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Different Vibration Types under Earth and surface Change Due to Tunneling

Ahmed Mohamed abu khadrah [a], Esam Eldeen Yousry Helal[b] , Fahmy Salah Abdelhaleem[c] .

a. Demonstrator - Civil Engineering Department - Faculty of Engineering - Menoufia University.
B.Sc. in Civil Engineering, Faculty of Engineering, Menoufia University.
Email: ahmedabukhadrah@gmail.com.

b. Prof. of Hydraulics, Civil Engineering Department, Faculty of Engineering, Menoufia University.
Email: esameman@yahoo.com.

c. Associate Professor, Civil Engineering Department, Faculty of Engineering, Benha University.
Email: fahmyhri@gmail.com.

الملخص العربى :

هناك العديد من التغيرات التي من الممكن حدوثها تحت الارض . تكون تلك التغيرات علي شكل هبوط في سطح الارض او انهيار مفاجئ للارض والمباني الواقعه فوقها . في مجال هندسه الري قد تكون تلك التغيرات عباره عن نحر يحدث في قاع القنوات بما يؤثر علي سطح المياه والملاحه او علي شكل انهيار لجوانب الترع . تلك التغيرات تقع نتيجه الاهتزازات التي تحدث تحت الارض . تلك الاهتزازات تحدث نتيجه العديد من الاسباب منها الاهتزازات الناتجه عن حفر الانفاق باستخدام معدات حفر الانفاق المختلفه وايضا من الاحتكاك الحادث بين المركبات والقطارات التي تمر في الانفاق الارضيه بسرعه كبيره وسطح الارض . الاهتزازات الارضيه من الممكن ان تنتج ايضا من الزلازل الارضيه التي تؤثر بشده علي التغيرات الارضيه . ولاهميه تلك الاهتززات وتاثيرها الهائل علي سطح الارض يقدم هذا البحث يقدم مراجعه شامله لكل انواع الاهتزازات التي من الممكن حدوثها تحت سطح الارض كما يقدم حجم التاثير والتشوهات الناتجه علي سطح الارض من تلك الاهتزازات الارضيه .

Abstract:

Many changes may occur on the surface of the earth. Those changes may be in the form of settlement of the surface of the earth, collapse in buildings and structures, and in the field of irrigation the changes may be in the form of scouring of canals and embankment failure. All these changes occur as a result of underground vibrations that result from many things include tunnel boring machines, movement of cars and trains under the surface of the earth in its tunnels. Underground vibrations can also be generated by explosions and earthquakes. This article presents a background on the causes of these vibrations. The article also presents a review of the effect of these vibrations on the ground.

Keywords:

Ground settlement; micro seismic; Tunnel boring machines; Underground vibration.

Introduction:

There is an accelerated increase in recent decades to increase the boring of tunnels in order to facilitate the transportation of vehicles and people. Tunnel is a civil infrastructure that may exist in every place and passes under canals and buildings. Drilling is done by using tunnel boring machines that emit many vibrations that affect the changes in the surface of the earth. Also, the transfer of fluids is done using pipes that are sometimes installed using drilling machines. These vibrations can cause soil changes, especially when faults occur in these pipes. Also with the increase in the number of people more and more heavy transportation is required. Transportation is also can produce high vibration which can also affect the earth and cause settlement.

