CHAPTER IV
TEST METHOD AND APPARATUS

4.1 Introduction

This chapter describes laboratory testing methods and apparatus. This applies to triaxial stress conditions. There are two types of triaxial tests: single stage triaxial compression tests and multi-stage triaxial compression tests. The effects of confining pressure on the rock deformations and compressive strengths have been investigated. The results are compared with the results from other studies performed elsewhere.

4.2 Single stage triaxial compression test

The objective of the triaxial compression tests is to determine the parameters (m and s) of the specimens in accordance with the Hoek-Brown criterion (Hoek-Brown, 1980) under varying confining pressures. After the confining pressure is increased a desired magnitude, the axial stress increases at rate of 1 MPa/s until failure occurs while the confining pressure is maintained constant. To find the strength envelope, the specimens are tested at different confining pressures in a single-stage behavior under axial stress until it fails, as per the ASTM standard procedure (ASTM D7012-14). The polyaxial load frame device (Fuenkajorn, Sriapai, and Samsri, 2012) applies axial and lateral loads to the specimens. Two pairs of cantilever beams, each measuring 152 cm in length, apply the lateral stresses in directions that are perpendicular to one another. The outside end of each beam is pulled downward by dead weights on a lower steel bar that connects the two opposing beams underneath. The inner end of the beam is hinged by a pin that is positioned between vertical bars on either side of the frame. As seen in Figure 4.1, all of the beams are positioned almost horizontally during testing, which places a lateral compressive force on the specimen at the center of the frame. Fuenkajorn et al. (2012) conducted a thorough analysis of the polyaxial load frame. Following the rectangular specimen's installation into the load frame, dead weights are positioned on the steel bar to determine the specimen's uniform lateral stress (σ_3), which has been predetermined. A 100-ton hydraulic jack is used to increase the vertical stress at the predetermined pace to begin the test. Throughout the testing, a dial gage accurately recorded the axial and lateral strains. The specimens' surface friction will be decreased by placing neoprene sheets between all interfaces and loading plates, and the failure stresses are then noted (Fig. 4.2). The results are plotted in the forms of axial stress-strain relations. Both axial and lateral deformations are recorded to the nearest 0.01 mm. The tangent of the stress-strain curves at about 50% of the failure stress determines the deformation parameters. The deformation moduli (E) and Poisson's ratio (ν) are determined by from 3-D elastic equations given by (Jaeger, Cook, and Zimmerman, 2007), as follows:

$$\varepsilon_1 = \sigma_1/E_1 - \nu(\sigma_2/E_2 + \sigma_3/E_3) \quad (4.1)$$

$$\varepsilon_2 = \sigma_2/E_2 - \nu(\sigma_1/E_1 + \sigma_3/E_3) \quad (4.2)$$

$$\varepsilon_3 = \sigma_3/E_3 - \nu(\sigma_1/E_1 + \sigma_2/E_2) \quad (4.3)$$

where σ_1 is vertical stress (major principal stress), σ_2 and σ_3 are horizontal stresses (minor principal stresses), and ε_1, ε_2, and ε_3 are major, intermediate, and minor principal strains, and E_1, E_2 and E_3 are the deformation moduli along the major, intermediate and minor principal directions. Here it is assumed that the rock specimens are homogeneous, as a result, E_1, E_2 and E_3 are identical.

