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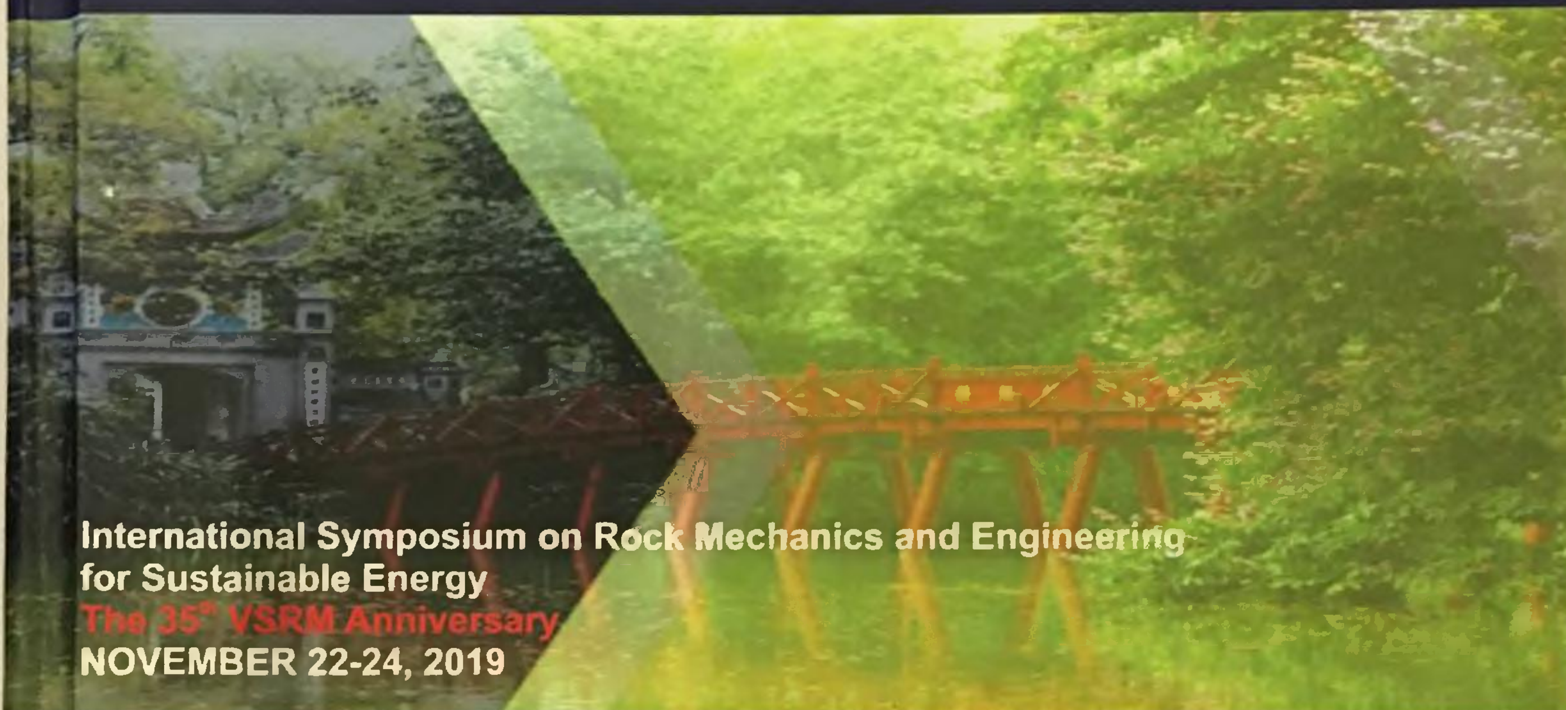

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Determination of destructive radius when applying a solitary explosion in block stone

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Abstract

Applying a solitary explosion in rock environment will make the contiguous zone destructive. This report shows the determination of destructive radius when applying a solitary explosion in underground construction. The calculation is established based on the determination of the stress field caused by explosion wave in the environment. The math test is determined by solving the equation of stress wave distribution in rock environment knowing the tensile strength limit. The result of the research could be used to indicate the distance between two explosives when using explosives to break the block stone.

Keywords: Wave Explosion, Underground Structure, Adverse Effect, Bomb's Load, Destructive radius.

