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PRACTICAL APPLICATION OF THE PHENOMENON OF ACOUSTIC EMISSION IN ROCKS

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Zjawisko emisji sejsmoakustycznej polegające na generowaniu fal sprężystych w czasie procesów dynamicznych znajduje szerokie zastosowanie przy rozwiązywaniu szeregu zagadnień geotechnicznych.

Uwzględniając podobieństwo procesów fizycznych, różnorodne zastosowania emisji sejsmoakustycznej sklasyfikowano w następujące grupy zagadnień:
— ocena stabilności wyrobisk i struktur geotechnicznych,
— przewidywanie momentu zniszczenia górotworu,
— inne zastosowania (jak np. do wyznaczania składowych głównych tensora naprężenia, który w przeszłości oddziaływał na skały, badanie zagrożenia lawinami, wykrywanie miejsc przepływu cieczy przez ośrodek porowaty itp.).

Oddzielnie przedstawiono lokalizację źródeł emisji sejsmoakustycznej traktując ją jako technikę pomiarów, która znajduje zastosowanie w ocenie stabilności, przewidywaniu momentu zniszczenia a także stwarza szerokie możliwości wykorzystania zjawiska emisji sejsmoakustycznej w geotechnice.

Dla każdej z grup zagadnień krótko opisano koncepcję zastosowań aktualny stan badań jak również czynniki ograniczające możliwość stosowania metody. Zastosowania zilustrowano najbardziej przekonywającymi przykładami z literatury.

Opis metod poprzedzono krótką analizą składu częstotliwościowego sygnałów sejsmoakustycznych w funkcji odległości od źródła w różnych typach skał.

Artykuł ma charakter przeglądowy i podsumowujący stan badań i został opracowany na podstawie obszernej literatury światowej.

1. Introduction

The notion acoustic emission (AE), which is also known as seismoacoustic, microseismic or geoacoustic, means the effect of elastic wave generation in rocks during dynamic processes. These processes may be caused by stresses within the rock body or certain unstable states.

Acoustic emission appears in solid and loose rocks as the result of plastic strains, microcracking, cracking, microcrack and crack growth or displacement of loose rock particles. Elastic strain energy is released during these processes. Such sudden release of energy develops elastic waves in rock mass, which propagate from the source to the boundaries of the rock mass, and may be recorded as a signal or AE.

Energy and frequency of the generated signals depend on the scale of the phenomenon and the way of generation of the elastic waves in the source. Therefore, the AE can be observed in a very wide range of frequencies, beginning from low range – a fraction of Hz up to very high ultrasonic ones – several MHz (Fig. 1).

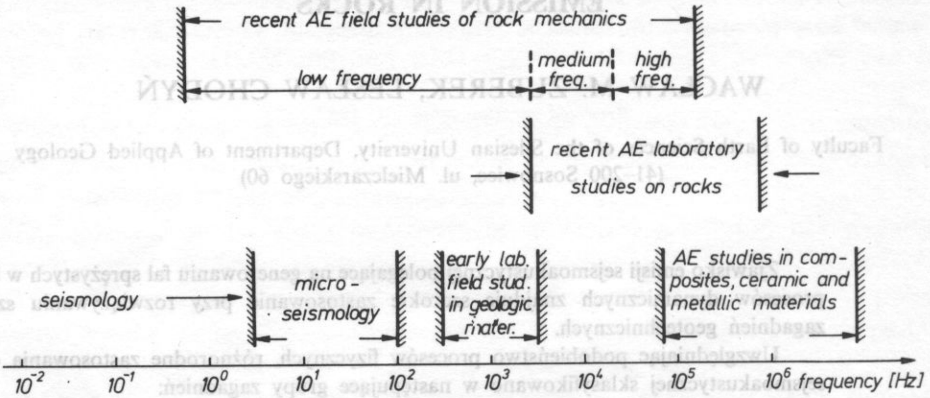

FIG. 1. Frequency range of various types of studies of acoustic emission in rocks and in related fields. Modified HARDY's diagram [27]

Similarly wide is the range of energy of signals emitted from the source, which are fractions of Joule, for the weakest ones, up to millions of Joules for the most intensive bursts close to tremors. The boundary of acoustic emission in the low frequency range has not been clearly determined. However it is most often assumed above 20 Hz for the most intensive bursts (lower frequencies are also investigated) up to several MHz which can be observed during the weakest microdeformations of rocks. Hence the range of frequencies recorded by local seismological and AE networks is partly the same for the lowest frequencies. However, in general, the notion of acoustic emission covers signals of much higher frequency and much lower energy as the ones recorded by standard seismologic networks.

