ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 2000
Seria: GÓRNICTWO z. 246 Nr kol.1480

Dou LINMING, He XUEQIU, Wang ENYUAN, Liu ZHENTANG
China University of Mining & Technology, Xuzhou, Jiangsu, P.R.China

MONITORING OVER THE MOBILITY OF THE TUNNEL'S SURROUNDING ROCKS

Summary. The effective signals, of which the relationship between the rise-time and the duration of the AE and the EME is applied, are determined when the influence of the noise, etc, is eliminated. The mobility of the tunnel's surrounding rock-mass is analyzed and the real-time survey is conducted when the variation regularity of the AE frequency, the energy rate and the EME pulse number is applied. These have provided the evidences to assess the stability of the building and the tunnel.

MONITOROWANIE ZACHOWANIA SIĘ SKAŁ OTACZAJĄCYCH TUNEL

Streszczenie. Do oceny zachowania się skał wokół tunelu w czasie rzeczywistym zastosowano obserwacje emisji akustycznej (AE) i elektromagnetycznej. Efektywne sygnały, określone relacją między czasem wzrostu i czasem trwania, otrzymuje się po wyeliminowaniu wpływu zakłóceń. O zachowaniu się skał świadczą zmiany częstości impulsów i prędkość przyrostu energii impulsów sejsmoakustycznych oraz liczba impulsów emisji elektromagnetycznej. Parametry te pozwalają określić stabilność budynku i tunelu.

1. The general situation of the tunnel

The tunnel, of which the shape of the cross-section is of semi-circular arch, is constituted by two holes, separated from each other by 20m, with four tracks. The height and the span of the rough hole are 8.26m and 12.20m respectively. There is a group of buildings overlying the left hole in the scope of 100m. The main building, of which the center line to that of the hole is of 20°, is of 36 stories. The roof of the standard rough hole is 10.90 m and 7.0 m away from the minus second floor of the building and the pile bottom respectively.

The surrounding rocks of the tunnel's left hole, in the scope of the building is of gently-inclined strata. The roof strata can be divided into three main parts which are of sandstone, silt mudstone, and sandstone respectively. The rocks are crack-generating and water-permeated. The tunnel's left hole in the scope of the building became headed through after the eighteenth floor of the building was constructed. Afterwards, the building continued rising. The tunnel, shortly after the construction was completed, witnessed plenty of cracks, which mostly concentrated on the sites where the pile bases were under high load and the piles were at short intervals in the tube-shaped body. According to the radar survey, the cracks was of crisscross and there existed a number of sites of anomalous bodies that were ill-sealed and ill-contacted between the lining and the surrounding rocks.

2. The principle of the survey

The acoustic emission (AE) refers to that the material of rock, concrete, etc, can release strain energy and produce elastic waves the moment the plastic deformation occurs from within or the cracks form and expand. The material of rock or concrete can generate acoustic emission in the course of its internal crack-generating, crack-expanding and breaking.

The electromagnetic emission (EME) refers to that the material of rock, concrete, etc, can outward give off energy in the form of electromagnetism the moment it is loaded to deform and rupture. The EME mainly appears in two ways. One is that the stronger the load on the rock-mass, the higher the intensity of the EME. The other is that the rougher the deformation and breakage of the rock-mass, the tougher the signals of the EME and the bigger the EME pulse number.

2.1. The determination of the effective signals

The influence of the environment or the noise is needed to be removed when the AE and EME survey is conducted. The AE and EME signals, in general, can be divided into 5 groups, based on the relationship between the rise-time and the duration, shown in Fig.1. The rise-time and the duration are both very short for group 1 while the rise-time is longer than the duration for group 2. These two groups both reflects the influence of the electricity and the mechanical noise. According to group 3, the linear relationship appears between the rise-time and the duration as a result of the AE, the EME, or the noise overlap. According to group 4, the rise-time is shorter than the duration as a result of the noise impact near the feeler. According to group 5, the AE and EME signals, which are mostly caused by the rock-mass or the structure, lie between group 3 and group 4. Therefore, the AE and EME signals can be determined effective when situated within the zones of group 4 and group 5.