1. Introduction

When applying the explosion, the environment climate will suddenly increase to 1500÷3600°C; a great energy of about 1000÷6000kJ/kg explosion is released; the volume of gas emissions and explosion pressure are increased. These effects are caused of propagation of stress wave in the environment and impacts of parts leading to the destructive environment.

The theory of wave propagation in heterogeneous environments is mentioned by many scientific researchers as Stocks. Poisson, Raylaigh (H. Kolsky, 1955). In the elastic, heterogeneous environment, the wave propagation equation has the form as:

$$G\Delta^2 u + (\lambda + G) GradDivu \quad + \mathrm{X} = \rho.\mathrm{u} \qquad (1)$$

Where (1): G - Lame coefficient; u- movement; ρ - specific gravity in wave propagation environment (for example: rock environment)

In elastoplastic environment and satisfactory Treski (Chita R., 1974) flexible conditions, the wave equation is represented as:

$$\frac{\partial u^2}{\partial r^2}+2\frac{\partial u}{r\partial r}-2\frac{u}{r^2}=2\chi\frac{\sigma_i}{r}+\frac{1}{c_p^2}\frac{\partial^2 u}{\partial t^2} \tag{2}$$

While including material's (rock) sustainable reduction phenomenon as a rule:

$$\sigma_\phi-\sigma_r=\chi\sigma_i+\sigma_i^*(\frac{\sigma_\phi}{k}-\varepsilon_\phi) \tag{3}$$

(2) can be rewrite as:

$$\frac{\partial\sigma_r}{\partial r}+\frac{2}{r}(\sigma_r-\sigma_\phi)=\rho\frac{\partial^2 u}{\partial t^2} \tag{4}$$

In these formulas (2), (3) and (4): σ_φ, σ_r - tangential stress and radial stress in planar coordinate system with (r, φ) pole respectively; ε - relative deformation; χ- coefficient mentioned changing sign (tensile: χ = 1; compressive: $\chi=-1$); σ_i^* - Material re-durability function.

When linearization the re-durability function, the spherical wave equation in elastic rock can be written as:

$$\frac{\partial u^2}{\partial r^2}+2\frac{\partial u}{r\partial r}-2\frac{u}{r^2}=\frac{1}{r}(1-\frac{E_1}{E})\frac{\chi\sigma_i}{(3K+E_1)}+\frac{1}{c_p^2}\frac{\partial^2 u}{\partial t^2} \tag{5}$$

In (5), c is transmission speed indicated by:

$$c=\sqrt{\frac{K(1+E_1/E)}{\rho(1-E_1/9K)}} \tag{6}$$

In (6): K- compressive volume modular; E_1- material re-durability modular according the linearization re-durability function in continuum mechanics (Navier motion equation; Cauchy geometric equations and equation of state for rock described by Poyting-Thomson model:

$$\dot{D}_\sigma=2GD_\sigma+2\eta\dot{D}_\sigma-\tau\dot{D}_\varepsilon \tag{7}$$

Could be helped to solve the problem of stress wave propagation in rock materials. In (7): D_σ, D_ε - offset stresses and strains tensors; τ, η - stress time and the environmental viscosity coefficient respectively.

According to (Chita R., 1974) and (Nguyen Van Can, 1991), in general case, it can be found an $A(t)$ function satisfied these four following conditions:

i). $t = 0$: $A(t) = 0$;

ii). $A(t)$ limited value;

iii). $$\tau\frac{\partial^2\sigma_r}{\partial_r\partial_t}+\frac{\partial\sigma_r}{\partial r}-\frac{12GA(t)}{r^4}-\frac{12\eta\dot{A}(t)}{r^4}-\frac{\rho\ddot{A}(t)}{r^2}-\frac{\tau\rho\dddot{A}(t)}{r^2}=0 \qquad (8)$$

iiii). $$\dddot{A}(\dot{D}_\sigma,\tau,\eta,\alpha)+\ddot{A}(D_\sigma,\eta,\alpha)+\dot{A}(D_\sigma,\alpha)+A(\alpha,t)+bF(t)+eP \qquad (9)$$