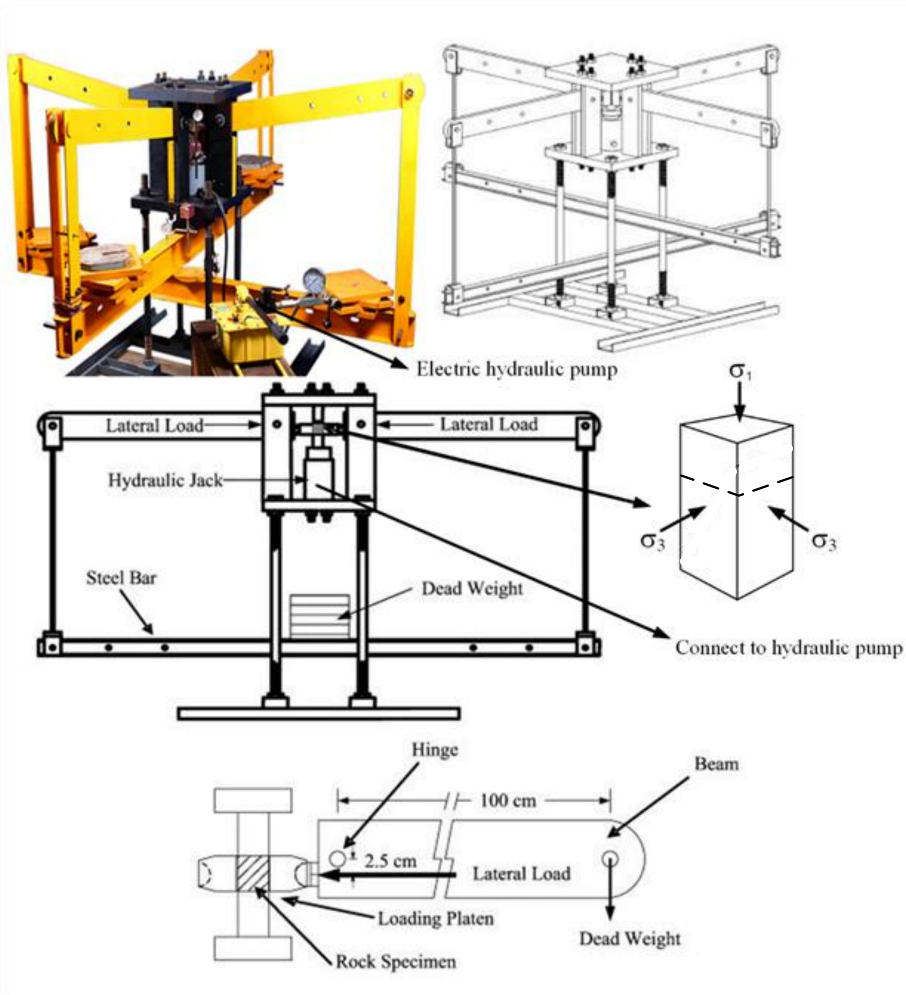

Figure 4.1 Polyaxial load frame used in single and multi-stage triaxial compression testing (Fuenkajorn et al., 2012).

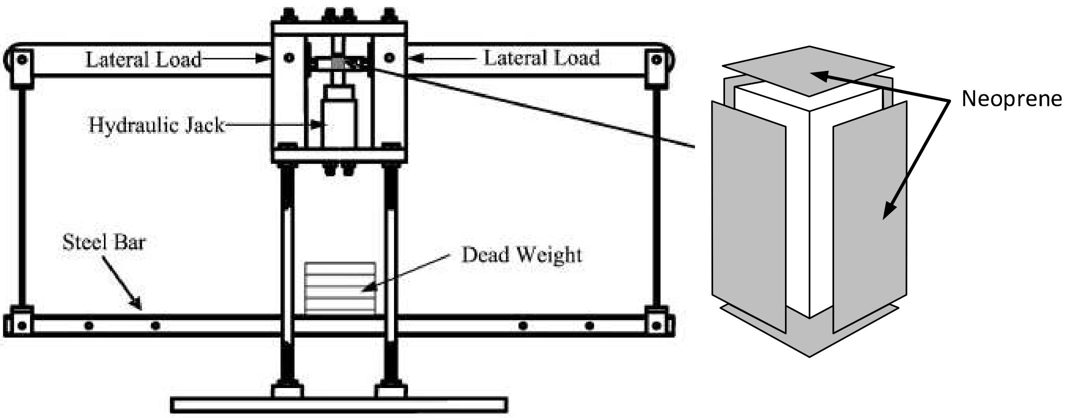

Figure 4. 2 Specimen with neoprene placed between all interfaces and loading platens in polyaxial load frame (Fuenkajorn et al., 2012).

4.3 Multi-stage triaxial compression test

The multi-stage triaxial compression testing aims to measure the maximum failure stress and axial and lateral strains during loading and reloading phases by conducting a multi-stage loading using polyaxial compression frame (Fuenkajorn, Sriapai, and Samsri, 2012). These tests are carried out under constant confining pressures between 0 and 40 MPa. The multi-stage stress path is shown in Figure 4.3. Under hydrostatic conditions, confining pressure (σ_3) and axial σ_1) stress are first simultaneously increased to the required confining pressure. The axial stress is then raised to failure and then released to the original confining pressure. Both axial and confining stresses then increased to the next level of confining pressure. After that, axial stress is once raised to reach the peak strength. This cycle is repeated to allow analysis of rock strength at various confining pressures. Axial stress and strains and lateral strains are plotted continuously from the first to the last loading stages. To find the deformation moduli (E) and Poisson's ratio (ν), the multi-stage triaxial compressive tests used reloading values of the stress–strain curve at about 50% of the failure stresses under different confining pressures. The deformation calculations used the same formulas as the single stage triaxial compressive tests method given by (Jaeger, Cook, and Zimmerman, 2007).

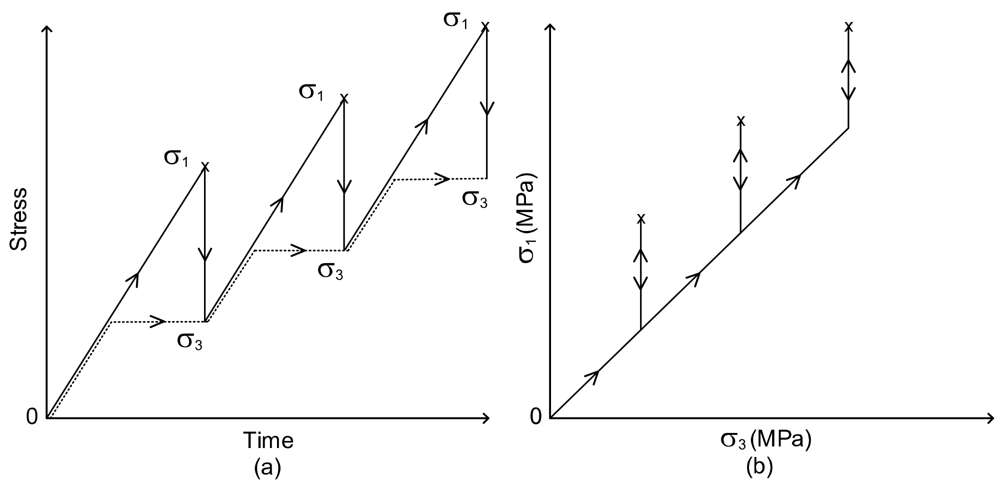

Figure 4. 3 Stress path for multi-stage triaxial compression test used in this study, (a) stress variations with time and (b) axial stress as a function of confining pressure (σ_3).