Various geotechnical applications of acoustic emission have been classified below in certain groups of problems, considering selected common physical features of the observed processes and the rules of using the effect of AE in practical cases, according to the concepts presented in earlier works [83, 84]. It should enable and make easier to obtain certain generalizations and comparisons of processes and applications that sometimes may seem apparently different.

2. Attenuation of AE events in rocks

Elastic waves that propagate in the rocks are attenuated which means irreversible loss of energy. As a measure describing the wave attenuation in rocks one can use undimensional Q factor defined as [1]:

$$\frac{1}{Q} = \frac{1}{\pi}\frac{\Delta A}{A}, \tag{1}$$

where: A — amplitude of a wave with determined frequency, ΔA — amplitude reduction on the wave's way through the rock.

It can be determined that in a homogenous and isotropic medium an amplitude of a harmonic plane wave at a distance r, $A(r)$ is given by:

$$A(r) = A_0 \exp\left(-\frac{\pi \cdot f \cdot r}{v \cdot Q}\right) \tag{2}$$

where: A_0 — an initial amplitude of the wave (for $r = 0$), f — frequency of the wave, v — phase velocity.

It results from the equation (2) that attenuation of the wave increases together with the increase of frequency (if $Q = \text{const.}$).

Until now it has been assumed in seismology and seismic prospecting that, for different rocks $Q \cong \text{const}$ in the range of low seismic frequencies from 10^{-3} Hz to 10^2 Hz, and even up to 10^3 Hz. Typical Q values for rocks vary from about 10 up to 300. The values of the Q factor are higher for longitudinal waves than for shear ones [25];

$$\frac{Q_p}{Q_s} \cong 2.25 \tag{3}$$

(if sliding on intergranular boundaries is the main mechanism of attenuation)

The loss of the signal energy (depending on the wave length), as the result of attenuation, limits the distance up to which specified frequencies may be observed in the signal. It may be assumed that the rock mass acts on the elastic wave as a lowpass filter, therefore in larger distances we can observe in the signal mainly low frequencies, similar to the seismic ones. Thus the whole phenomenon of generation and propagation of elastic waves which develop in dynamic processes in the rock is usually called, in mining geophysics and rock mechanics, an effect of seismoacoustic or microseismic emission. The same phenomenon, in material sciences and acoustics, is called acoustic emission (AE).

Let us assume, that the maximum frequency of a signal $f_{\max}$ describes such a frequency that decrease of an amplitude, caused by attenuation, is equal 20 dB (higher frequencies will be attenuated more intensively). The dependence of $f_{\max}$ upon the distance r for rocks with different Q factor may be determined according to the formula (2), (for $Q = \text{const}$) which is presented in Fig. 2. An empiric

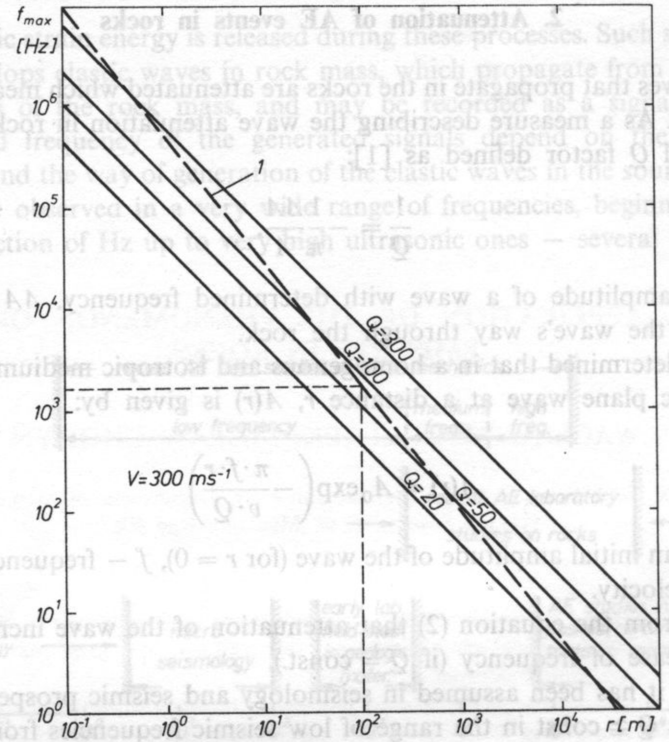

FIG. 2. Detection range r of AE signals as a function of maximum frequency $f_{\max}$ for a number of geological materials. Assumed wave velocity $v = 3000\ \mathrm{ms}^{-1}$. The empirical curve of AE detection range has also been plotted after HARDY [27] curve 1

relation of the range of AE signals as a function of frequency, according to HARDY [27] has been drawn in the diagram for the comparison.

