ABSTRACT

In the twentieth century, manmade disasters, e.g. bomb blast, projectile attack, mine blast have created headlines in the news due to blast in London and Paris underground metro tunnels, projectile attack in Gaza, landmine blast in Kashmir. The disastrous events like blast or projectile attack, when happens underground, create ground shock that gives rise to a high rate of loading in soil and rock in the surroundings. The strain rate generated in rock when subjected to blast loading may go as high as $10^2$/s to $10^4$/s. The stress-strain response of rock, its peak stress and stiffness are significantly affected when subjected to such high rate of loading.

The present thesis aims to understand the stress-strain response of ten different types of rocks under high loading rate through detailed experimental and numerical analyses. The high strain rate characterisation of these ten rocks are done for two different diameters, and five different slenderness ratios of the rock specimens using a 76 mm diameter split Hopkinson pressure bar (SHPB) device to understand the standard specimen dimension for the rocks in SHPB test exhibiting highest sensitivity to loading rates. The stress-strain response of the rock specimens is studied by varying the length of the striker bars and the gas gun pressure values systematically. Petrological and static characterisation of the ten different types of rocks are also carried out to assess the response of the rock specimens. Based on the test results, a methodology is proposed to characterize the rock specimens under high loading rate. Further, numerical validation of SHPB test on these ten different types of rocks are performed using strain rate dependent Johnson-Holmquist (JH-2) model in the finite element software, LS-DYNA and the parameters are determined. The parameters obtained are then used in blast analysis of a tunnel subjected to 20 kg trinitrotoluene (TNT) explosion.

The major findings of this thesis comprise of modification of a 76 mm SHPB device design to characterize heterogeneous materials like rock, concrete and ceramics. The physical, petrological and mechanical properties of the rock create a database for designing of underground structures.

The appropriate specimen dimension for characterising ten different types of rock by using SHPB device are determined and recommended based on two approaches, e.g., the highest sensitivity of DIF with respect to loading rate and highest sensitivity of energy absorption with respect to volume of the specimen. A strain rate dependent JH-2 constitutive model is calibrated using the experimental stress-strain response of the appropriate specimen size. The determined JH-2 parameters are used in blast analysis of tunnels in each rock type. The response obtained are studied and final design propositions are made. Moreover, parametric studies on blast analysis in tunnel has been conducted for one rock type from each formation category, e.g., granite (igneous rock), limestone (sedimentary rock) and phyllite (metamorphic rock). The results obtained from the parametric studies support the recommendation made on the selection of appropriate specimen dimension from the experimental results. Lastly, a classification system based on the dynamic characterisation is proposed based on the compressive strength and dynamic modulus of the rocks.