Loganathan and Poulos (1998) analytically determined the settlement and the movement of the ground in clay soil. They take in considerations the parameters that affect the settlement, such as the equipment used in drilling, the depth of the tunnel and its diameter, the initial stress state of the soils, and the behavior of the soil around the tunnel. They showed the limitations of empirical methods, such as they can be used under different conditions of the soils and with any construction technology. Lu et al. (2019) do centrifuge tests to determine ground surface subsidence, many intersection angles were considered, also many different ratios between the depth of tunnel and the diameter of the tunnel (C/D). The tests showed that the influence of the construction of the tunnel is ±1.25D along the tunnel. They also found that the settlement in the surface decreases by increasing the value of (C/D). Sun and Dias (2019) studied the perturbations that may happen to the initial stress state of the soil around the tunnel due to the construction of the tunnels and the effect of this disturbance in the initial state on the response of the tunnel during seismic waves by using numerical analysis. They found that the change in initial state has more effect on the axial force of seismic more than the bending moment of seismic. Singh and Seth (2017) studied the buried box tunnels which are exposure to seismic waves. And used these results to study the surface vibrations coming from on underground train and identify structural damage due to these vibrations. Mair (1993) discovered that the settlement in subsurface due to tunneling in clay can be subjected to a Gaussian curve, also he found that the value of (K) can vary with change in depth, where k is The parameter of trough width. Helal (2019) studied experimentally the existence of defects in pressure flow pipe and its effect on the bed morphology of the channel, he found that the Froude number and diameter of the defect in pipe have a great effect on the erodible bed than the other parameter. Hajian et al. (2009) used an artificial network to determine the location of qanats that exist under the earth. They found that any destruction in these Qanats can form a hazard for pipelines and structures. The ability of the hazard also increases in the existence of vibration around this Qantas. From this point of view, this article is a review of the different types of vibrations that can change the surface of the earth and the values of ground settlement.

Vibration induced by tunnelling:

Huang et al (2018) developed a system which can monitor the vibration of cutter-head which comes from the friction between the rock around the tunnel and tunnel boring machine (TBM).

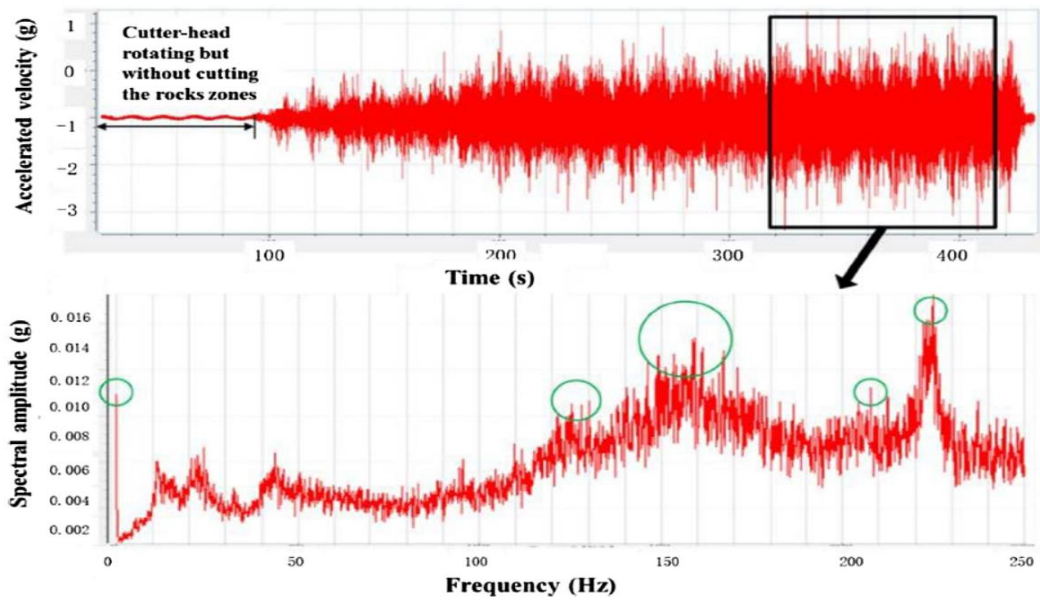

Fig. 1. Shows Frequency-domain analysis due to tunnel boring machine drilling.

The system is formed of sensors, data acquisition subsystem, and remote data storage – transmission. They using Fast Fourier Transformation for frequency analysis and found that during the stable digging, the vibration has a wide frequency range, and the spectral amplitudes of vibration between the frequencies 160 Hz to 170 Hz, 200 Hz to 210 Hz and 220 Hz to 230 Hz are bigger than amplitudes of other frequencies (Fig. 1). They found that the vibration of the cutter-head is markedly related to geological conditions of surrounding soils and the advanced parameters of tunnel boring machine. They also found that the vibration of cutter-head increases significantly with the increase in the penetration rate and the rotational speed.

Huo et al (2015) studied the dynamic response of the tunnel boring machine and determined the horizontal acceleration for the tunnel boring machine main frame during excavation. They found that the amplitude of the acceleration is about 1.5–2.5 g in normal conditions of excavation.