A radius of emitted signal detection depends on a type of rocks; their state e.g. fracturing, a degree of pores and fissures filling (which determines the Q factor), and it is also – as it can be seen in Figure 2 – distinctly and quickly decreasing together with an increase of frequency. Therefore, only frequencies lower than 10^3 Hz can be observed at large distances from the source e.g. of the order 100 m. Actual investigations [25] indicate that in fact Q factor depends on frequency and for frequencies below 10 Hz it is increasing with frequency. It means that presented considerations should be treated only as a first approximation, and the detection distance has to be estimated in each specific case on the basis of accurate attenuation characteristic in the whole frequency range.

3. Stability of openings and geotechnical structures

According to Drucker's definition [68], as a stable system one can consider a system which configuration is determined by the history of loadings in such a way that small disturbances of conditions, under which the system exists, cause such reaction of the system that no abrupt changes of configuration will occur. A system is unstable when small disturbances of conditions cause large and sudden reaction of the system which is connected with a dynamic transition to a new state of equilibrium, together with a sudden change of the system configuration and the transfer of a part of the potential strain energy into kinetic one.

When we consider the above definition and assume as a system a configuration of openings, their support and the surrounding rock mass, or certain natural elements and structural forms, then many apparently different phenomena, such as; rock bursts, sudden outbursts of gas and rocks, roof falls in mines, side walls slides, landslides of slopes, cavern and chambers collapses, failure of soil dams and embankments may be considered as a whole common group of problems connected with unstability of the system or the geotechnical structure.

The proposed application of AE to determine current stability of a system or a structure usually means periodical measurements of AE burst rate or another parameter of the emission to compare changes of this parameter in time. As it is assumed, when activity is low or it does not exist, the system is stable. High level of activity may indicate transformation of the system into an unstable state which makes necessary to undertake proper action increasing stability, or decreasing the existing hazard. This method is used to determine stability of mining openings [62, 63, 60, 67, 27, 28], as well as landslides of scarps and slopes, embankments and ramparts, underground water reservoires, repositories and caverns [26, 27, 38, 39, 40, 31, 66]. Occurrence of AE effect is strictly correlated with nonelastic deformations occuring in the rock mass. It also appeares that recording of the AE is more convenient and sensitive than traditional methods of deformation measurements, as even slight and local deformations of the rock mass may generate waves propagating from the source for relatively large distances.

On-time determination of stability may be also carried out using the level of artificially generated (AE) in the rock mass. Destressing blastings, concussion or concussion wining blastings, small and large diameter borehole drillings, mining by shearer loader, injections of water into rocks, and firing a standard blowing charge in small diameter boreholes are used for this purpose [82, 67, 7, 79, 80, 81, 55, 77, 78, 19].

It has been noted that high AE burst rate after blasting of the standard blasting charge and a long time period of the burst rate return to the level before blasting are connected with transformation of the system into an unstable state, while low burst rate and a short period of increased burst rate immediately after the blasting are typical for stable systems.

Some examples of the determination of stability based on artificially generated AE in the rock mass are presented in Fig. 3 [19]. The emission has been initiated in the rock mass by firing a standard blasting charge (1 kg of explosive) placed in a 3 m deep blast hole. A geophone, placed in the distance of 5 m from the blast hole in a bore hole 1.5 m deep, has been used as a detector of the AE. The curve 1 in Fig. 3 has been recorded in the undestressed part of the coal seam (unstable system), while the curve 2 in the same picture, in the destressed part of the coal seam (stable system).

