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Measuring, Monitoring and Prediction of Vibration Effects in Rock Masses in Near-Structure Blasting

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Abstract

Blasting and the transmission of vibration involve numerous variables which makes it impossible to predict the levels of vibrations. Therefore an effective blast design and optimization require a multitude of variables be integrated into a single instance. In prior research the existence of the strong relation between PPV and damage to structures has been well established. Besides PPV, the frequency is one of the most important factors controlling the response of structures. This paper presents a case history of Olympic Stadium renovation in Helsinki, Finland with a focus on blasting near the Olympic Stadium Tower. It will be concluded whether the current vibration criteria, measurement and approach are suitable and sufficient for near-structure blasting.

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Keywords: near-structure blasting; blasting design; PPV prediction; monitoring; measurement; rock masses; vibration; damping effect

1. Introduction

Blasting and explosions in the vicinity of retaining structures raise two principal areas of concern. First, an air blast spreads outward over the ground surface from the point of near surface explosion. These shocks waves induce stress waves in the ground producing dynamic stresses on the structures. In addition to that, the stress waves originating from the point of an underground explosion and moving directly through the ground. These waves induce stresses in any wall or underground structure along their path [1].

There are many variables and “site factors” that collectively result in the formation of a complex vibration waveform. Many parameters of both controlled and uncontrolled nature influence the amplitude of ground vibration

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(safety, distance from the source, rock properties, local geology, surface topography, explosive quantity and properties, geometrical blast design, operational parameters, such as initiation point and sequence, delay intervals patterns, firing method, etc.) [2, 4].

In order to control and protect the excited structures from deleterious effect of ground and air vibration, standards and regulations have been established. These regulations vary from country to country depending on the type and construction material used. In addition, many damage criteria and propagation equations have been designed that derive varying degree of success [4, 6].

This paper presents a case history of Olympic Stadium renovation in Helsinki, Finland with the focus on blasting near the Olympic Stadium Tower. It will be concluded whether the current vibration criteria, measurement and approach are suitable and sufficient for urban environment and near-structure blasting.

2. Ground vibration measurement

Ground vibration measurements serve two purposes: (1) to derive predictive equations of generation and propagation, and (2) to assess the potential for damage to nearby structures.

The propagation of ground vibration waves is a complex phenomenon. Even in short distances from the blast source, rocks and unconsolidated material are anisotropic and non-homogeneous. These difficulties restrict theoretical analysis and derivation of a propagation law and consequently research workers have concentrated upon empirical relationships based on field's measurements.

There have been considerable studies on vibration and air blast effects from surface mining operations, but there has been little research done on construction blasting and even less on the particulars of near-structure blasting. Case history data taken alone has not so far provided an adequate basis for identifying thresholds for vibration-induced damage [2]. Data from systematic studies using a carefully controlled vibration source in the vicinity of buildings has therefore been used as the basis for defining damage thresholds. There is a lack of reliable data on the threshold of vibration-induced damage in buildings also in countries where national standards already exist [3]. Consequently, the current national regulations do not reflect the type of blasting and blasting effects generated by near-structure blasting.

Despite the fact that the measurement techniques have developed significantly, the evaluation, forecast and interpretation of the vibration measurements often result in unsatisfied declarations. One of the key reasons is the fact that there is no standardized concept of reference values or limits for various types of buildings [2, 4].

3. Blasting and the transmission of vibration

As mentioned earlier, blasting and the transmission of vibrations from the blast involve numerous variables so it is impossible to theoretically predict the levels of vibration produced by a blast. A systematic, critical comparison of single proceedings formulating "charge-weight" distance relations is applied to increase the precision and statistical reliability of the calculation methods as well as the prediction of vibration. Alternatively, in some cases a detailed engineering analysis (the response spectrum technique) may be useful in evaluating the vibration of a building. This technique includes the effect of frequency and damping and can be used for any type of time history, however has so far been applied mainly to seismic effects and shock.

It is essential the following factors be considered and evaluated in building response to vibrations:

3.1. Peak Particle Velocity (PPV)

PPV is the maximum instantaneous velocity of a particle at a point during a given time interval. While the disturbance caused by a vibration source propagates away from that source with a certain wave velocity, ground particles vibrate with a variable particle velocity. At given location along the propagation path the motion may be defined in terms of three mutually perpendicular components (usually vertical, transverse and longitudinal or radial). In order to ensure the PPV is correctly measured, all three components have to be measured simultaneously.