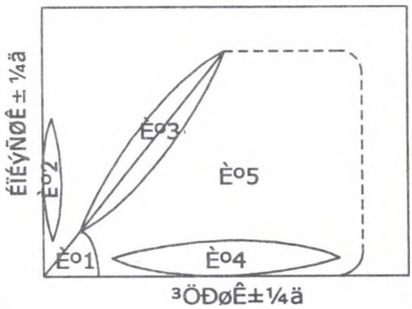

Fig.1. The distributive diagram of the AE and EME signal groups rise-time duration group 1,2,3,4,5

2.2. The analysis of the mobility

The AE frequency will also vary in the course of the variation of the load on the rock-mass or the structure. So will the EME. In line with this principle, the mobility of the rock-mass and the structure can be analyzed and appraised.

1. It can be divided into three scales, that is, A, B and C, according to the frequency of the AE signal in the course of raising the load (pressure-increasing).
2. It can be divided into non-mobility, weak mobility, mobility and strong mobility, according to the load rise (pressure-increasing) and the load-keeping (pressure-maintaining).

3. The result of the AE survey

According to the facts that large amount of cracks, which largely concentrated on the sites where the pile bases were under high load and the piles were at short intervals in the tube-shaped body and mainly arose at the roof arch and haunch in the left side of the surrounding rocks of sandstone, appeared in the tunnel, the AE and EME survey was focused on the worse sites as well as the other parts were taken into account.

The result of the AE survey to the piles of the building reflected the load's variation regularity of the building's pile bases. The result of the real-time survey that began at 18:46 of the 17th is shown in Fig.2. The ring-vibrating numeration rate, seeing to Fig.2, was of obvious change and rise and the AE was of mobility from 12:00 in the midnight to 4:00 and at 5:00 in the morning.

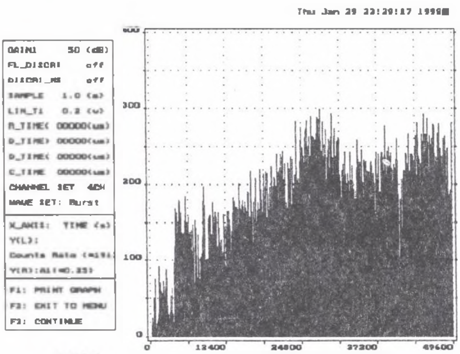

Fig.2. The variation of the AE ring-vibrating numeration rate at 19-C pile base

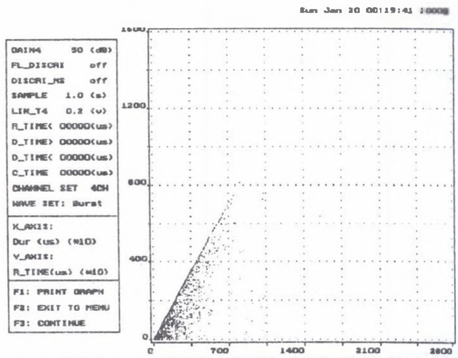

Fig.3. The relationship between the rise-time and the duration of the AE at 21-C pile

The relationship between the rise-time and the duration of the AE is shown in Fig.3. The AE occurred could be divided into three categories. The first was of very short both the rise-time and the duration, which resulted from the electricity and the mechanical noise, that is, group 1. The second was the result of the AE and the overlapping noise, that is, group 3. And the third was mainly caused by the rock-mass or the structure, that is, group 5, which proves that the rock-mass or the structure was under mobile status.

The result of the survey within the bore holes is shown in Fig.4. The rock-mass near the 4# bore hole, seeing to Fig.4, was of mobility round 12:00 of the 18th and from 3:00 to 4:00 of the 19th. However, the rock-mass near the 3# was of comparatively large mobility within near 5 hours from 17:30 to 23:00 of the 18th. The movement was intermittent and discontinuous. The longest duration was up to 3.5 hours. This proves that the AE within the bore hole was of certain mobility.