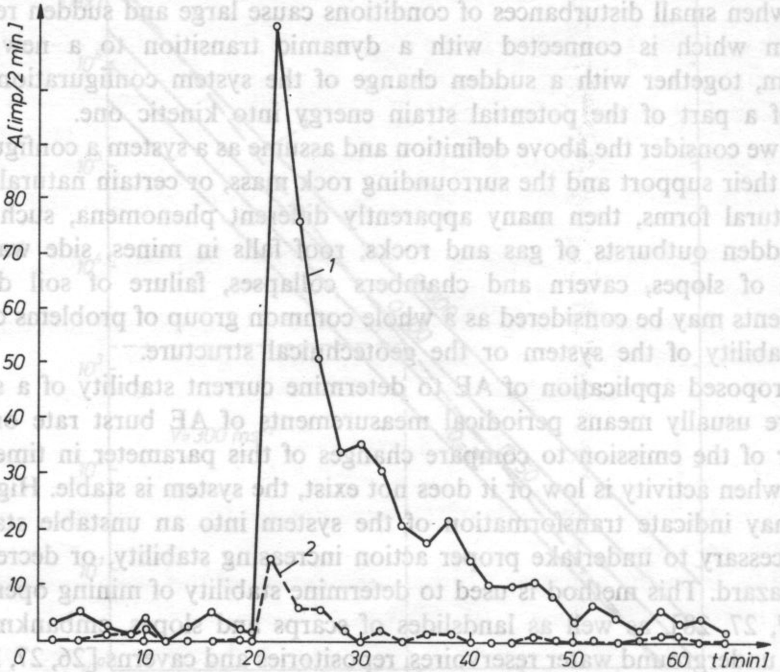

FIG. 3. AE burst rate after blasting in an underground mining face, coal seam 510 of the "Pokój" coal mine; 1 — in the undestressed part of the coal seam, 2 — in the destressed part of the coal seam (after CHACHULSKI and TROMBIK [19])

The level of AE burst and the maximum burst amplitude of the signals recorded during small diameter borehole drillings in a coal seam may also be indicators of stability. It was determined that high AE burst rate and high amplitude of the recorded signals are connected with the system transition into an unstable state. The AE burst rate distinctly correlates with flow-off of drillings from the borehole, and it is a more distinctive indicator of location of the exploitation stresses zone ahead of the working face [58, 67, 81].

Similarly, by means of the AE we can determine effectiveness and the transition time of the rock mass to the stable state after large diameter destressing drillings, injection of water or another liquid into the rock, dewatering, grouting or under — cutting of a scarp or a slope.

Certain ambiguity may appear during determination of openings stability caused, among others, by the facts that:

— definitions of a low and a high level of the AE burst rate are ambiguous, because they depend on the assumed detection threshold,

— it is necessary to.consider only particular zones where occurrence of the emission is extremely important for determination of the stability,

– a high level of the AE burst rate is not always connected with unstability of the system or the structure.

However suitable practical experience may diminish and even eliminate these ambiguities.

The AE phenomenon is applied to continuous observation and stability control of mining openings, chambers and caverns, embankments of reservoires, landslides, scarps and sidewalls in open-pits and also rock mass subsidence due to previous mining activity. The method is unique because, using suitably sensitive equipment and the network of properly placed transducers, it may remotely and relatively early detect, localize and signalize changes occuring in the rock mass.

The example of AE application for stability estimation of the active landslide is presented in Fig. 4 [53]. The broken line presents AE burst rate which values increase about one month before the deformations measured geodetically on bench-marks installed in the landslide (solid line).

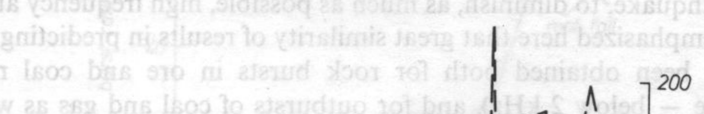

FIG. 4. Variations of AE burst rate broken line and displacement of the bench-mark solid line obtained during measurements in Thornton Bluffs slope, San Francisco penninsula, California USA after MC CAULEY [53]

4. Failure prediction

This problem is partly connected with the stability estimation of a system or a structure, but it is much more difficult, because the solution should include the following estimations (with appropriate accuracy):

– the place of failure,
– the time of failure,
– the area affected by the process of failure (the event magnitude).

Only determination of the above mentioned parameters is understood as failure prediction or prognosis of the failure moment. However it must be stated initially that despite great efforts and numerous investigations, which have been carried out for almost fifty years, and contradictory results, the problem of failure prediction has not been solved reliably and satisfactorily anywhere in the world yet. Nevertheless some results have been very encouraging and promising [61, 3, 76, 60, 42, 17, 16, 71, 8, 45, 44, 30, 48, 74, 73, 57, 20].

Some attempts have been made to determine these parametres when predicting earthquakes [4, 5, 56, 21]. However, there are great difficulties because of a limited detection range of the signals in the rock mass, especially at high frequencies. Therefore AE signals are sometimes recorded on the sea, directly above the focal zone of the earthquake, to diminish, as much as possible, high frequency attenuation.

It must be emphasized here that great similarity of results in predicting the failure moments have been obtained both for rock bursts in ore and coal mines (low frequency range – below 2 kHz), and for outbursts of coal and gas as well as roof falls (high frequency range – about 40 kHz). It appears that the process of the rock mass destruction is always preceded by increase and decreases of AE burst rate. The examples are shown in Fig. 5 – diagrams of AE burst rate preceding roof fall [47], rock burst [60] and outburst of coal and gas [30]. It seems that the recorded course of AE burst rate of the rock mass is independent upon the frequency range. The curve of AE burst rate before the roof fall was measured in 12-minutes time periods within the frequency range 36 kHz to 44 kHz (Fig. 5b), the curve before the rock burst was measured in 4-hours time periods within the frequency range from several Hz up to 1500 Hz (Fig. 5c) and finally the curve before the outburst in 5-minutes periods within the range of several to dozen or so kHz (Fig. 5a).

