Article

Site experiments for blasting vibration reduction using controlling initiation

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Test blasting was carried out for the applicability of vibration reduction method by controlling the initiation time in the quarry. The blasting design was taken like that the blast hole interval is 2m as 10 holes 4 stages, line of least resistance is 2m, blast hole diameter is 65 mm. The blasting initiation time of the experiments set difference time every 10 holes 1 stage. The initiation delay time was calculated by the frequency analysis of the test blasting vibration. Simultaneously, it also obtained a delay time as largest negative correlation according to autocorrelation function of vibration waveform, and the setting method of optimum delay initiation time was discussed.

The maximum of vibration level is about 22.5 Hz as the result of the frequency analysis of test blasting. So the optimum time difference is 22.2 ms each initiation time. This value shows a negative value even in the analysis according to the autocorrelation function. It was shown that the blasting vibration could be reduced by the interference of the blasting vibration with optimum time by the frequency analysis using precise initiation machine and electric detonator on the field experiment in the quarry.

1. Introduction

Blasting is widely used in mining and fundamental construction because of its speed and economy to destroy the rocks and building. Blasting has the advantages of reduced excavation costs and shortened construction time when compared to the use of heavy machinery for excavation and cutting such as that with a tunnel boring machine. However there are some problems with blasting, including the noise, vibration and fly rock. It becomes a serious problem that the blasting vibration is reduced in mining and fundamental construction. As general blasting vibration method for reduction, the following method are used: method of reducing the charging volume used in the blasting of one time and method of increasing number of steps of delay time blasting. However in these methods, the work efficiency of blasting will be lower, and the operation costs increase. Therefore, by controlling the initiation time precisely with the precise blasting machine, the reduction method of blasting vibration using interference phenomenon of blasting vibration was studied. In this method, the vibration reduction was examined by the interference of generating vibration. In addition, the result is good from PMMA plate model test by the mortar block and small scale experiment of protective wall[1)2)]. Test blasting was carried out on the applicability of vibration reduction method by the initiation time control method to the quarry.

Received : May 17, 2002
Accepted : September 2, 2002
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2. The principle of the vibration reduction

The principle of the vibration reduction method of the blasting vibration by the interference is according to the following. For example the blasting