The result of the survey to the rock-mass near the cross-section at 926m is shown in Fig.5. The ring-vibrating numeration rate of the AE witnessed a peak value round 20:10 of the 20th, which proves the rock-mass here was of certain mobility. There happened a sudden rise for the AE of the rock-mass when the building started operation at near 5:00 of the 21st, which proves the effect the dynamic load of the building had on the tunnel's surrounding rock-mass.

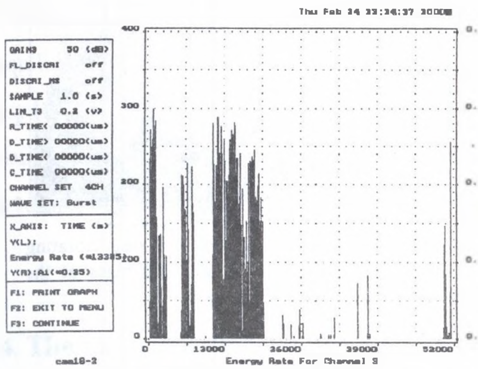

Fig.4. The energy rate occurred within the 3# bore hole

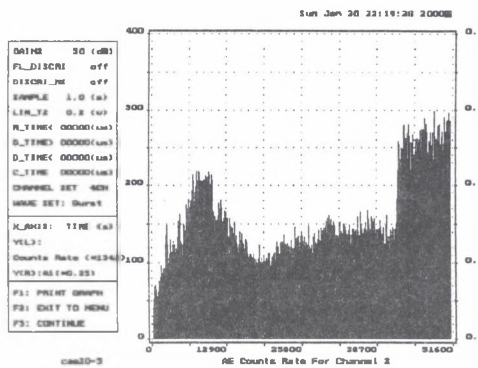

Fig.5. The variation of the AE ring-vibrating numeration rate at the cross-section of 926m

The result of the survey to the rock-mass near the cross-section at 916.5m proves that the variation regularity of the AE in the tunnel's walls was consistent with that near the cross-section at 926m. Nevertheless, the variation regularity of the AE in the arch feet was inconsistent with that in the arch walls. The ring-vibrating numeration rate of the AE of the rock-mass near the arch feet witnessed a comparatively large peak value while the energy rate of the AE also witnessed a high peak value, shown in Fig.6, which proves the rock-mass here was of certain mobility.

The result of the survey to the rock-mass of the arch walls proves that the AE was of comparatively fierce mobility. The AE variation of the rock-mass of the tunnel's arch walls, before and after the beginning of the building's operation on the 25th (at 01:43), is shown in Fig.7.

The result of the survey to the rock-mass of the arch walls at the cross-section of 884m indicates that the AE of the rock-mass of the tunnel's arch walls and feet, before and after the finishing of the building's operation, was varying significantly. And the rock-mass of the arch walls was of mobility. Besides, the tunnel's filling was also of certain mobility.

The result of the EME survey also reveals that all the rock-mass around the tunnel was of certain mobility. Moreover, the movement of the various cross-sections was intermittent, discontinuous and non-synchronizing. The mobility surveyed by the EME is consistent with that by the AE. Fig.8 shows the result surveyed by the EME at the cross-section of 903m on the 25th, consistent with Fig.7.

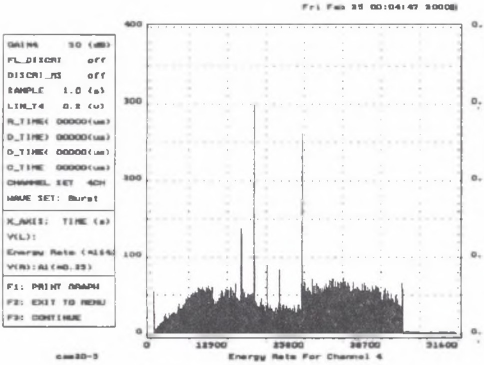

Fig.6. The variation of the arch feet's AE energy rate at the cross-section of 916.5m

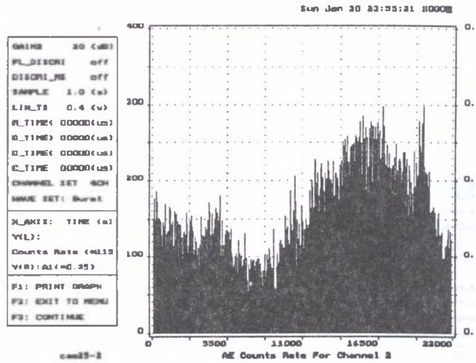

Fig.7. The variation of the AE ring-vibrating numeration rate in the rock-mass at the cross-section of 903m

3.1. The mobility of the AE and its analysis

The dynamic survey of the AE to the building's pile bases, the geological bore holes, etc, and the tunnel shows that all the points surveyed are of certain mobility (generation of tiny fractures) and the movement is intermittent.

