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THE EFFECT OF STRUCTURE AND SWELLING OF CONCRETE ON THE FREQUENCY OF ACOUSTIC EMISSION SIGNALS

W. KOŁTOŃSKI

Institute of Fundamental Technological Research Polish Academy of Sciences
(00-049 Warszawa, Świętokrzyska 21)

In this paper results of experimental studies on the relationship between fundamental frequency of acoustic emission signals and time of water percolation into cement as well as its structure, are presented and discussed. Possibilities of practical application of this relationship for use in the building industry have been indicated.

1. Introduction

Experiments described in the first and second issue of Archives of Acoustics in 1990 [3] have proved that the process of water percolation into cement is accompanied by acoustic emission AE within a wide frequency range. It was initially stated that this effect can be used for remote signalling of water leaks through bad sealings of concrete prefabricated products, controlled at the experimental stand. However, further studies including various parameters have disclosed new possibilities of its application. One of these is interesting from the cognitive and practical point of view. It concerns the relationship between fundamental frequency of AE signals, and structure and swelling of moist concrete. This is the object of this paper.

2. Description of performed studies

Rectangular blocks of lightweight and dense concrete with 240 × 240 base and 150 or 450 mm height were tested. Every block had a metal rod inserted in a suitable place, to which the AE signals receiver (accelerometer was attached).

Every experiment started with the measurement of the natural level of AE in the concrete block prepared for measurement and placed on its base in a dry laboratory tank. This level was compensated by an adequate setting of the sensitivity threshold of the apparatus. Then the controlled flow of water (0.5 l per hour) into the bottom of the tank was turned on. Fundamental frequency f_p of received AE signals was measured in

1 min intervals, while their total energy E_s and number (event rate N_e') was measured in 10 s intervals. The purpose of simultaneous measurement of these three parameters is explained further on in this paper.

Experimental results indicate the existence of AE signals with frequency ranging from a few kHz to about 100 kHz in moist concrete. Hence, the overall frequency response of apparatus was equal 5 kHz –150 kHz. A rather low lower limit frequency did not allow total elimination of acoustic noise from the surroundings. Therefore, investigations had to be performed at low ambient noise.

In order to check the effect of the path length of an AE signal on its fundamental frequency f_p, measurements were made in blocks from identical concrete but with different heights 0.15 m and 0.45 m. This way AE signals travelling along a shorter and longer path were received. In accordance with previously made observations it was assumed that for water flow to the base of the concrete block equal to 0.5 l / h, AE sources are only created in the moist zone which reaches to about 2 cm above the base of the block during 2 hours [2].

Figure 1 presents the block diagram of the used measurement system, where: *1* – KD 91 accelerometer, *2* – investigated concrete block, *3* – laboratory tank, *4* – preamplifier of AE signals type 233-5, *5* – 232 B band amplifier, *6* – digital storage oscilloscope 2230, *7* – 1210 printer, *8* – EA-3, apparatus for AE parameter measurement designed by the author, *9* – B72BP two-channel analogue *X* – *Y* plotter.

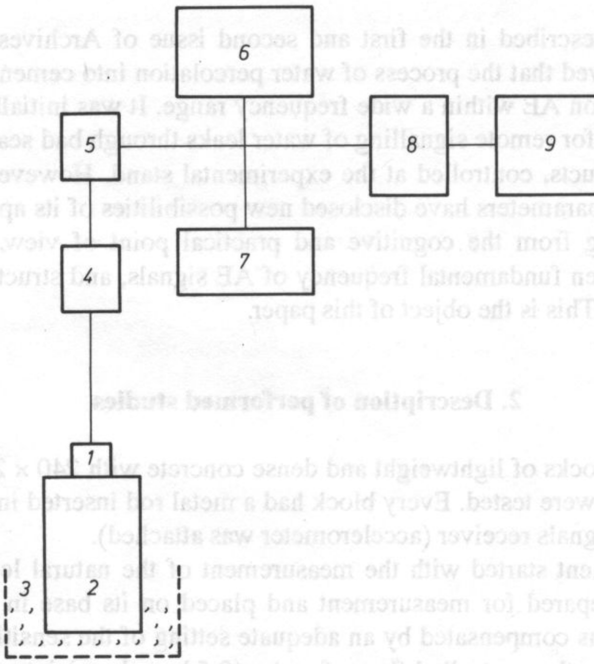

FIG. 1. Block diagram of measuring system.