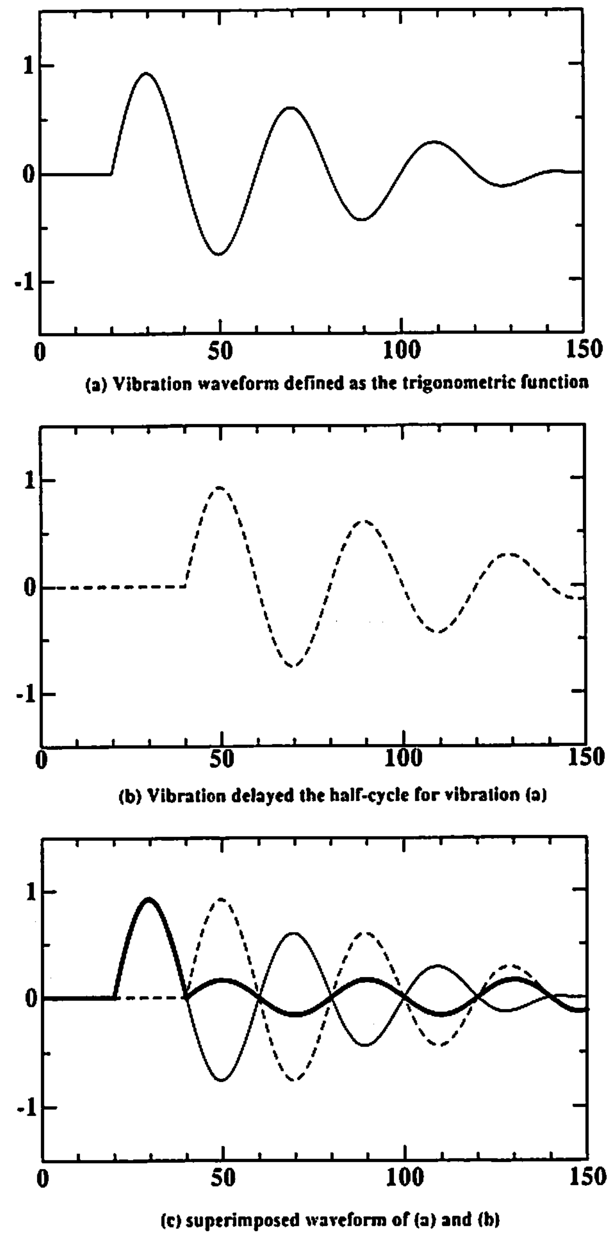


Fig. 1 Principle of the vibration reduction method by the interference

vibration assumes the vibration waveform defined as the trigonometric function which attenuates in the fixed period shown in Fig.1. When the vibration waveform (a) is superimposed by the vibration waveform (b) delayed the half-cycle frequency time in Fig.1, the amplitude of the interfered waveform is reduced. The first peak amplitude of blasting vibration becomes a half less than the case in which there are same waveform at the same time, and the vibration can be reduced. However, in actual blasting, the waveform of blasting vibration is complicated, and it is not easy to decide time difference. Therefore, the method for deciding the optimum time difference using the correlation function was examined and the good result by model tests was obtained. Correlation function and optimum time difference by frequency analysis are theoretically same. The method to decide the optimum time difference by the frequency analysis method out of consideration of applicability with field was examined.

3. Experiment

3.1 Experimental method

The field experiment was used the blasting bench (bench height: about 5m) of the quarry under work at present. The blasting design was taken as follows; interval of the blast hole is 2m and 10 holes stage × 4 stage, line of least resistance is 2m, blast hole diameter 65 mm, the blasting initiation time of the experiment set each stage at the difference time. The summary of the blasting design for these experiments is shown in Fig.2.

The 1st stage 10 holes was connected in the one initiation circuit and it initiated in order from the first stage to the final stage using the precise initiation machine (initiation circuit : 5ch, initiation accuracy : 1 μs, setting time : 1 μs ~ 10s, charging voltage : over 2500V, condenser capacity : 4μF/ch, output current : over 1kA) made by Nippon Kayaku Co.,Ltd.. In the experiment, the following two kinds of detonator were used and the difference was examined: Instantaneous electric detonator and electric detonator for seismic exploration. ANFO explosive 7.2kg charging volume was used for each hole. The slurry explosive 0.2kg was used as a booster for the initiation of ANFO explosive. The blasting waveform was measured using the accelerometer which were set in the field (50 ~230m) between the initiation point and front face.

3.2 Decision method for the optimum time difference.

In the experiment, the referential blasting vibration generated by the blasting of 10 holes per 1 stage is measured in order to decide the optimum time difference at the beginning. The time difference of initiation for each blasting was calculated from the frequency analysis of reference

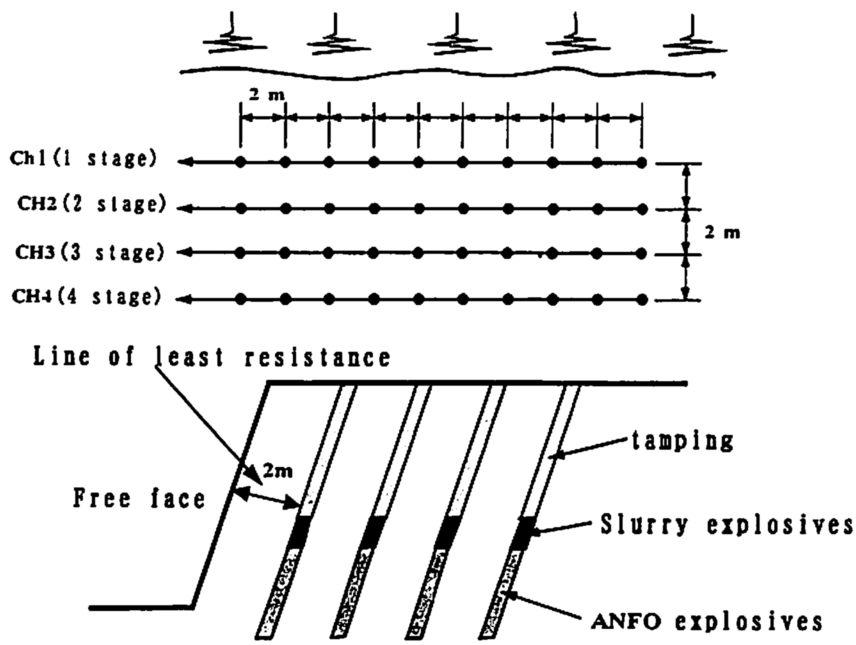


Fig. 2 Blasting design for experiments

blasting vibration. Simultaneously, a time difference as the most negative correlation according to autocorrelation function of blasting waveform was also obtained. The optimum time difference for vibration reduction method was examined from these results.

