A Study of Variation in PPV through Different Types of Soil Using Geophones during Blast Loading

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Abstract - *Environmental problems arisen from ground vibration and air blast have been faced and discussed in various industries such as mining, construction, quarry, pipe line etc. where blasting is unavoidable. The solution methods have been sought in order to make the problems as small as possible. With increasing environmental constraints on the levels of disturbance induced by blasting operations on nearby residents, there is an increasing need to design cautions blasting with greater precision. Also the prediction of ground vibration components is extremely important for the minimization of the environmental complaints. The blast load on structures is caused by quarrying, mining activities, accidental explosion of underground explosives, excavation activities, etc. The vibration level at a distance depends on charge per delay, vibration frequency, rock characteristics, blast hole conditions, presence of water, propagation of surface and body waves in the ground, and to a lesser extension method of initiation. Fractures are developed in rocks due to tensile and shear stresses. Hence, studies of blast-induced ground vibrations in rocks and soil have become important. There are general equations as per site conditions which are used to calculate the PPV (Peak Particle Velocity). These equations mainly depend upon the site constants which are proportionately related to field density. This paper studies the variation in PPV with the soil characteristics so as to predict the extend of structural damage and the effects in soil properties.*

Key Words: PPV, vibration, structure, blast load, rocks.

1. INTRODUCTION

The recent decades have shown various effects of blast loads on natural and man-made structures and such effects gained much attention. Site specific empirical relationships for calculation of blast induced vibration parameters like peak particle velocity (PPV) and peak particle displacements are commonly used for the blasting designs. Blasting effect is also produced during tunneling, mining, drilling, earthquake loads, underground explosives, excavation activities etc. The effect of blasting can cause changes in the soil properties and also in rock behavior which have considerable implications on the stability and integrity of structures. The vibration level at a distance can depend upon various factors such as charge per delay, vibration frequency, rock characteristics, blast hole conditions, presence of water and propagation of surface and body waves in the ground. Effects due to the stresses developed during the propagation of the vibrations can be much more damaging not only to the structures nearby but also to the environmental stability.

1.1 Objective of Study

Various experimental site-specific studies have been performed to predict and control blasting effects. The various parameters associated with vibration have to be analyzed with respect to the stability limiting conditions of various types of structures. The variation in PPV through different types of soil during blast loading is studied to identify the maximum variation in intensity of vibration that may occur to the nearby structures. The propagation of surface and body waves through the soil is evaluated by seismic refraction technique; a recently developed geophone has been used for monitoring the vibration during blast loading. This enabled the study of effect of the vibrations in the soil.

1.2 Vibration Criteria for Various Facilities (HA & MG (ASCE 2000))

Category	Source	Particle Velocity mm/s (in/s)
Industrial Buildings	Wiss(1981)	100 (4)
Buildings of Substantial Construction	Chae	100 (4)
Residential & new construction	Chae	50 (2)
Residential, Poor condition	Chae	25 (1)
Residential, Very poor condition	Chae	12.5 (0.5)
Buildings visibly damaged	DIN 4150	4 (0.16)
Historic buildings	Swiss Standard	3 (0.12)
Historic and ancient buildings	DIN 4150	2 (0.08)

2. GROUND VIBRATIONS AND THEIR PROPOGATION

The vibrations from a typical loading instrument propagate through the ground to a distant vibration-sensitive receiver by means of Rayleigh (surface) waves and secondarily by body (shear and compressional) waves. The amplitude of these waves decreases with distance from the source of the loading point. This attenuation is due to two factors: expansion of the wave front (geometrical attenuation) and dissipation of energy within the soil (material damping). The rate of geometrical attenuation mainly depends upon the type of wave and the shape of the related wave front. Material damping in soil can be caused by many parameters, including soil type, moisture content and temperature. Clays tend to exhibit higher damping than sandy soils (Wiss, 1967). Propagation of Rayleigh waves is insensitive to the presence or absence of water (Richart, *et al.*). Frozen soil attenuates less than thawed soil (Barkan). Thus, using a geophone which could monitor these surface waves during blasting helps us to analyse the variation in PPV while using various blast loads at different sites.

3. INSTRUMENTAL SETUP

A new vibration measurement system has been designed to measure the vibration frequency when blasting activity is taking place. A wireless system is necessary since measurement of vibrations using wire lines is very heavy and unsuitable for locations where blasting is conducted. The system design has been done as a complete package at the hardware and software levels. The hardware level comprises units in three basic functional areas of (1) data measurement/transmission, (2) data reception and (3) data logging. Based on four Micro-Electro-Mechanical System(MEMS) accelerometers, the data measurement/transmission modules is defined as the miniaturized mechanical and electro-mechanical elements made using the techniques of micro- fabrication. A data receiver module consisting of four trans-receiver modems is fabricated, that receives data from transmitting accelerometers through independent channels avoiding any sort of data interference. To log and store real-time vibration data into a connected computer, a user friendly software interface has been developed. The different components of the vibration measuring equipment with a computer, is shown in fig 2.1.

