete

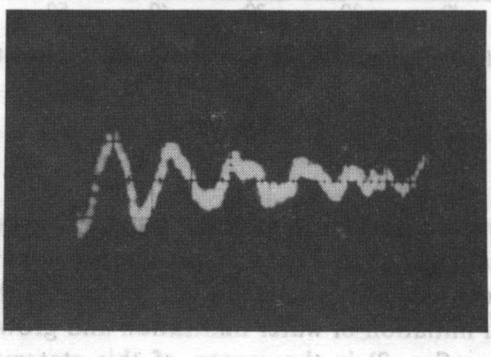

FIG. 18. Image of the AE signal after travelling distance of 0.85 m within a light concrete

2. Measurements of AE event rate can be applied at test stands for remote signalling occurence of water leaking and for observation of its consequences. This is peculiarly helpful in the case of experimental objects such as models of joints, partitions and other structures where their lightness is needed. Aparatus IB–AE 1 constructed and made in the IFTR of PAS has been very usefull for this experiments.

3. Magnitude of $\dot{N}_e$ level as well as basic frequency of the AE signal are the approximate indicators of the humid region boundary with respect to the place of observation at the test stand. Practical applicstion of this AE parameters to defining the size of the humid zone needs experimental calibration of the aparatus. This aparatus can be similar to the aparatus IB–AE 1 applied for experiments reported in this paper and it must contain a system for frequency measurements.

4. It can be expected that measurements of different parameters of acoustic emission then reported in this paper can give more precise information concerning the process of water infiltration into the concrete. Such parameters as maximal amplitude of acoustic emission, its energy and frequency spectrum of the signal could be applied. For this reason, the experiments reported in this paper should be continued.

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