Vibration induced by vehicles:

Li et al (2019) studied the vibration from vehicles by made a vibration test to a tunnel passes underwater by using a network of accelerometer .The vibration test was done on The Tunnel which passes under Nanjing Yangtze River (NYR) .

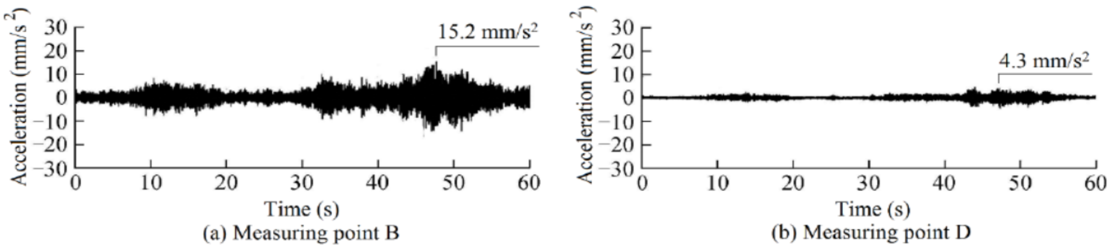

Fig. 2. Shows the Time-domain curve for the vibration acceleration at the middle lane.

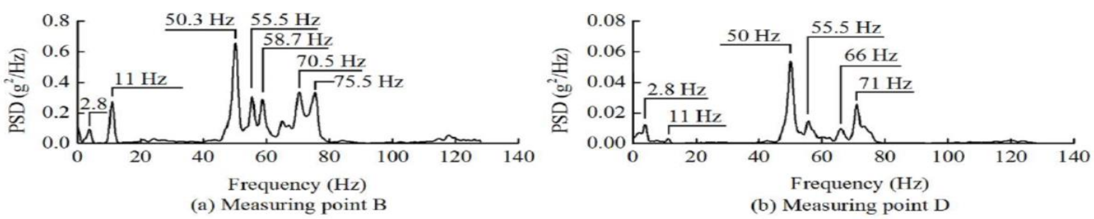

Fig. 3. Shows the vibration frequency of acceleration at the middle lane.

The Tunnel is an urban expressway tunnel with a design speed of vehicles equal to 80 km/h, and level A is the designed vehicle load for this tunnel. Layers of silty sand layers and soft soil existed. The results show that the maximum accelerations of the box culvert, the segment, and the pavement slab were 4.3 mm/s^2, 9.4 mm/s^2, and 19.7 mm/s^2, respectively. These results indicate that the amplitudes of the vibration of the tunnel's components which come from the vehicles are decreased obviously along its transmission path. They also found that the vibration frequency which is caused by local vibration of the supported slab under the pavement is about 11 Hz, and vibration frequencies up to 71 Hz are happened because of the roughness of pavement (Fig. 2 and Fig. 3).

Effect of Vibration on the surrounding ground:

Tsinidis et al (2019) introduce alternative methods for analyzing the damage modes steel pipelines buried under the earth and subjected to seismic wave produces ground deformations. Taking into consideration factors affecting the phenomena such as the pipeline pressure, the geometric problem in the wall of the pipeline, the properties of the site, and the spatial changeability of the seismic ground movement along the pipeline. Excavation of tunnels and the vibration from vehicles under the earth can cause movements of the underground soil around the vibration resource and can produce a disturbance of the initial stress state of the ground. The change in the soils can produce a change above the earth. Many scientists studied the effect of boring tunnels on the surface of the earth. Peck (1969) introduces an equation to evaluate the settlement which happens due to boring the tunnels in the transverse direction:

$$S = s_{max} \exp(-x^2 / 2i^2) \quad (1)$$

Where (S) is the value of subsidence at specific point of the ground surface, (S_{max}) is the greatest value of subsidence of the ground surface above center line of the tunnel, (x) is the lateral length from the centerline of the tunnel .the value of (i) is the length from inflection point to the center of the tunnel (Fig. 4.).

Golpasand et al (2019) developed a Numerical modeling which can determine the settlements of the ground, which is induced by tunneling near the earth (shallow tunneling).