Event rate, N_e', and energy, E_s, was measured with the AE-3 apparatus and results were recorded by the plotter. The fundamental frequency f_p, of AE signals was read off the digital display of an oscilloscope and printed. Mean f_p values for successive 10 – minute periods were calculated. Owing to this $f_p = f(t)$ diagrams became more readable and could be more easily interpreted. Above mentioned measurements were performed in individual concrete blocks during 2.6 – 3 hours. After this time the process of concrete swelling terminated and an increased stream of water would be necessary to initiate the process again. But this would change the conditions of the experiment, which should be constant [6].

3. Research results and their discussion

Fundamental frequency measurements of AE signals as a function of time were made in 21 concrete blocks. Examples of typical results for lightweight concrete and AE sources situated about 0.15 m from the signal receivers are presented in Figs. 2, 3, 4, 5. While results for greater distances travelled by AE signals – up to about 0.45 m – are shown in Figs. 6, 7, 8.

An increase of path length of AE signals from 0.15 to 0.45 m in dense concrete only slightly influenced frequency f_p and, thus, it was messured only in concrete blocks with 0.15 m height. Figures 9, 10, 11 present examples of results obtained from this measurement.

It is characteristic of results of $f_p = f(t)$ measurements in lightweight concrete blocks with 0.15 m height that increases and decreases of AE signal frequency are noted alternately. The range of these variations decreases with time and the f_p value decreases at the same time (see Figs. 2, 3, 4, 5).

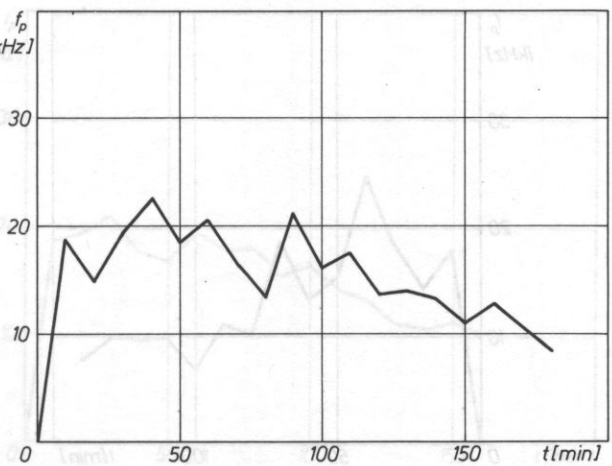

FIG. 2. Example of changes $f_p = f(t)$ in lightweight concrete with length 0.15 m.

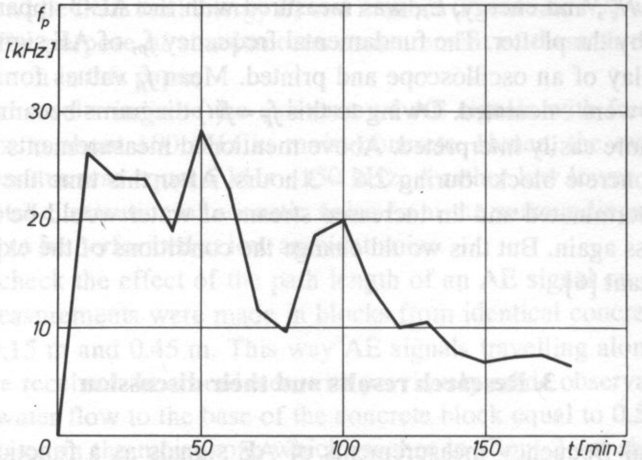

FIG. 3. Example of changes $f_p = f(t)$ in lightweight concrete with length 0.15.

The dimension of the source of acoustic emission is the fundamental factor conditioning the fundamental frequency of the signal. If a crack in the material is such a source (as e.g. in case of concrete swelling) then f_p is inversely proportional to the crack's length. Taking this into consideration one might expect f_p changes in diagrams to illustrate deformations in concrete due to its dampness. Initial small cracks in binding material (accompanied by higher frequency AE signals) cause it to expand and shift (lower frequency AE signals). This is promoted by the porous and weak structure of the material. This process repeats in cycles with decreasing intensity as the concrete becomes saturated with water. In the final stage of the experiment, deformations generating low frequency AE signals dominate. These can be bigger cracks (bigger than those

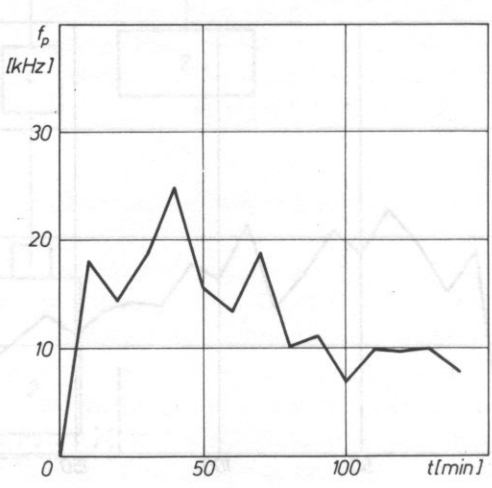

FIG. 4. Example of changes $f_p = f(t)$ in lightweight concrete with length 0.15 m.