In (9), besides known parameter: $F(t)$- momentum wave explosion function; P- static pressure effects on rock; b, e- constant; α- parameter depends on type of transmissions ($\alpha = 1$ when spherical wave, $\alpha = 2$ when cylindrical wave). The calculation of (8) is not easy. By experience of separate example and choosing the suitable type of math test by (Nguyen Van Can, 1991) and (Nguyen Van Can, 1990), the calculation of (8) is implemented by finding function $A(t)$ that is satisfied the following equation:

$$\dddot{A}(t)+\frac{1}{\tau}\ddot{A}(t)+2\eta\dot{A}(t)+2GA(t)=\frac{a(1-\tau\alpha)}{\tau\rho}\left[F(t)-P\right] \qquad (10)$$

In (10): a- radius of explosion cabinet; $F(t)$- momentum wave explosion function that can be indicated according to (Nguyen Van Can, 1990) as:

$$F(t)=P_0\exp(-\psi t) \qquad (11)$$

According to (Nguyen Dinh Au, Nhu Van Bach, 1996):

$$P_0=\frac{0{,}1033V_0T}{273(1-\alpha_0\Delta)} \qquad (12)$$

In (11) and (12): V_0- air explosion volume, m^3; α_0 - coefficient; T- explosion temperature by Kelvin, °K; ψ - coefficient depends on the amount of explosives Q, explosion cabinet radius a, explosion temperature and: ψ = 6,4 T 104 a $Q^{-1/6}$.

Replace (12) into (11), then to (10), the equation is:

$$\dddot{A}(t)+\frac{1}{\tau}\ddot{A}(t)+2\eta\dot{A}(t)+2GA(t)=\frac{a(1-\tau\alpha)}{\tau\rho}\left[\frac{0{,}1033V_0T}{273(1-\alpha_0\Delta)}\exp(-\psi t)-P\right] \qquad (13)$$

The equation (13) is inhomogeneous equation that has constant coefficient and the characteristic equation form as: $S^3+\frac{1}{\tau}S^2+2\eta S+2G=0$, with S_i (i=1,2,3). Its own experience has a form of: $S_4=d\ t\ +f\ t\ e^{-\psi}$. The extensive experience of (13) is: $A\ t\ =D\ t\ +\sum_1^4 C_i\ t\ e^{k_i}$, where, $C_i\ t\ =f\ t$, k_i- depends on τ, η, a, α, Δ, T, V_0, ρ, Q,...; $D(t)$ - polynomial of t. Replace $A(t)$ into (8) will lead to the partial equation of $\sigma(r, t)$. Calculation of (8) give the result as:

$$\sigma\ r,t\ =\left[P+\frac{Pa^3}{r^3}\right]-\frac{2}{r^3}\times$$

$$\times\sum_{i=1}^{4}\frac{-\left[\ P_0-P\ S_i-P\psi\ \right]a.e^{S_i t}}{S_i\left[S_i^3+\frac{S_i^2}{\tau}+\frac{4\eta S_i+4G}{\tau\rho a^2}+\ S_i+\psi\ \left(3S_i^2+\frac{2S_i}{\tau}+\frac{4\eta}{\tau\rho a^2}\right)\right]\left[-\frac{S_i^3}{r}-\frac{S_i^2}{\tau\rho}+\frac{2\eta S_{i}}{\tau\rho r^3}+\frac{2G}{\tau\rho r^3}\right]}$$

Shorthand expression and name as M_i (i =1,2,3,4), it is shown as:

$$\sigma\ r,t\ =\left[P+\frac{Pa^3}{r^3}\right]-\frac{2}{r^3}\sum_1^4 M_i e^{S_i t} \tag{14}$$

Knowing $\sigma(r, t)$ could help to calculate other parts of stress and movement. For example, movement:

$$u\ r,t\ =\frac{Pa^3}{\tau\rho r^2}+\sum_{i=1}^{4}\frac{-(1-\tau S_i)[(P_0-P)S_i-P\psi]ae^{S_i t}}{r^2 S_i\left[S_i^3+\frac{S_i^2}{\tau}+\frac{4\eta S_i+4G}{\tau\rho a^2}+(S_i+\psi)(3S_i^2+\frac{2S_i}{\tau}+\frac{4\eta}{\tau\rho a^2})\right]}$$

Shorthand expression and name as N_i (i=1,2,3,4), We has:

$$u\ r,t\ =\frac{Pa^3}{\tau\rho r^2}+\sum_1^4 N_i e^{S_i t} \tag{15}$$

In the equations (14) and (15): S_i, M_i and N_i- depend on the mechanical indicators of environment G, η, τ and other constants. For example, for granite: G=927,4KN/cm^2; η = 830514 KN.s/cm^2; τ =8148 s then S_1 =-0,03; S_2=-0,002; S_3=-82,10; S_4 =-207,632.