It has been stated, that in the period preceding the time of failure, mean energy of signals increases, or the value of an exponent γ of the AE energy distribution decreases, which is given by the equation below;

$$n(E)dE = a'E^{-\gamma}dE, \tag{4}$$

where: $n(E)dE$ – the number of AE signals with energy from E to $E+dE$, a', γ – distribution parameters.

It means the decrease of the exponent m value of the amplitude distribution of the AE given by the equation

$$n(a)da = Ka^{-m}da, \tag{5}$$

where: $a > 0$ – maximum amplitude of the signal, K, m – distribution parameters.

However it has not been possible to formulate unique criteria of prognosis and the problem of rockbursts, outburst of rocks and gases and roof falls prediction is still unsolved. Despite the numerous, quoted in the literature, examples of ap-

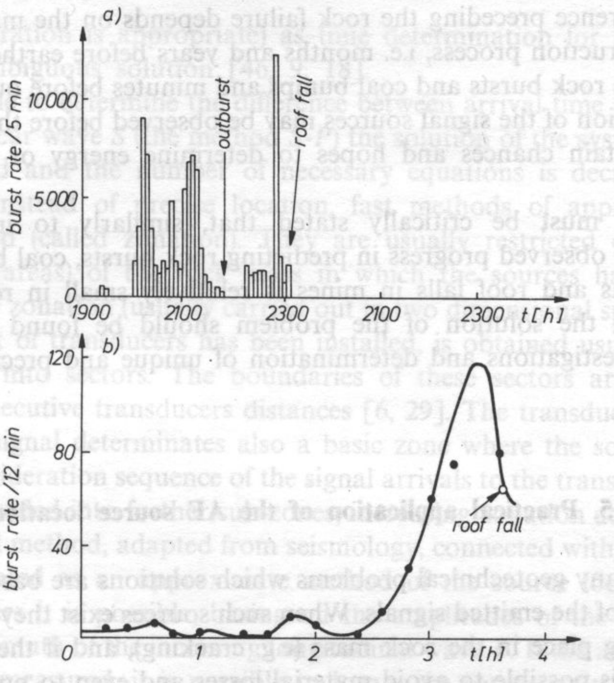

FIG. 5. AE burst rate preceding: a) outburst of coal and gas after HARDY and LEIGHTON [30], b) roof fall after LEIGHTON and STEBLAY [47], c) coal burst bump after NEYMAN et al. [60]

plication of this specific features of the AE to predict the time of failure, there are examples of sudden release of energy of a different course. There are also examples when after prediction the destruction does not occur.

Some new possibilities of interpretation can be obtained due to the AE signal source location and zonation and the possibility to observe changes in space and in time that occur in the rock mass. Such approach to failure prediction was proposed by B. T. BRADY [10, 11, 12, 13, 14, 15, 16, 17] according to his theory of soft inclusion. The results that have been obtained so far indicate that the time of precursor occurrence preceding the rock failure depends on the magnitude and the scale of the destruction process, i.e. months and years before earthquakes, hours or even days before rock bursts and coal bumps and minutes before outbursts and roof falls. Concentration of the signal sources may be observed before the failure process. That makes certain chances and hopes to determine energy or the scale of the expected event.

However, it must be critically stated that, similarly to investigations on earthquakes, the observed progress in predicting rock bursts, coal bumps, outbursts of rocks and gas and roof falls in mines is relatively small in recent years. The authors suggest, the solution of the problem should be found mainly through fundamental investigations and determination of unique and precise definitions of the phenomena.

5. Practical application of the AE source location

There are many geotechnical problems which solutions are based mainly on the source location of the emitted signals. When such sources exist they indicate changes which are taking place in the rock mass (e.g. cracking), and if they are sufficiently early located it is possible to avoid material losses and even to prevent disaster. In some other cases, source location is an important information about the process which takes place in the rock mass. The phenomenon of AE in this type of practical application creates unique possibilities which cannot be obtained by other methods used in geotechnique.

Recording of AE signals, by a network of properly placed detectors makes possible to locate sources of the signals if we determine the arrival time of a longitudinal waves P or shear waves S, on N transducers placed in the area around the source.

Then, the problem of source location is solved when solution of N nonlinear equations, in a form given below, is found.

$$v(t_i - t) = [(x_i - x_0)^2 + (y_i - y_0)^2 + (z_i - z_0)^2]^{1/2} \tag{6}$$

where v – elastic wave propagation velocity P and S waves may be used, t – the time of the signal occurrence in the source related to the reference time, t_i – the wave arrival time on consecutive detectors, x_0, y_0, z_0 – Cartesian coordinates of the signal source, x_i, y_i, z_i – Cartesian coordinates of the detectors $i = 1 \ldots N$.