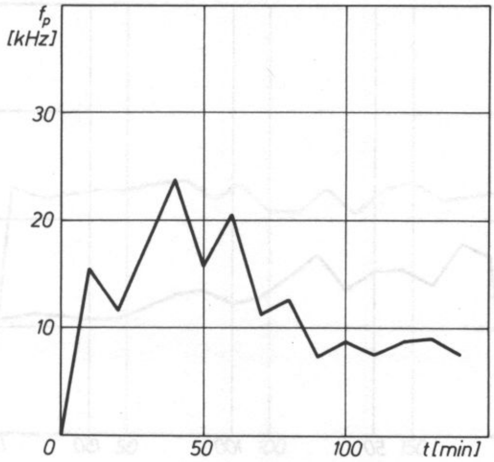

FIG. 5. Example of changes $f_p = f(t)$ in lightweight concrete with length 0.15 m.

in the binding material) created by releasing of energy, cumulated locally in the concrete body due to prolonged expanding action caused by material swelling.

When the path of AE signals in lightweight concrete legthens out up to about 0.45 m, then higher frequencies are attenuated much more strongly than lower ones. Hence, the measured range of f_p values is relatively small, but the downward tendency in f_p values is observed as in previous experiments with lightweight concrete blocks with 0.15 m height (see Figs. 6, 7, 8).

In dense concrete f_p value fluctuations are small and they oscillate around the same average level (see Figs. 9, 10, 11) even for a short path of AE signals (about 0.15 m). This indicates a different process of material deformation than for lightweight concrete. Low porosity, high compaction and rigidity of dense concrete structure promotes the

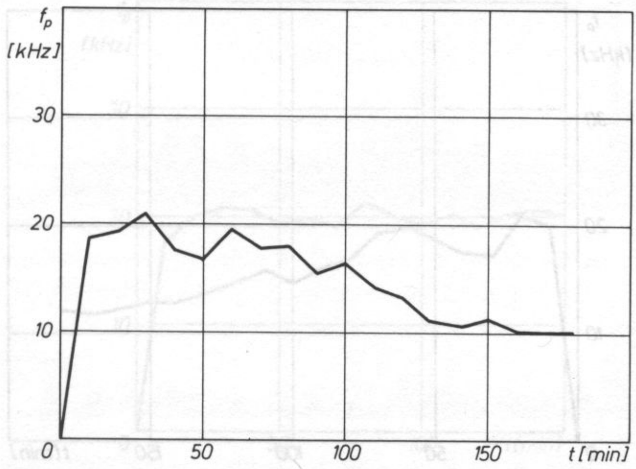

FIG. 6. Example of changes $f_p = f(t)$ in lightweight concrete with length 0.45 m.

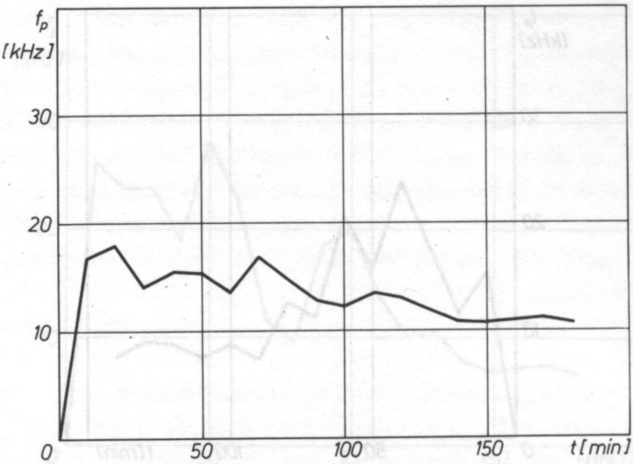

FIG. 7. example of changes $f_p = f(t)$ in lightweight concrete with length 0.45 m.

formation of rather small cracks and at the same time it resists the displacement of swelling binding material. This can surely explain the process of rather stable deformation of dense concrete due to moisture. It finds confirmation in results of $f_p = f(t)$ measurements.