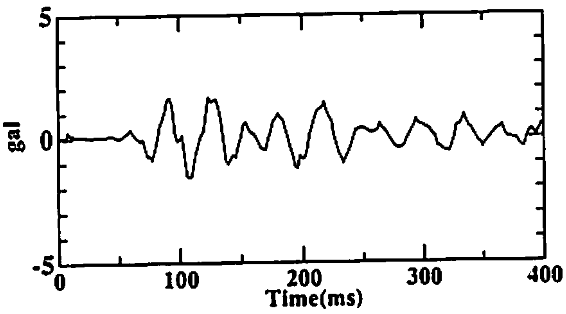
4. Results

4.1 Analytical result of referential blasting vibration

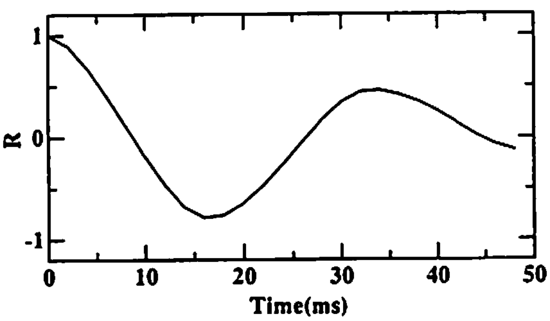
The waveform generated in the blasting of 10 holes per 1 stage as a referential waveform is shown in fig.3 (a). Results of autocorrelation function and frequency analysis of this vibration are shown in Fig.3 (b)(c). The maximum frequency by the frequency analysis result became about 22.5Hz and the initiation time difference became 22.2ms difference. This time difference also became a negative value in the analysis according to autocorrelation function. From these results, the vibration reduction by the interference of waves can be expected by setting an initiation time difference with 22.2ms. The experiment of the 10 holes stage × 4 stages blasting design was carried out on the optimum time difference to be 22.2ms. In blasting vibration reduction experiment by using the wave interference method, it was made to be an initiation time difference of first stage =0ms, second stage =22.2ms, third stage =44.4ms, fourth stage =66.6ms was used.

4.2 Prediction of the blasting vibration.

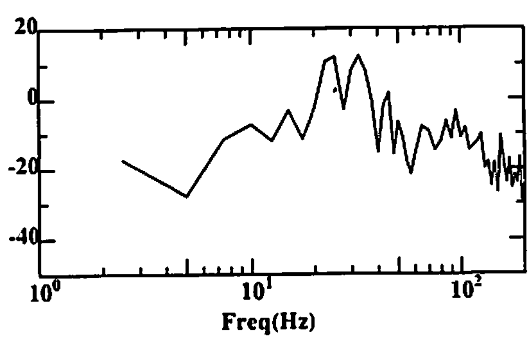
Blasting vibration waveform generated by the blasting waveform of 10 holes of 1 stage which was gotten in the referential blasting at 10 holes of 4 stages is estimated in order to confirm vibration reduction effect by a setting time difference. The vibration level was predicted on the computer simulation in case of 10 holes 4 stages blasting. The blasting vibration reduction effect was estimated by superimposing the referential vibration waveform by the difference time at frequency analysis result, autocorrelation function and time difference in the simultaneous initiation. The peak value of blasting waveform simulation is shown in Fig.4. The maximum amplitude values of each difference time were shown in Fig.4(referential vibration: ○, correlation function analysis: ◎, frequency analysis:△, simultaneous initiation:●). In simultaneous initiation method, the peak of blasting vibration became 4 times of referential vibration from the analytical result. However, the blasting waveform interferes, when it initiated with time difference at frequency analysis and correlation function analysis, and it can be estimated that the sufficient vibration