If it is assumed that the seismic wave velocity in rocks is constant and known then, to determine uniquely location of the source in three dimensional space, it is necessary to calculate four unknown values, which are source coordinates x_0, y_0, z_0 and the time of signal occurence in the source t.

If the system of equations (6) is solved by means of the method of P or S waves it is necessary to determine times when the signal reaches at least 5 stations (if the network configuration is appropriate) as time determination for four transducers may give an ambiguous solution [46, 9, 18].

If it is possible to determine the difference between arrival time of a longitudinal wave *P* and a shear wave *S* (the method *S-P*) the solution of the system of equations may be modified and the number of necessary equations is decreased by one.

Sometimes, instead of precise location, fast methods of approximate source location are used (called zonation). They are usually restricted only to indicate certain regions (areas) of the rock mass in which the sources have appeared.

Signal source zonation (usually carried out in two dimensional space), in the area where a network of transducers has been installed, is obtained usually by dividing the whole area into sectors. The boundaries of these sectors are designated by bisectors of consecutive transducers distances [6, 29]. The transducer which is first reached by the signal determinates also a basic zone where the source must exist. Taking into consideration sequence of the signal arrivals to the transducers, the basic sector may be divided into further sub-zones, increasing zonation accuracy [29, 84].

An azimuthal method, adapted from seismology, connected with the *S-P* method may also be treated as an approximate method of the source location. Installing traxial transducers it is possible, basing on the amplitudes of the first arrivals, to determine the azimuth of the incoming longitudinal wave *P*. If the arrival time of the shear wave *S* is measured, it is possible to locate the source only from one of the three component stations [74, 73].

The above mentioned methods of AE source location have certain limitations which are connected mainly with a limited detection range of AE signals of relatively small energy. If we cannot record the signal by a sufficient number of transducers at a given signal/noise ratio, determination of the source is impossible. On the other hand an algorithm of location for most of the cases is constructed assuming that the velocity of the seismic wave propagation is constant and most often the same in all directions, which is not true in real geological conditions. Limited accuracy of arrival time determination and heterogeneously of the velocity distribution in rocks causes that in the specific geological conditions accuracy of source location is limited. However as experiments indicate, when accuracy of the arrival time determination is higher than 1 μs it is possible to obtain location accuracy up to several milimetres, and at the accuracy below 1 ms, up to several metres. This is usually sufficient for many geotechnical applications.

In case of the *S-P* method additional limitations may result from difficulties in determination of the time differences of the longitudinal and shear waves.

Some examples of application of AE sources location have been presented in Fig. 6 [81]. The sources of emission located after drilling of a destressing hole in a coal seam are presented there. Position of the signal sources shows the destressed part of the seam. As we suppose high accuracy of location was possible due to the small area of the investigated region, a large number of transducers and relative homogenity of the rock mass.

AE source location may be also used, in underground mining, to solve purely

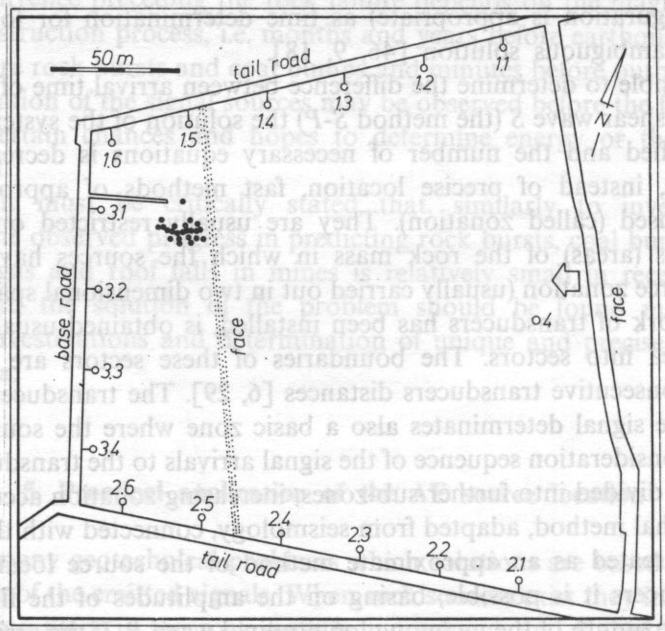

FIG. 6. The example of application of AE source location to determine destressed areas in the rock mass after destressing borehole drilling: ○ — locations of transducers, ● — located AE sources (after WILL [81])

exploitation problems, e.g. control of roof cave developing in a room and pillar system of mining [64]. AE source location was applied to control natural reservoires of crude oil and gas [27, 26, 2] and also to test and control underground storage openings and caves e.g. for food, hot water, compressed air and radioactive waste. Higher AE burst rates the areas as well as where signals occur may show places where the rock mass is weaker and it is necessary to seal it. In some cases, testing of, e.g. natural underground reservoires of natural gas or compressed air, may be performed using so called overpressure, i.e. using pressure higher than the working pressure, and to record the rock mass reaction with source location of AE signals. If there are no signals during the test at overpressure it means proper sealing and ensures correct service of the reservoire at the lower working pressure.