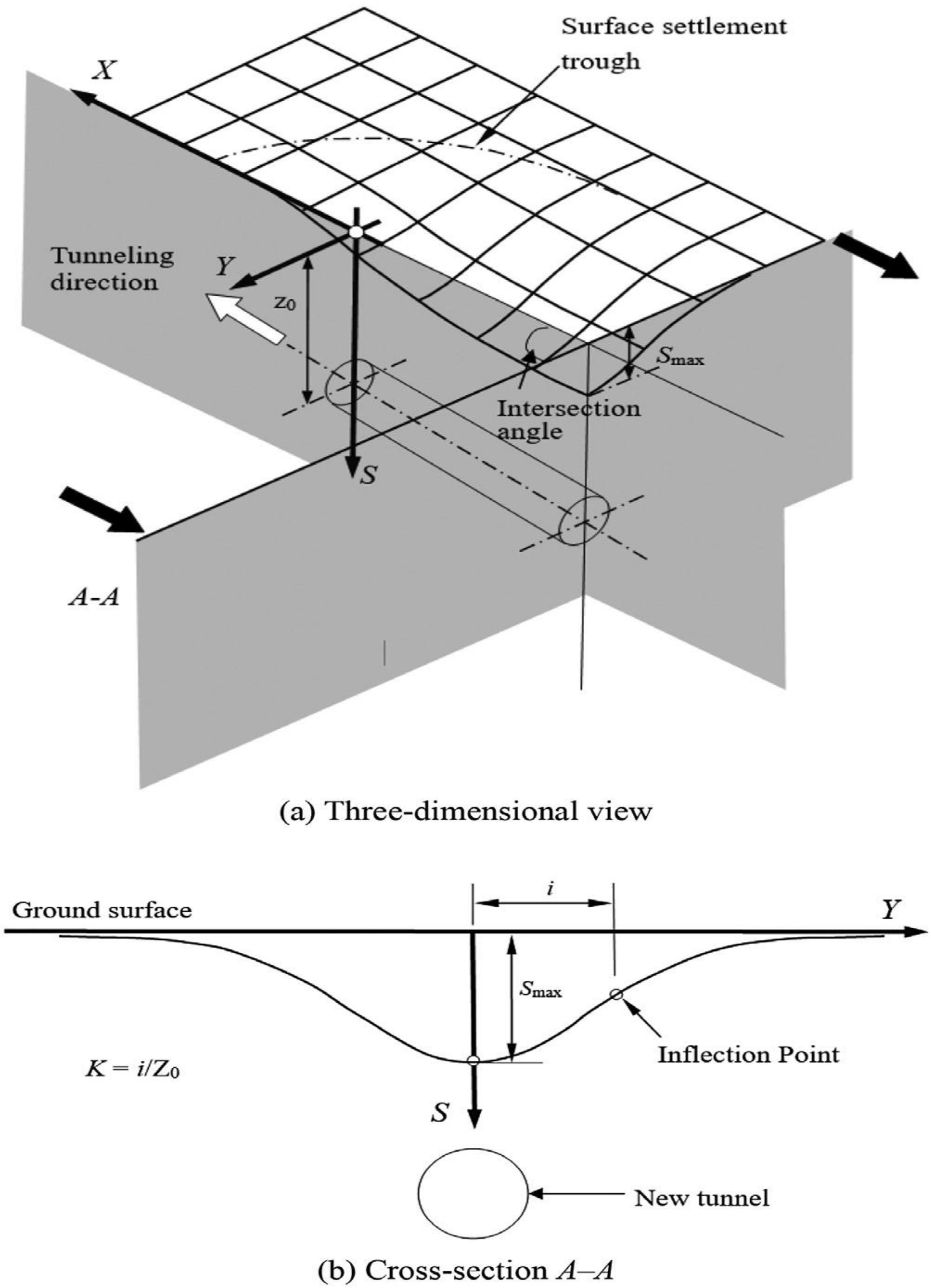

Fig. 4. Shows the ground settlement due to tunnel machine.

They used FLAC3D to build the 3D numerical analysis. In the numerical analysis Tunnel Boring Machine was made in simulation with similar properties to the site to simulate its effect and. They also define the geotechnical properties of the surrounding soil which is used in the model (Table .1).

Element	Thickness (m)	Elasticity modulus (GPa)	Poisson's ratio	Density (kg/m^3)
Segment	0.35	30	0.25	2500
Shield	0.35	200	0.20	7800

Table. 1. Shows the Properties of the segments and shield.