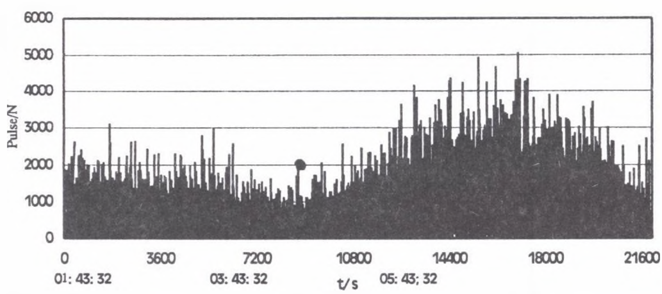

Fig.8. The variation regularity of the EME pulse number in the rock-mass of the arch walls at the cross-section of 903 m

The deformation and breakage of the rock-mass, on the average, results from unbalanced stress. The rock-mass and the concrete are non-homogeneous. The rock-mass and its deformation, from a macro point of view, is continuous while the structural mechanical characteristics of its various parts (or rock-mass elements), from a micro point of view, are remarkably different. The deformation and breakage of the rock-mass under certain load, simply from a micro point of view, is discontinuous and heterogeneous.

The breakage and the energy emission will come to the sight where the force exceeds the element strength in the rock-mass. Some of the stress, after breakage, transfers to the surrounding rock-mass, which is consequently under the stage of energy -accumulating. Thus, the two tendencies finally form. One is that when the stress in the rock-mass tends toward equilibrium, the structure of the rock-mass inclines toward stability. The other is that when the load goes beyond the rock-mass long-term strength in the structure, the tiny cracks, after deformation, can be seen on the rise, developing into uneven movements, and eventually resulting in the instability and failure of the structure.

4. The main conclusions and suggestions

The main conclusions may come up from the AE and EME survey to the pile bases, the rock-mass within the geological bore holes and the floor of the basement of the building, the filling, the arch walls and the rock-mass within the bore holes of the arch feet of the cross-sections at 926m, 916.5m, 903m and 884m in the tunnel.

1. The pile bases and the rock-mass within the geological bore holes of the building are of weak mobility and the movement is intermittent.
2. The rock-mass of the tunnel's various cross-sections and its filling are both of weak mobility. The latter is stronger than the former.
3. The rock-mass mobility of the cross-section at 903m, from the cross-sections surveyed, is the highest, then 884m, 916.5m (with comparatively high energy rate of the AE) and 926m in turn.
4. It is suggested that the building and the tunnel be continuously monitored with the methods of the AM and the EME in long term in order to guarantee the safety of the building and the normal operation of the tunnel.

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Recenzent: prof. dr hab. inż., dr h. c. Bernard Drzęźla

Podsumowanie

Praca zawiera opis utylitaryzacji metod emisji akustycznej (AE) i emisji elektromagnetycznej (EME) do ciągłego monitorowania stanu tunelu i budynków usytuowanych w jego najbliższym otoczeniu. Pierwszym z rozwiązanych problemów było wyeliminowanie szumów AE i EME zakłócających pomiary stanu skał. Każda z wymienionych metod umożliwia ciągły monitoring zagrożonego obszaru przez analizę ilości i energii sygnałów sejsmoakustycznych (AE) i liczby sygnałów elektromagnetycznych (EME). Obydwie metody umożliwiają wskazanie miejsc o podwyższonym ryzyku zniszczenia skał. Uzyskane rezultaty wskazują na użyteczność metod AE i EME do stałej kontroli zagrożenia obszaru budynków i tunelu.