Storage of radioactive waste, both solid and liquid, in underground workings is a separate problem. Such storage must be remotely controlled because of the possibility of high contamination of the environment in case of the growing process of the rock mass cracking. Radioactive waste storage is connected with emission of a large amount of heat, which causes thermal stresses in rocks. As a consequence, rocks may crack and sources of AE appear. A properly installed set of transducers enables remote control and the process observation in the storage [52, 51, 49, 33].

Location of sources of AE signals has been used to control hydraulic fracturing of rocks which is used in many cases e.g. to increase effective porosity of rocks and to recover crude oil and natural gas from a deposit, in geothermal heat plant construction and others. Growth of a macro-crack caused by influence of water injected under high pressure into a sealed part of a well is going discretly and it is acompanied by a large number of AE. Their sources cluster close to the macro--crack edge. Location of the signal sources enables to control currently the process of fracturing, observation of the direction of the macro-crack growth, determination of its magnitude and velocity of its growth, both in reservoire rocks and in the surrounding ones [50, 24, 65].

Application of location of AE signals at works on grouting of a rock mass, e.g. cement or special resin injections, is similar in its character [35]. In this case, the aim of location is to determine the range and velocity of movement of the injected medium in the rock mass.

The phenomenon of AE has also been used to observe movements of the thermal stress front in a process of underground fire flooding of heavy crude oil (to decrease its viscosity and to increase recovery of crude oil from the deposit) [22, 23]. Observing, by AE, the fire flooding and movement of its flame front, it is possible to control the process by regulation of oxygen or air inflow. Similar technique may be used to control a process of underground coal gasification [27]. Location of AE sources during this process enables to observe and control the process and to localize the range of gasification of the coal seam.

It must be stated that the possibility to locate sources of AE signals has caused lately large increase of interest in AE method, and distinguished growth of the range of applications of the effect in geotechnique.

6. Other applications

The examples of geotechnical applications of acoustic emission technique presented above, do not cover all possibilities of AE method. It should be added that the phenomenon connected with an effect of memory of maximum stresses in rocks (Kaiser effect) enables to determine maximum values a stress tensor main component, which influenced the rock in the past due to tectonic phenomena, mining or explosions [36, 32, 34]; as well as to determine preconsolidation pressure of the soil [39, 37, 54]. Despite the fact that results are very promising it is still necessary to explain how such factors as e.g. time, water content influence the effect of memory in rocks.

Fig. 7 presents an example of the course of AE cumulative count number during cyclic loads of samples of granular soil. The solid line represents cumulative count number in particular cycles of load as a function of the stress currently imposed, normalized in relation to the failure stress σ_F for the sample, while the dotted line marks maximum normalized stresses which have been imposed in particular load

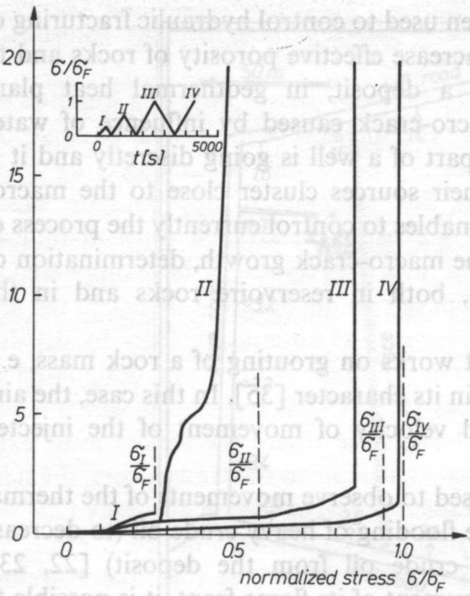

FIG. 7. The cumulative AE count number during cyclic loading of a granular soil sample. I, II, III and IV – the loading cycle number

cycles. One can notice two "stages" of AE course, connected with the memory effect of maximum stresses. Similar effect observed during investigations carried out on granite samples in cyclic load conditions is presented in Fig. 8 [41].

