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Numerical Simulation of Rock Blasting Induced Free Field Vibration

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Abstract

As the free field geological condition is usually complex, the conventional wave attenuation law established for the homogeneous open field may not be applicable for actual field situations. Thus, to understand the impact of the attenuation law and the geological features on the blast wave propagation, a field rock blasting test is conducted and the ground vibration is carefully monitored. To better understand the phenomenon, a numerical model considering the field geological features is established using the finite difference method. The field test results are then used to calibrate the numerical model. From the calibration, the parameters involved in the general form of peak particle velocity have been determined. It is demonstrated that the blast wave propagation in the free field is significantly governed by the field geological conditions, especially the interface between rock and soil layers.

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Keywords: rock blasting; PPV; geological condition; rock-soil interface; numerical simulation

1. Introduction

Drilling and blasting is one of the most commonly used methods for large-scale excavation in rocks and soils. However, rock blasting induces adverse effects, for example ground vibration [1–6] and annoying noise. The magnitude of ground vibration, often measured by the peak particle velocity (PPV), is highly dependent on blasting design adopted, ground geological condition, e.g., heterogeneity, characteristic of wave propagation in the media, response to dynamic wave propagation and discontinuities, and distance from the blasting location [2, 7].

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Not only do these geological conditions affect the ground properties significantly, but also they determine its seismic responses [7]. Therefore, a proper predicting and monitoring scheme has to be considered and implemented [2] during blasting. Over the years, many studies have been carried out, based on field tests (e.g. [8–14]) and numerical simulations (e.g. [12, 14]). Yet, so far there is no investigation on the significant effect of the rock-soil interface on the blast wave propagation in ground. In this paper, a field rock blasting test is performed and the ground vibration is monitored. A finite difference method (FDM) based on the platform of universal distinct element code (UDEC) is used to simulate the field test. For comparison, a FD model with same dimension but without rock-soil interface is established and simulated. The results demonstrate that the rock-soil interface plays a crucial role in the blast wave propagation in the ground.

Nomenclature

ANFO	ammonium nitrate/fuel oil
VOD	velocity of detonation
r	radius of equivalent single blast hole
m	charge per delay
h	charging length of ANFO
ρ_e	ANFO charging density
P_e	blast hole wall pressure

2. The field test

A field rock blasting was conducted at a location in the western part of Singapore. The blast holes are 12 m in depth with 60 kg ammonium nitrate/fuel oil (ANFO) charge per delay. The on-site measured PPVs are listed in Table 1. From the location of the blasting area and the monitoring points, the geological profile between the blasting area and monitoring points can be interpolated from the geological investigation report. The material properties can be found in Table 2.

Table 1. Ground vibration monitoring data.

Monitoring location	VM1	VM2	VM3	VM4	VM5
Distance (m)	265	275	295	320	370
Measured PPV (mm/s)	3.20	2.50	2.44	2.13	1.89

Table 2. Material parameters used in the simulations

Material	Rock	Soil
Young’s modulus (MPa)	64.41×10^3	20
Poisson’s ratio	0.16	0.3
Density (kg/m^3)	2650	1800

3. Numerical simulations

3.1. Numerical simulation procedures

In the field blasting test, two holes are detonated simultaneously. The two holes can be replaced by an equivalent one in 2-dimensional modeling. Based on the amount of charge per delay and the blast hole depth, the radius of the equivalent single blast hole can be calculated as