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ANALYSIS OF THE FUNCTION RELATIONS BETWEEN THE DEPTH OF GAP OR SLOT AND THE SPEED OF VIBRATION IN MILLISECOND MULTIPLE-ROW HOLES BLASTING

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ABSTRACT

In order to analyze the attenuation law of blasting vibration wave through the damping groove, and to explore the function relations between the damping groove depth and damping effect of affiliation; the discussion about the blast hole millisecond firing initiation technique is based on the numerical simulation analysis software ANSYS / LS-DYNA; in the process of explosion, vibration wave of blasting through the damping groove attenuation in a plurality of rows of holes is researched; and get the membership function by MATLAB simulation. The engineering blasting damping ditch used in breaking for verifying the rationality. By comparing simulated and real results, when the damping groove depth is 1.2 times the depth of the hole, the damping effect is the best.

KEYWORDS

Gap or slot, millisecond blasting, attenuation law, modeling and simulation.

1. INTRODUCTION

With the development of economy, the blasting excavation technology in the application of the engineering construction is becoming more and more widely. And use of large-scale blasting excavation technology make many blasting hazards increasingly highlighted. For example, blasting vibration on the damage of structures is one of the problems that not allowed ignoring [1,2]. Blasting vibration can affect the safety of buildings, sometimes it can even lead to a civil dispute or major social problems. So, the research on the harm of blasting vibration and the corresponding control measures are important hot topic in the field of blasting.

Because of the blasting vibration wave is ephemeral and mutability, it involves multiple natural disciplines, which is explosion dynamics, structure mechanics, and the theory of nonlinear respectively. So, the study of blasting vibration damage mechanism is a complicated process, it is hard to obtain exact solution by theoretical analysis. So, analyses the harm of blasting vibration on the surrounding buildings object by numerical simulation method becomes crucial. At present, the method to control the explosive charge, decoupling charge, millisecond blasting, and pre-split isolation are commonly used to reduce blasting vibration wave propagation [3]. In pre-split isolation, the people usually play a row hole, the depth of which is as well as the main blast hole. Before the main blast hole blasting, forming a damping groove. Concerned from the economic and technical level, what a function relationship between the damping groove depth and vibration velocity can lead to a best effect of Shock absorption is the focus of research article [4]. We adopts the numerical simulation analysis software ANSYS/LS-DYNA to study attenuation law of blasting vibration wave that have gone through damping groove in the process of Multiple-row holes blasting, take the damping ditch for example, through the numerical simulation analysis, linear regression equation is established, then obtained the curvature radius of regression equation , obtained subordinate function relations between groove depth and reduce vibration velocity , and work out the best distance ratio of the depth of the damping groove and the depth of blasting hole in the way of Multiple-row Holes Blasting [5].

2. NUMERICAL SIMULATION OF DAMPING GROOVE IN MOUNTAIN BLASTING

2.1 The numerical simulation models

Regarding the grading excavation blasting, according to the engineering requirement, the whole excavation divided into a zone and B zone, the numerical simulation was carried out on the area A, validation analysis was carried out on the area B [6]. Through measured, district is 90 m, width is 120 m, to 20 m high, and the rock is light weathered granite. Using bench blasting excavation, millisecond multiple-row holes blasting, the main blast hole diameter of 90 mm, the minimum resistance line for 3 m, 11 m hole deep, pitch of 3.5 m, from 3 m, Single hole charge of 42 kg [7]. On an area excavation blasting simulation, the Relations between the depth of Gap or slot and the speed of vibration in Millisecond Multiple-row Holes Blasting is studied.

2.2 The selection of model parameters

2.2.1 The selection of rock parameters

The selection of rock parameters is according to rock mechanics parameters standard proposed by the exploration and design institute of Kunming. Blasting object is granite, density of material (ρ) is 2600 kg/m^3, the elastic modulus (E) is 5.57 e+9 Pa, Poisson's ratio (u) is 0.27, the yield stress is 100 Mpa, the cohesive strength (C) is 0.8 e+6 Pa, hardening parameter (β) is 0.5. The rock material is 3D Solid1.