The face pressure is modeled in the model as a linearly varied normal stress affected to the face of tunnel. Also the Values of face pressures and grouting are chosen to accurate simulate the tunnel boring in the site as shown in (Table. 2).

Face Pressure (kPa)	Grouting Pressure (kPa)
150	170

Table .2. Shows the used numbers of face pressures and grouting used in numerical model.

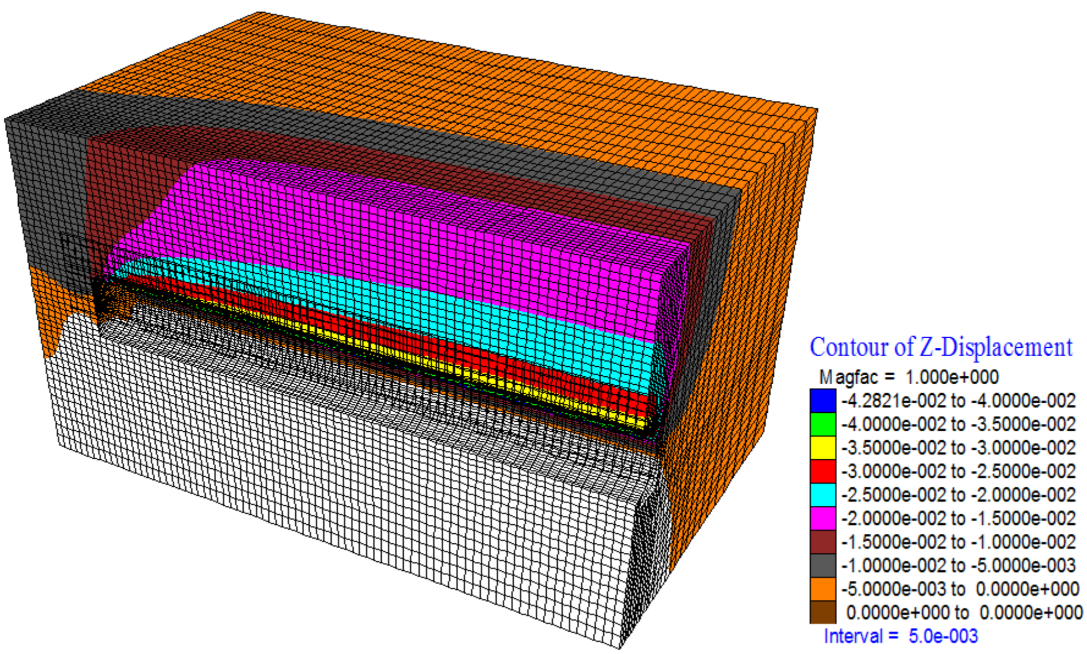

Fig. 5. Shows contours of the displacement due to tunnel excavation.

The numerical analysis results shown in (Fig. 5.). The figure shows the contours of the vertical displacements and contours of the vertical stresses. It was found that the maximum displacement in the surface of earth is happened above the tunnel center line and its value (S_{max}) range from 15 mm to 20 mm. Also (Fig. 6.) shows the value of the subsidence happened in the ground in a transverse section.