Independently of the type of tested concrete, AE signals with fundamental frequency equal to about 100 kHz were observed in the final stage of most experiments. A supposition arises here that after a longer period of water percolation some eroded aggregate grains undergo swelling. However, these grains are harder and more resistant to compression than concrete binder. This creates conditions for the formation of microcracks in these grains, which can be sources of high frequency AE signals.

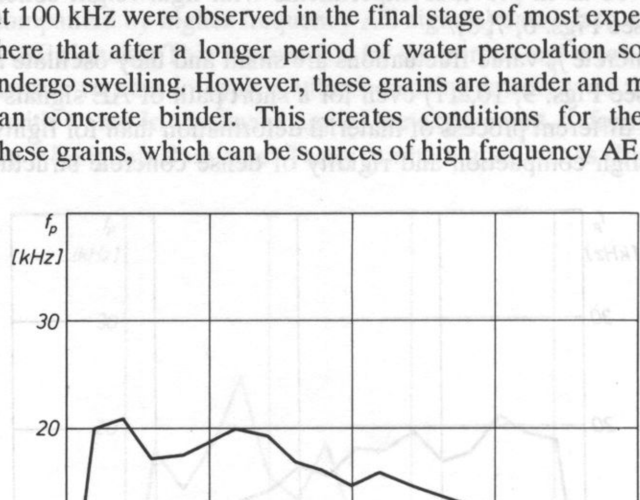

FIG. 8. Example of changes $fp = f(t)$ in lightweight concrete with length 0.45 m.

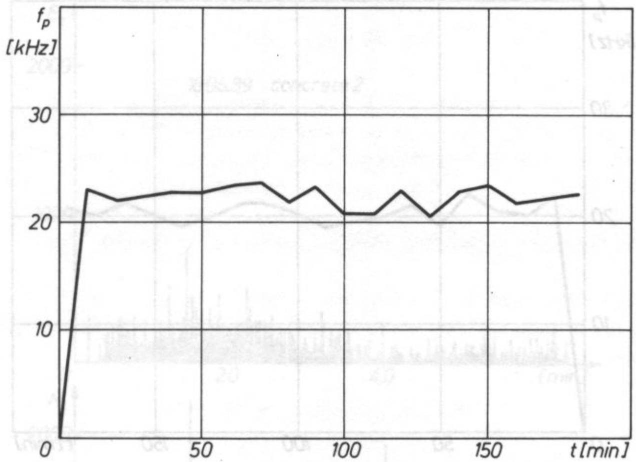

FIG. 9. Example of changes $f_p = f(t)$ in dense concrete with length 0.15 m.

For the last several years the AE signals energy to event rate ratio has been considered as an important source of information about the type of material deformation. High values of this ratio indicate the formation of big but not numerous cracks. whereas for low E_s/N_e' values numerous, small cracks are formed.

Figure 12 presents an example of measurement results of E_s energy of AE signals and event rate N_e' versus time for lightweight concrete. In Fig. 13 we have the same relation for dense concrete. Comparing these results we can find that in most 10-second intervals $E_s/N_e' > 1$ in lightweight concrete and $E_s/N_e' < 1$ in dense concrete Similar results were achieved in experiments with other concrete blocks.

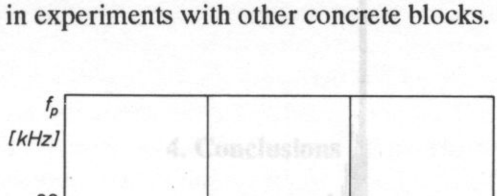

FIG. 10. Example of changes $f_p = f(t)$ in dense concrete with length 0.15 m.

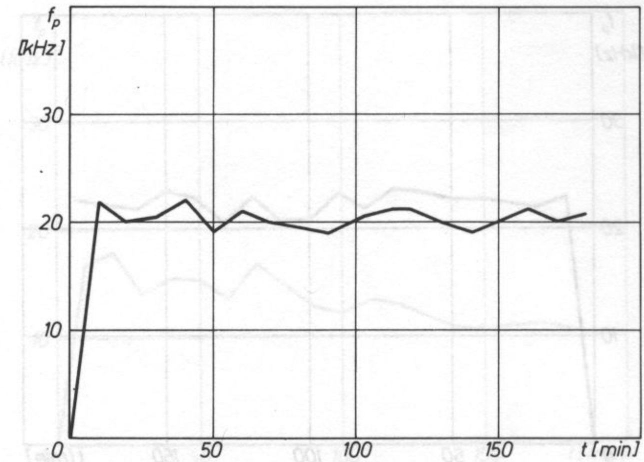

FIG. 11. Example of changes $f_p = f(t)$ in dense concrete with length 0.15 m.