2.2.2 The selection of explosive model

In simulation analysis, the explosive materials are based on LS-DYNA of high explosive material. It is shown in table 1

Table 1: Model of explosive parameters selection

MID	RO	D	CJ	BETA	K	G	SIGY
1	1.049E+00	4.530E+00	2.70E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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2.2.3 The selection of air model

Air material selection of LS-DYNA fluid material; use the multiple linear state equations to provide pressure components. The state equation is:

$$P=[C_0+C_1\mu+C_2\mu_2+C_3\mu^2]+[C_4+C_5\mu+C_6\mu^2]e_{ipvo} \qquad (1)$$

The related parameters are shown in table 2

Table 2: The selection of the air state equation parameters

C_0	C_1	C_2	C_3	C_4	C_5	C_6	E_{ipv0}	V_0
0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.25	1.0

2.2.4 Select state equation

LS-DYNA program uses JWL (Jones-Wiikins-Lee) equation to describe the relationship of high explosive detonation products' pressure - volume. Unit pressure of high explosive detonation products is obtained by the state equation, relation of P - V in JWL state equation is as follows:

$$p=A\left(1-\frac{\omega}{R_1V}\right)e^{-R_1V}+B\left(1-\frac{\omega}{R_2V}\right)e^{-R_2V}+\frac{\omega E_0}{V} \qquad (2)$$

The parameters are shown in table 3.

Table 3: The JWL state equation parameters selection

EOSID	A	B	R1	R2	OMEG	E0	V
3	7.41E+11	0.182E+11	5.56E+00	0.35E+00	1.65E+00	3.6E+09	3.0E+00

2.3 The establishment of the model

Based on Finite element analysis software ANSYS LS-DYNA, the space model is established. In order to simulate the engineering practice, a top surface and three sides in a free boundary reflection condition, bottom and back under no reflection boundary condition [8,9]. Obtained model diagram and the grid after inputting the model parameters, the model diagram and the grid is shown in figure 2.

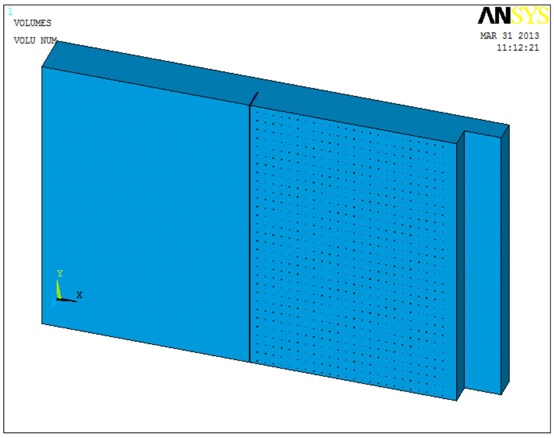

Figure 2: Finite element divisions

2.4 Modeling and simulation

To study the different depth of the damping groove, have influence on damping Effects, choose groove depth of 7 m, 9 m, 11 m, 13 m, 15 m in the simulation. The damping groove depth to drilling depth ratio is 1:0.6 ; 1:0.8 ; 1:1 ; 1:1.2 ; 1:1. 4respectively.In the mid-line of the damping groove, setting two monitoring stations to detect three directions of vibration velocity, the first monitoring station for 50m distance to the damping ditch, the second monitoring station for 80m distance to damping ditch [10-12]. Its monitoring location is shown in figure 3.

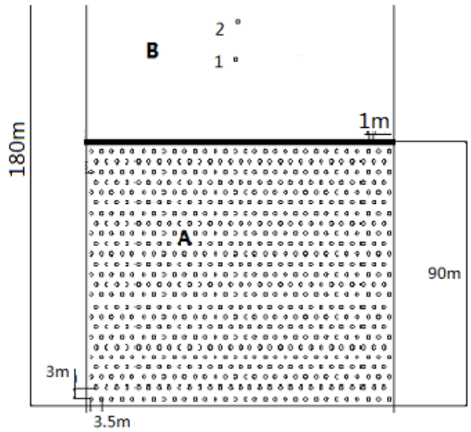

Figure 3: Sketch map of monitoring station

2.5 Data analysis and processing

In the mid-line of the model, the damping ditch 50 m and 80 m distance set two key points A and B, A point coordinates of (40, 60, 20), point B coordinates of (10, 60, 20). The position parameter of the reference point as shown in table 4.

