Chapter 8
Blast Induced Damage Due to Repeated Vibrations in Jointed Gneiss Rock Formation

M. Ramulu
Central Institute of Mining & Fuel Research, India

T. G. Sitharam
Indian Institute of Science, India

ABSTRACT
Blasting is the most common method of rock excavation technique in mining and civil construction and infrastructure projects. Rock blasting produces seismic waves similar to those produced by earthquakes, but with relatively high frequency and low amplitude. General blast induced damage was extensively studied by researchers globally, but the studies on damage due to repeated blast vibrations is not yet reported, quantitatively, on underground openings. This paper deals with the research work carried on the effect of repeated dynamic loading imparted on the jointed rock mass from subsequent blasts in the vicinity, on the jointed rock mass at Lohari Nag Pala Hydroelectric Power Construction Project. The blast induced damage was monitored by borehole extensometers, borehole camera inspection surveys and triaxial geophones installed at three test sites of different joint orientations at the Main Access Tunnel of power house. The study reveals that there was extra damage of 60%, exclusively due to repeated blast vibrations. The results of the study indicate that repeated dynamic loading, resulted in damage even at 33% of the conventional damage threshold vibrations ($V_c$) in case of favorable joint orientations and 23% of $V_c$ in case of unfavorable joints. The paper concludes in quantification of effect of repeated blast loading and the orientation of joints on the extension of damage zone in jointed rock mass of underground excavations.

DOI: 10.4018/978-1-4666-0915-0.ch008
1. INTRODUCTION

Blasting produces seismic waves similar to those produced by earthquakes, but with relatively high frequency and low amplitude which can create damage to surrounding structures. The degree of structural damage depends on the total energy of explosion, distance from the source, and the characteristics of the medium. Extensive experimental investigation in this regard was carried out by Thoenen and Windses (1942) of United States Bureau of Mines (USBM), Leet (1946) and Crandell (1949). Based on the experimental results the USBM recommended that no structural damage occurs if the acceleration of vibration is less than 0.1 times the gravity (g) and 0.1 to 1g is caution range; and the acceleration greater than 1g is danger zone. Leet (1946) prefers to limit the size of blasts by the displacements that they produce in the structure and the index of damage is a limiting displacement of 0.03 inches. Crandell (1949) proposes to limit the size of the explosion by limiting the kinetic energy delivered to the ground, which is proportional to the quantity of the explosive. A number of studies attempted to correlate ground-motion levels with observed damage to structures. It is generally agreed that the amount of blast damage correlates best to the peak particle velocity ($V_{\text{max}}$). The blasting criteria for residential structures is generally less than 5 cm/s and for massive concrete structures is generally less than 25 cm/s (Charlie, 1985). Oriard (1989) observed that $V_{\text{max}}$ of 8-10 ips normally and not damage the structure, because of the very high frequencies and the rapid, localized attenuation. Tart (1980) observed that at high frequencies the vibration levels of 275 ips generate minor cracks in old concrete. Rock mass damage in underground openings occurs mainly due to blast induced forces, stress redistribution and weathering. As underground excavations are carried out, the in-situ stresses redistribute around the boundary of the openings, leading to high stresses on the backs and corners of the excavations and the blasting activity creates initiation and extension of fractures in the surrounding rock mass. Blast damage is defined as either creation or extension of new fracture surfaces or opening of pre-existing geological discontinuities or both in the rock mass (Law et al, 2001). Blast induced damage weakens a rock mass, potentially leading to stability problems in the underground excavations. The stability of the underground structure is very much dependent upon the integrity of rock immediately surrounding the excavation. The blast damage can easily extend few meters into the rock and the loosened rock can give rise to serious safety and stability problems to the surrounding rock mass of the underground openings. The blast damage problem is more severe and vulnerable for the jointed rock mass in underground excavations (Singh and Xavier, 2005). In spite of recognition of the importance of duration of ground motion on the dynamic response, current engineering practice correlates damage to peak ground motion during an episode of dynamic loading, since it can be related directly to peak transient stress in the ground wave, and the second power of velocity is related to dynamic strain energy (McGarr, 1983). Unfortunately, there are no specific safety guidelines available for the blasted tunnels with regards to the threshold limits of vibrations caused by repeated blasting activity in the close proximity. Many efforts have been made to study blast induced cracking and framing of safety guidelines in residential structures (Langefors and Kihlstroam, 1963; Dowding, 1985; Scott, 1996; Anon, 1997), but less attention was found to study blast induced damage to rock mass in underground openings (Persson et al., 1994). Studies on blast induced damage on underground openings are well documented by many researchers globally (Langefors & Kihlstrom, 1963; Hendron, 1977; Holmberg, 1993; Singh, 1993; Paventi et al, 1996; Yu & Vongpaisal, 1996; Chakraborty et al., 1998; Zhang & Chang, 1999). In a series of experiments the Swedish Detonic Foundation has investigated the extent of cracking emanating from blastholes.