2. Identify the destructive

Analyzing these equation (14) and (15), it can be seen that:

i) When t =0, $A(t)$ = 0 and calculating that:

$u\ r,t\ = \dfrac{Pa^3}{\tau\rho r^2}, \sigma\ r,t\ = \left[P + \dfrac{Pa^3}{r^3}\right]$ - This is Lame formula

ii) - Function $\sigma(r,\ t)$ decreases from the maximum value of $\sigma\ r,t\ \max = \left[P + \dfrac{Pa^3}{r^3}\right]$

when $r = a$ to 0 when r reaches interminable value.

iii) - Assume that at time $t = t_0$, after explosion corresponding to the distance between the explosion cabinet to considered point $r=r(t_0)=r_0$, $\sigma(r,\ t) = \sigma(r_0,\ t_0) = \sigma_0=[\sigma]_n$, stress wave value is equal to the durability limitation and create the boundary area:

- When: $r \leq r_0$: $\sigma(r,\ t) \geq [\sigma]_n$ - destructive area;

- When: $r > r_0$: $\sigma(r,\ t) \leq [\sigma]_n$ - elastic fluctuating area (the commotion): rock is not destroyed.

Therefore, by knowing $\sigma(r,\ t)$ it can be identified the destructive area by explosion (means that the destructive area radius) from the condition of:

$$\sigma\ r,t\ \geq \sigma_{*} \tag{16}$$

Where $[\sigma]_n$ - rock durability limitation.

The formation of changing environment area around the explosive is explained as followed: While explosion, the rock surface is interacted with the explosive and affected by the explosion wave all over the contact area. The high-speed explosion wave changes to high amplitude beating wave leading to rock crush. When the area is far from the explosion, the amplitude of beating wave decreases. At one distance, the beating wave becomes elastic wave with the same speed transmission of rock and environment:

$$v = \sqrt{\frac{E\ 1-\mu}{\rho\ 1+\mu\ \ 1-2\mu}} \tag{17}$$

where: E, μ - rock elastic module and Poisson coefficient respectively; ρ- rock density. If the stress of explosion wave is more than rock compressive strength limitation $[\sigma]_n$ rock will be destroyed. In this area, rock is also destroyed by great gas explosion pressure (about (20÷70).108 N/m^2). Under the effect of explosion wave and gas explosion pressure, there are radial cracks and around cracks in by the stress and tangential stress effects. The further the explosive is the lower the explosion stress is. This value is also lower than rock durability limitation. The environmental elements are not destroyed and fluctuated around the equilibrium position to create the commotion.

The destructive area radius can be identified following the formula (16) or empirical formula as (Nguyen Dinh Au, Nhu Van Bach, 1996):

$$r_6 = \frac{d_t k_m}{2}\sqrt{\frac{\sigma_*}{2\sigma_k}} \qquad (18)$$

where: d_t - diameter of explosives; k_m- cabinet expansion coefficient (k_m=$2r_2/d_t$); r_2- small crush rock radius (near the explosive); r_2/d_t=2÷5; σ_k- rock tensile stress limitation.

1. The full explosion production explosion cabinet; 2. Rock's destructive area; 3. Elastic deformation area

Fig. 1. Changing environment area by explosion effect

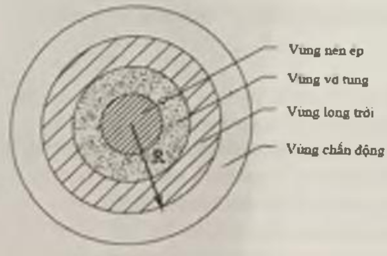

Fig. 2. Rock's destructive area when explosion

a b

a- ground; b- hard rock When applying the explosion

Fig. 3. Inside destructive area

The commotion area is the quality to test the seismic situation and the concussion situation of construction works around

3. Conclusions

- Explosion creates the stress wave propagation due to explosion pressure: radial stress and ring stress:

Radial stress makes environmental movement and appearance of cracks around the explosive.

Ring stress leads to radial cracks

The result is the destructive environment divided into discrete elements related to radial cracks and ring cracks, ...

- If the explosion stress and environmental material duration limitation are determined, the destructive area radius and effected commotion radius area can be identified.

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