Table 4: Vibration velocity of reference points A and B

Monitoring Station	Distance	Depth (*m*)	Horizontal radial velocity cm/s	Vertical radial velocity cm/s	Horizontal tangential cm/s	Horizontal radical slope *k*
A	50m	—	4.3217	4.1528	2.5239	
		9	3.2827	3.3083	1.7379	
		11	2.8198	2.3491	1.5382	k=0.2314
		13	2.2732	2.1029	1.0346	k=0.2733
		15	1.9983	2.0392	0.8394	k=0.1374
B	80m	—	3.8770	3.2348	2.1394	
		9	2.9893	2.6379	1.5237	
		11	2.4879	2.1837	1.3784	k=0.2507
		13	1.9273	1.7823	1.0938	k=0.2803
		15	1.5374	1.6383	0.8374	k=0.19995

It Can be seen from the numerical calculation data that The influence of vibration wave on horizontal radial velocity is the largest; when damping groove depth is less than the depth of the hole, the damping effect is not obvious; When the damping groove depth is 11-13 m, the ratio of damping groove depth to the depth of holes equal to1 ~ 1.18, the vibration reduction effect is best; When the ratio is greater than 1.3, the improvement of vibration reduction effects is not obvious [13]. The research results show that improve overmuch the damping groove depth in blasting engineering, the improvement of vibration reduction effects is not obvious, it's also unreasonable in the aspect of economy. Through calculation of the horizontal radial slope, the location of the maximum change rate of the groove depth and vibration velocity in the damping groove depth of 11 to 13m is 1 to 1.2 times the depth of the hole. Using the least square fitting to deal with the data. Making curve fitting for horizontal radial velocity [14]. In the process of blasting vibration wave transmission, vibration velocity will decay with the increase of damping groove depth, according to the distribution of vibration measuring point, fitting equation to get the Function Relations between the depth of Gap or slot and the speed of vibration:

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$$y = ae^{\frac{b}{x}} \quad (3)$$

The fitted curve is shown in figure 4.

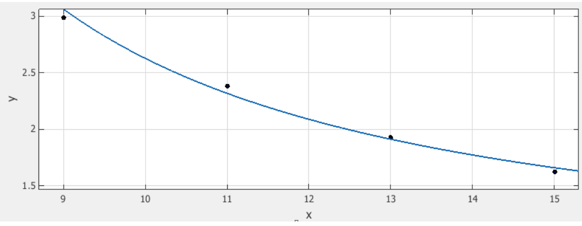

Figure 4: The function fitting curve

Through curve fitting, parameters a, b is a = 0.6624, b = 13.78. A function of the damping groove depth and the speed of vibration-damping as follows:

$$y = 0.6624e^{\frac{13.78}{x}} \quad (4)$$

The curvature equation is:

$$K = \frac{|y''|}{(1+y'^2)^{3/2}} \quad (5)$$

For the derivative of y, got $y' = 9.127872(-\frac{1}{x^2}) \cdot e^{\frac{13.78}{x}}$,let y'=0, Get the smallest curvature point and that's the function extreme point, x=13.1983

So when x = 13.1983, the function have maximum rate of change, when the depth of the damping ditch is 1.2 times that of blast hole, the damping effect is best.

3 ENGINEERING VERIFICATION ANALYSIS

3.1 The main blast hole design

Blasting validation analysis was carried out on the B area, adopting the CL100Y down-the-hole drill, including the main blast hole diameter is 90 mm, explosive choose powdery emulsion explosive, explosive load per linear meter hole is 6 kg. Bench height H to 10 m, the blasting network parameters as shown in table 5.

Table 5: Main blast hole network parameters

No	Parameter Name	Calculation method	Unit	Result
1	Bench height	H	m	10
2	Bore diameter	d	m	0.9
3	Chassis line resistance	W_d=(0.4～1.0)H	m	3
4	Pole distance	a=(1.0～2.0)W_d	m	3.5
5	Row distance	b=(0.8～1.0)W_d	m	3
6	Hole depth	L=H+h	m	11
7	Charge quantify	Q	kg	42
8	Charging length	L1	m	7
9	Block length	L2=L-L1	m	4

3.2 Parameter design of pre-split holes

Blasting of slope excavation using presplit blasting, charge structure adopts divided charge, Tie the roll diameter of 32 mm cartridge on the detonating cord, each hole charge 3.6 kg, strengthen charge within two meters at the bottom of the hole, Middle part adopts the non-coupling charge, close-grained filling orifice 1.2m with stemming, initiated with detonating tube detonator. Pre-splitting blasting parameters as shown in table 6:

Table 6: Pre-splitting blasting parameters

No	Parameter Name	Unit	Result
1	Bore diameter	mm	90
2	Pole distance	m	1.2
4	Hole depth	m	11
5	Cartridge diameter	mm	32
6	Charge quantify	kg	3.6
7	Block length	m	1.2

3.3 Error between two rows of holes

Blasting area near the south road, the southwest of blasting area 215 m have one houses. In order to reduce the largest single charge and reduce blasting vibration velocity, hole by hole blasting technique is adopted. Powdery emulsion explosive is used in the construction, learned Short delay of between 7.8 ~ 17 ms from the experience formula. So, the 2 detonator MS2, delay time of 25 ms. After calculating the time interval between two rows of holes for 48 ~ 62 ms, so adopting the 4 segments (MS4) millisecond delay detonating tube detonator, delay time of 75ms, adopting 2 segments millisecond delay detonating tube detonators between the hole and hole, adopting 10 millisecond delay detonating tube detonators inside of hole, the total delay time of 2925 ms.

3.4 Monitoring location

In the mid-line of the damping groove, setting two monitoring stations to detect three directions of vibration velocity, the first monitoring station for 50m distance to the damping ditch, the second monitoring station for 80m distance to damping ditch.

3.5 The vibration test and analysis

Test instrument by Chengdu VIDTS Dynamic Instrument Co. Ltd production EXP3850 blasting vibration meter and the speed sensor of form a complete set, which can measure the horizontal radial and horizontal tangential and vertical direction vibration velocity at the same time. Horizontal radial vibration has the biggest influence on the speed of vibration, so it is reasonable to study horizontal radial maximum blasting vibration speed. After blasting, got waveform diagram of A, B two parameters point, as shown in figure 5.

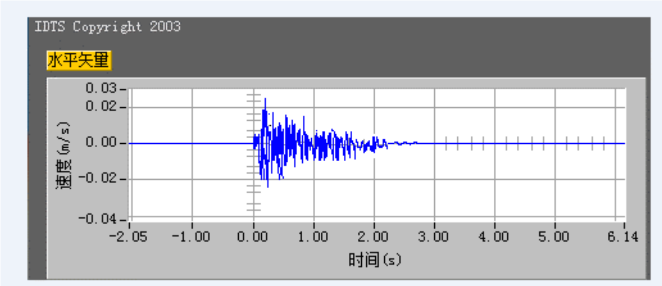

Figure 5: (a) Point A horizontal radial vibration velocity waveform figure

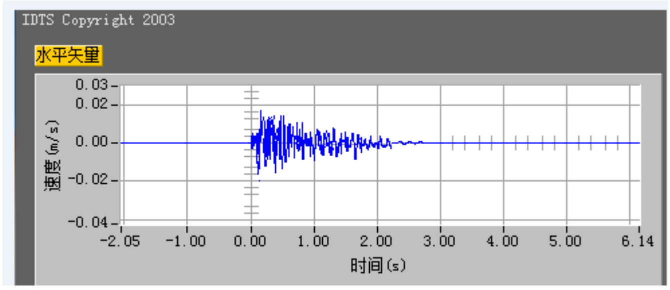

Figure 5: (b) point B horizontal radial vibration velocity waveform figure A and B two points of maximum vibration velocity of 2.1 cm/s and 1.8 cm/s can be got from waveform figure. The vibration parameters as shown in table 7

Table 7: The vibration parameters of A, B

Monitoring point	Distance to damping groove m	Depth of damping groove *m*	Horizontal radial vibration velocity *cm/s*
A	50	13	2.1
B	80	13	1.8

4. CONCLUSIONS

According to the vibration tester to get the measured blasting vibration velocity number of A and B two points were 2.1 cm/s and 1.8 cm/s. Known of A and B two points of the blasting vibration velocity numerical simulation results were 2.27 cm/s and 1.93 cm/s. The results of numerical calculation compared with the measured values, the error was 8% and 7% respectively. That is relatively close to numerical simulation and the measured values, it is also verify the validity of the conclusion that “when the depth of the damping ditch is 1.2 times that of blast hole, the damping effect is best. This was got in the experiment of modeling and simulation.

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