(a) Referential waveform of blasting vibration



(b) Result of autocorrelation function analysis for referential wavefrom



(c) Result of frequency analysis for referential waveform

Fig. 3 Result of analysis for blasting vibration

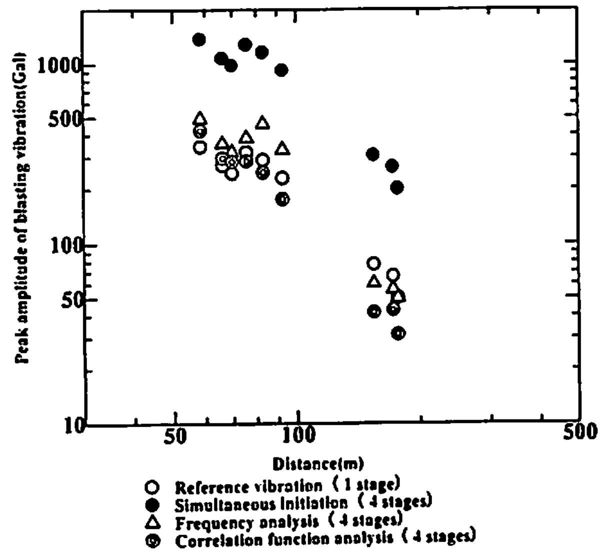


Fig. 4 ○Reference vibration (1 stage)
●Simultaneous initiation (4 stage)
△Frequency analysis (4 stage)
◎Correlation function analysis (4 stage)

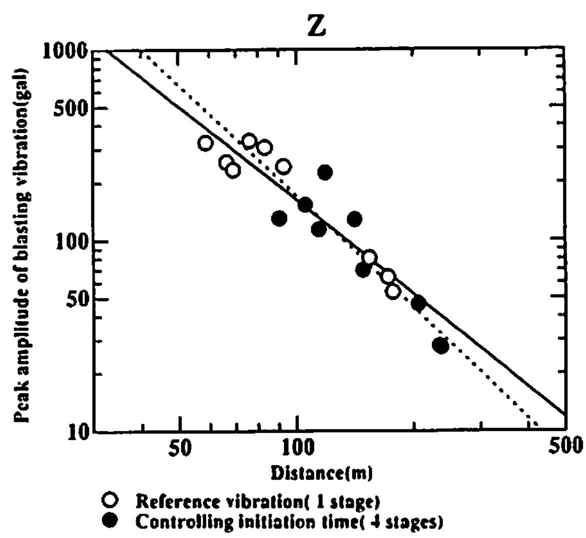


Fig. 5 ○Reference vibration (1 stage)
●Controlling initiation time (4 stage)

reduction effect will be obtained. It can be estimated that the vibration reduction is more effectively on far from the initiation point from the analytical result. It can be estimated that the vibration reduction by the setting of the initiation time difference according to the correlation function is more effectively than by the setting of the initiation time difference by the frequency result.

4.3 Vibration reduction result by the wave interference

The blasting experiment of the 10 holes of 4 stages was carried out changing the optimum time difference of each line with 22.2ms obtained by the analytical result of referential waveform. The analysis of referential waveform generated by instantaneous electric detonator and detonator for seismic exploration was almost similar. It was shown that it is able to initiate by the instantaneous electric detonator at the accuracy sufficiently. The each blasting line was initiated from the measurement of vibration waveform to the setting way, and it is proven that the blasting vibration has interfered each waveform. The maximum acceleration of the referential and controlled vibration by the initiation time is shown in Fig.5. The ○ symbol in the Fig.5 shows the maximum acceleration in the referential blasting vibration (10 holes of 1 stage) The ● symbol in the Fig.5 shows the maximum acceleration in vibration reduction experiment (10 holes 4 stages) by the wave interference. It was shown that by setting at the initiation time difference by the frequency analysis and using precise initiation machine, usual instantaneous electric detonator or detonator for seismic exploration from the analytical result, the waveform interfered in the blasting of 10 holes 4 stages, and that it can control the maximum amplitude which is equivalent to the waveform of 10 holes 1 stage as reference waveform. The initiation time difference was set from blasting experiment of real scale from the analytical result of vibration waveform, and it was clarified that the sufficient vibration reduction effect was obtained by initiating precisely.

5. Conclusion

The field application experiment was carried out on vibration reduction method by the wave interference in order to reduce the blasting vibration. Conclusions are briefly summarized as follows;

1. It was proven that there was no difference between blasting vibration by instantaneous electric detonators and by detonators for seismic exploration. The optimum initiation time was set from the frequency analysis of vibration waveform, and it also was shown the negative correlation even in the correlation function.
2. It was clarified that the blasting vibration reduction effect could be expected even in the prediction of blasting vibration on the computer using initiation time difference from frequency analysis and correlation function of referential blasting vibration. And, it was shown in the prediction of blasting vibration that that the vibration reduction effect of the setting of an initiation time difference according to the correlation function is more than that of the setting of a time difference estimated by the frequency analysis.
3. It was shown that the blasting vibration could be reduced by the interference of the blasting vibration with optimum time by the frequency analysis using precise initiation machine and electric detonator on the field experiment in the quarry.

Reference

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