All E_s and N_e' measurements were performed in the same conditions. Hence, we can pressume on the basis of given above dependences that moisture generates bigger cracks in light weight concrete than in dense concrete. This conclusion agrees with results of f_p measurements.

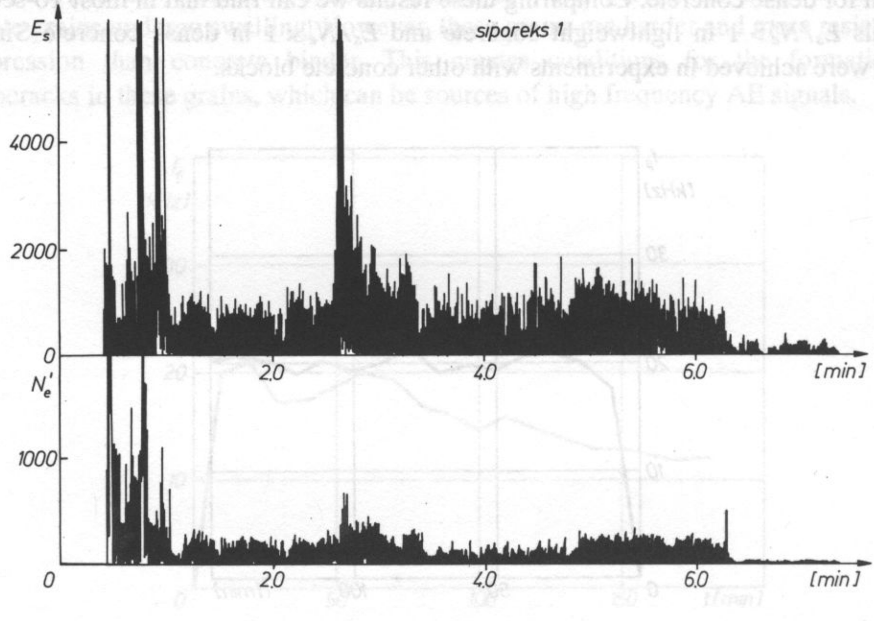

FIG. 12. Typical example of experimental results of E_s, $N_e' = f(t)$ in lightweight concrete.

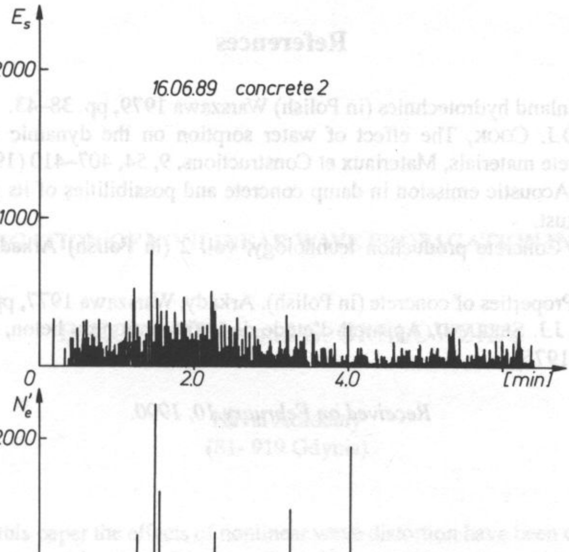

FIG. 13. Typical example of experimental results of E_s, $N_e' = f(t)$ in dense concrete.

4. Conclusions

It results from performed experiments that observations of fundamental frequency f_p changes of AE signals as a function of time, can supply information about the type of concrete into which water begins to permeate and about the swelling process itself. In case of lightweight concrete the magnitude of f_p variations indicates approximately the location of the moist zone in relation to the position of AE receiver. In practice this means that $f_p = f(t)$ measurements in concrete elements (eg. prefabricated joints) controlled on testing stands can remotely signal the location of a possible water leak and approximately its duration.

Results of $f_p = f(t)$ measurements obtained for lightweight and dense concrete also lead to a more accurate reproduction of the process of their swelling (see p. 3) than that found in literature concerning properties and production technology of concrete [1, 4, 5].

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