The trans-receiver will be used together with a microcontroller. It provides extensive hardware support for packet handling, data buffering, burst transmissions, clear channel assessment, link quality indication and wake on radio. It can be used in 2400-2483.5 MHz ISM/SRD band systems. 9V rechargeable batteries are used for powering accelerometer.

Fig.2.1. Components of the vibration measuring system

4. INDEX PROPERTIS OF SOIL

The tests for index properties and engineering properties of soil from the blasting site were carried out as per IS specification.

Sl. No.	Property	Value
1	LIQUID LIMIT	56%
2	PLASTIC LIMT	37%
3	LIQUID LIMIT	24%
4	SPECFIC GRAVITY	2.37
5	WATER CONTENT	33%
6	FIELD DENSITY	1.35(g/cc)

The test for specific gravity was carried out as per IS 2720:1980 using a Pycnometer and the value obtained is 2.37. The particle size distribution curve was plotted for dry sieve analysis of the soil and the weight retained on 75 micro meter sieve was found to be 33g which shows only 0.526 % fine soil. Flow curve was plotted for obtaining the liquid limit of the soil by conducting Atterberg's test and the plastic limit was obtained as 37% and the liquid limit as 24%. From the IS plasticity chart it was clear that the soil was MI or OI classification. Field density of the soil was obtained using a core cutter and the value is 1.35 g/cc.

5. PPV STUDY

The variation of Peak particle velocity in soil has been studied, by using the Geophone setup at a blasting site in Oonjapara near Kothamangalam, Kerala, India. A type of Nitrogen mixture was used for blasting at the site.

The Geophone was placed at specific intervals from the loading point, and at the time of loading the vibration frequency was from the Accelerometer module to the Interpretation program. The velocity obtained by the pressure meter is in three directions and the maximum is selected or the mean value. This value is converted into mm/s. The PPV was calculated at various points using the equation,

$$SD=R/Wd^{0.5} \quad \text{.......................eq.1}$$

Where,

SD=Scaled distance
R=Distance between the shot and the station (m)
W_d=Maximum charge per delay (kg)

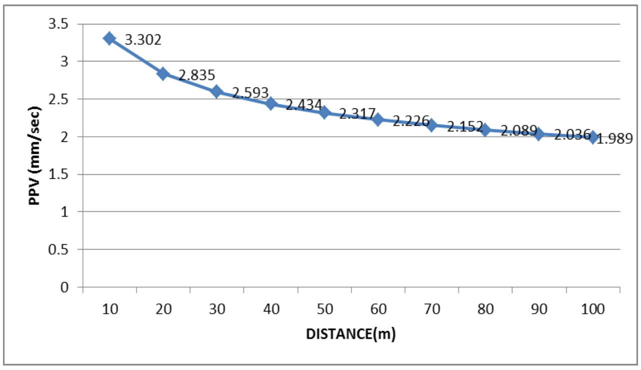
$$PPV\ (mm/s) = K*(SD)^{\beta} \quad \text{............................eq.2}$$

Where,
K=Ground transmission Coefficient
β= Specific Geological Coefficient

(Kahriman.A,Gorgun.S,Karadogan.A and Tuncer C(2000)). Graph was plotted showing variation of PPV with Distance from the values obtained using the above equations. It was observed that PPV varied considerably with distance: as distance increased the intensity of vibrations decreased.

5. ANALYSIS OF RESULTS

As per the results obtained it is safe for construction of any type of buildings beyond a distance of 90m with respect to the obtained characteristics of the soil and also the PPV of the corresponding blasting using 0.75kg nitrogen mixture explosive.



Graph-1: Variation of PPV with distance

Actually the values obtained in the instrument are in terms of millivolts are converted into acceleration and then to velocity. The PPV obtained at 20m and 30m was 2.835mm/s and 2.593mm/s and the other PPV values are obtained by substituting the scaled distances in eq.1.

6. CONCLUSIONS

Various advanced technology applications are subjected to impact from nearby constructions due to their high sensitivity to vibrations. Constructions near existing vibration-sensitive facilities are unavoidable in this era.

This paper studied the PPV of the vibrations during the blasting and their prediction which assessed appropriate safe distances for various types of buildings nearby. The vibration limits applicable to the various constructions vibrations have been presented together with the results of a representative site study. A recently developed geophone was setup at the site and the body wave frequency was evaluated using equations from other literature bodies for calculating the site-specific propagation of spectral data. The reader is cautioned that the measurement results presented herein are applicable only to the site at which those measurements were made. The methodologies can be used at any site, but the propagation characteristics and vibration performance of specific equipment should be evaluated on a site-by-site basis.

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