There are also attempts to apply acoustic emission to investigate snow avalanche hazard [69, 43]. It has also been successfully applied to investigate glaciers cracking [59]. The above examples may be considered as typical examples of geotechnical problems.

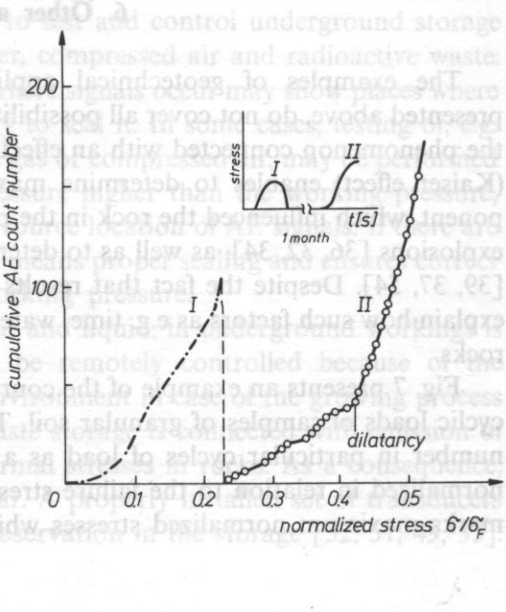

FIG. 8. The cumulative AE count number during cyclic loading of a granit sample (after KURITA and FUJI [41]). The loading path is presented in the upper part of the figure

Successful results have also been obtained during research of AE generated by a cone penetration of soils, to prepare a fast method of in situ soil penetration [75, 72]. It was found that the AE burst rate is strictly correlated with strength features of soils and it may be simply applied to distinguish layers of different soils as it has been presented in Fig. 9.

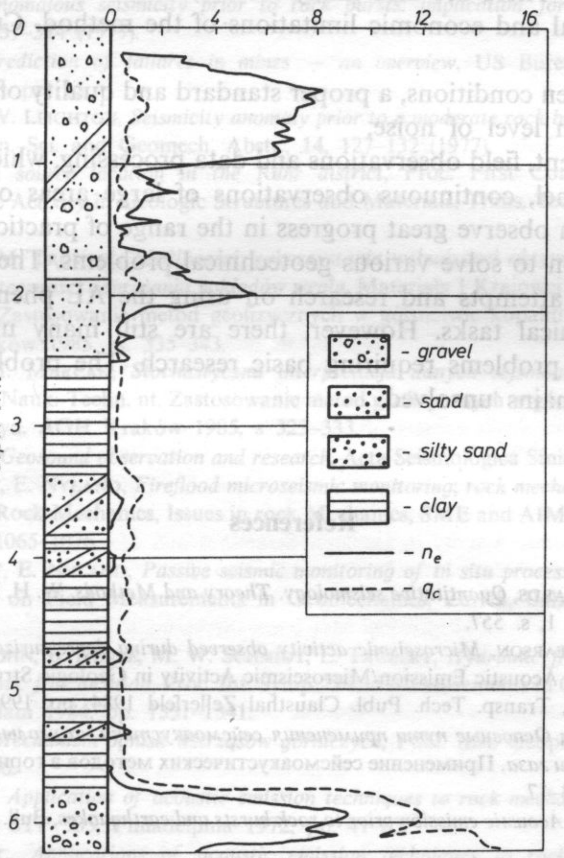

FIG. 9. Variations of the cone penetration resistance q_c and AE count rate n_e obtained during in situ cone penetration studies (after TANIMOTO and NAKAMURA [72])

Slightly different, but very practical, is the application of the AE to the detection of liquid seepage through porous rock. It has been observed that, flow of liquid through porous rock generates distinct signals which may be detected. As it appeared, there are good correlation between the level of the AE and the seepage velocity [35].

7. Conclusion

The presented examples prove distinctly that many geotechnical problems can be solved using the method of acoustic emission and there are vast potential possibilities of its application. It seems, it has already found permanent place in geotechnique, as there are many problems hard to solve without application of the AE effect. However it must be remembered that the method has not been fully developed yet and adapted to practical usage, as it is still at a development and improvement stage. There are also many factors, which in certain situations may cause both technical and economic limitations of the method. Currently the most important are:

– to obtain, in given conditions, a proper standard and quality of a received signal, especially at a high level of noise,

– costs of equipment, field observations and data processing, which may be high in case of multi-channel, continuous observations of large areas or structures.

Actually, we can observe great progress in the range of practical applications of the AE phenomenon to solve various geotechnical problems. There is also a lot of information about attempts and research on using the AE phenomenon to solve particular geotechnical tasks. However, there are still many unsolved technical aspects, as well as problems requiring basic research. The problem of the failure prediction also remains unsolved.

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