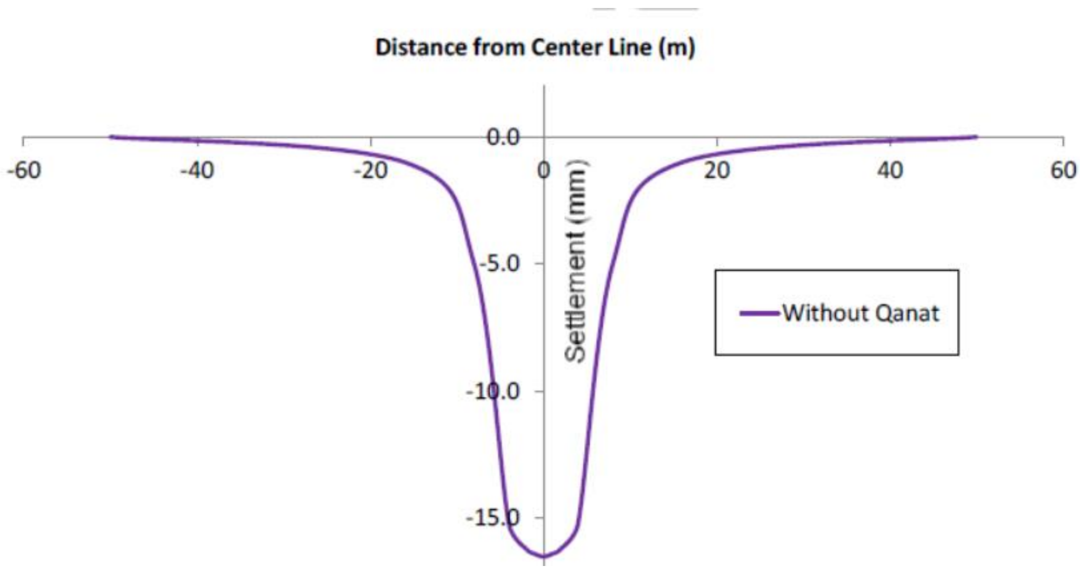

Fig. 6. Shows the ground subsidence due to tunnel excavation in a transversal section.

Cao et al (2016) are also studied the underground vibration by constructed a system which can evaluate and monitor the rock masses stability during the boring by tunnel boring machine. The micro seismic (MS) system can locate the unstable areas and the energy of instability events (cracks) in the local surrounding rock. TBM activity and the micro seismic event rate relationships and the relationships between TBM activities and energy released are shown in (Fig. 7.). They found that the number of energy released around drilling place and micro seismic events increase with the increase in tunnel boring machine activity .they also showed that to avoid the instability and cracks in the surrounding rock can be reduced by decreasing the speed of TBM tunneling.

Chapman et al. (2007) are also did a ‘‘1g” model tests that can define and locate the ground surface subsidence from twin tunnels and from multiple tunnels. They discovered that superposition of the Gaussian distributions from the individual tunnels is not able to give accurate results for estimation of ground settlement.

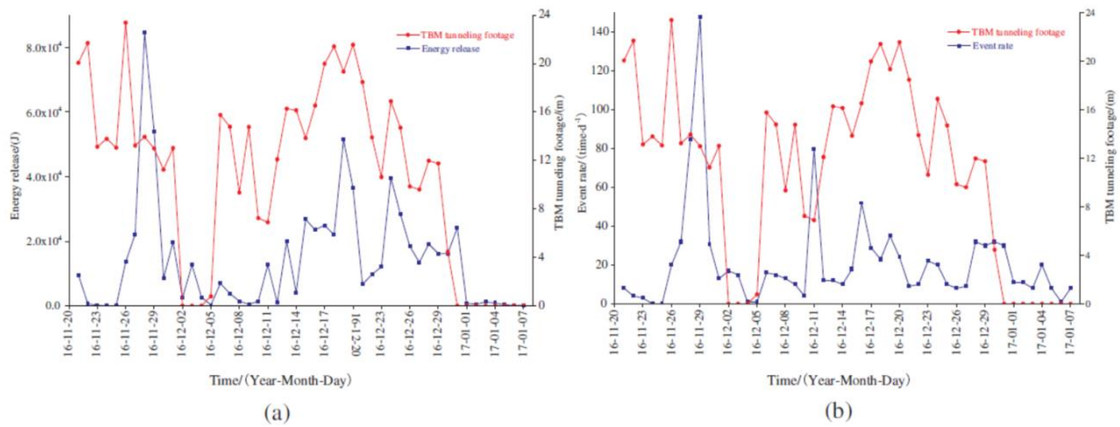

Fig. 7. (a) TBM activity and energy release relationship; (b) TBM activity and the micro seismic event rate relationship.

Conclusions:

Many types of vibrations may occur underground. These vibrations may result from tunneling machines, earthquakes, and also from vehicles passing underground. These vibrations cause changes in the surrounding soil. This article provides a brief overview of those vibrations and their impact on the surrounding environment. It's found that these vibrations have an effect on the surrounding earth, whether through a settlement in the soil or a collapse. Therefore, these vibrations must be taken into account when constructing these tunnels and develop systems that can suppression the vibration of tunnel boring machines.

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