CHAPTER IV
TEST APPARATUS AND METHODS

4.1 Introduction

This chapter presents test apparatus and methods used to determine the CERCHAR abrasivity index (CAI) and the parameters required for calculating the CERCHAR specific energy (CSE). These parameters encompass ploughing force, vertical displacement, and mean groove volume. Additionally, the chapter describes the test apparatus and methods employed to ascertain the physical and mechanical properties, as well as the mineral compositions of the rock specimens.

4.2 CERCHAR test

CERCHAR testing is conducted on saw-cut surfaces of rock specimens with varying bedding plane angles using a device based on West apparatus, as depicted in Figure 4.1. The apparatus comprises a vice for holding the rock specimen, a pin chuck or casing for the stylus pin, a static load of 70 N, and a hand crank. During testing, the specimen is moved beneath the stylus at a constant scratching rate of 1 mm/s, achieved by rotating the hand crank ten times over a duration of ten seconds, given the 1 mm pitch of the screw connecting the hand crank and the vice holding. This ensures adherence to the test procedure recommended by the International Society for Rock Mechanics (ISRM) and American Society for Testing and Materials (ASTM).

The stylus pin, with a Rockwell hardness (HRC) of 55 ± 1, is subjected to scratching over a standardized length of 10 mm for each test. Following scratching, the wear flat of the stylus tip is meticulously measured under a microscope with 50x magnification, with measurements taken at four angles (0°, 90°, 180°, and 270°) around its axis. Results from these measurements are averaged for each pin, with five pins used for testing each rock type. The CERCHAR abrasiveness index (CAI) values are then determined using the formula: CAI = d × 10, where d represents diameter of the scratch flat area of the stylus tip resulting from smooth surface testing. The diameter d can be correlated with smooth surfaces testing (d_s) by (eq .2):

$$d = 1.14 \cdot d_{sc} \qquad (4.1)$$

where d_{sc} is the wear flat of stylus tip for the saw cut surface specimen performed in this study.

It is recognized that smooth surface testing is an option for CAI test methods of ASTM and ISRM. To meet the objective of determining the effects of bedding planes on CERCHAR abrasivity index, the effect of surface roughness is excluded here. It is noted that surface roughness of rock is difficult to control, as the same rock type may yield different surface roughness values. This adds an uncontrollable variable to our test plan. Some investigations that perform CAI tests on both rough and smooth rock surfaces find that CAI obtained from rough surfaces shows higher variation than those from smooth rock surfaces. As a result, they recommend using smooth rock surfaces for CAI testing. In addition, mathematical representations of rock surface roughness require relatively long surface profiles, while CAI testing uses only 10 mm. This may pose difficulty when such CAI is correlated with a roughness parameter, particularly when the roughness profile is not uniform along the entire length.

Additional parameters have been incorporated beyond those suggested by the ISRM. The vertical displacement of the stylus is currently being measured along the scratching length using digital displacement gauges with a precision of 0.001 mm, allowing us to determine the groove depth produced by scratching. Moreover, the lateral force exerted on the stylus is calculated based on the torque applied to the crank. A torque meter with a precision of 0.01 N·m is utilized for this purpose. The lateral force can be determined using the equation:

$$F = 2 \cdot \pi \cdot T / P \qquad (4.2)$$

where F represents the ploughing force (N), T denotes the torque (N·m) applied on the crank, and P signifies the screw pitch of 0.001 mm.

Furthermore, volume of the scratching groove is obtained through laser-scanning profiles along the 10 mm scratching length. Both the groove width and depth are meticulously measured to the nearest 0.001 mm, ensuring precise characterization of the scratching morphology.

Figure 4.1 Device based on West CERCHAR apparatus with additional torque and vertical displacement measurements (Kathancharoen and Fuenkajorn, 2023).

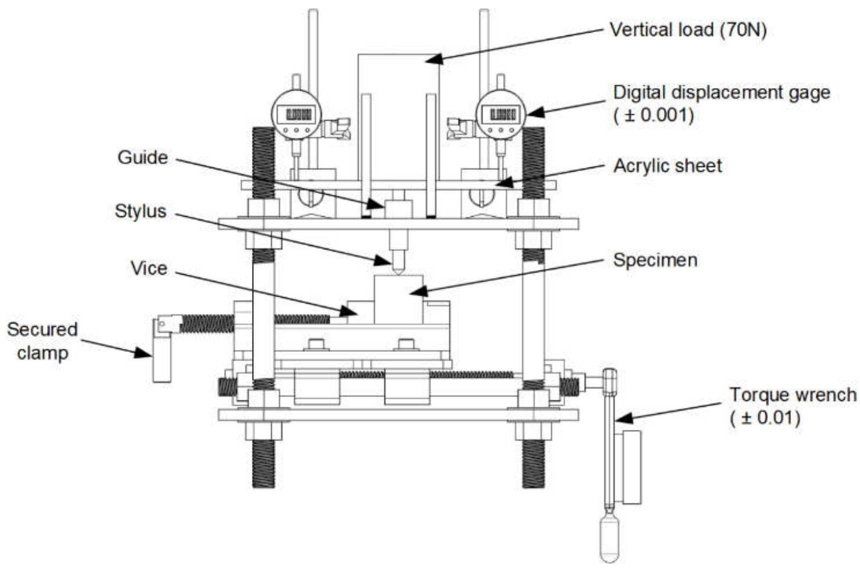

Figure 4.2 Schematic drawing of CERCHAR device (Kathancharoen and Fuenkajorn, 2023).

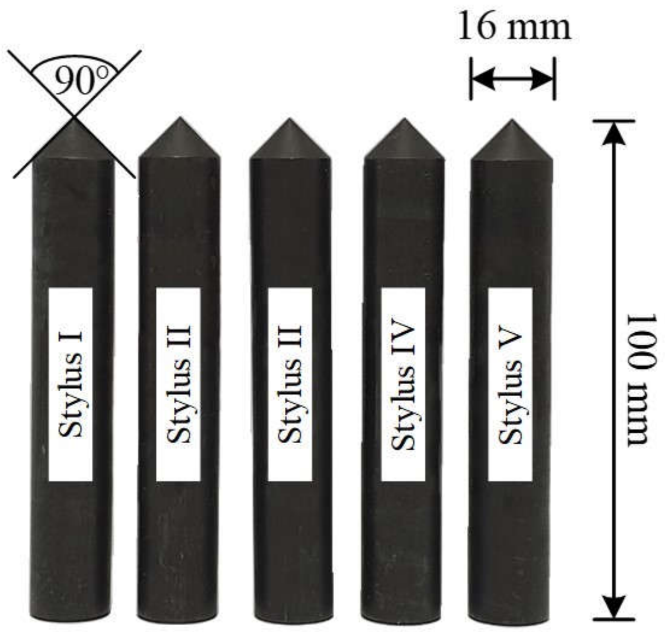

Figure 4.3 Stylus pins (HRC 55) are used in this study.

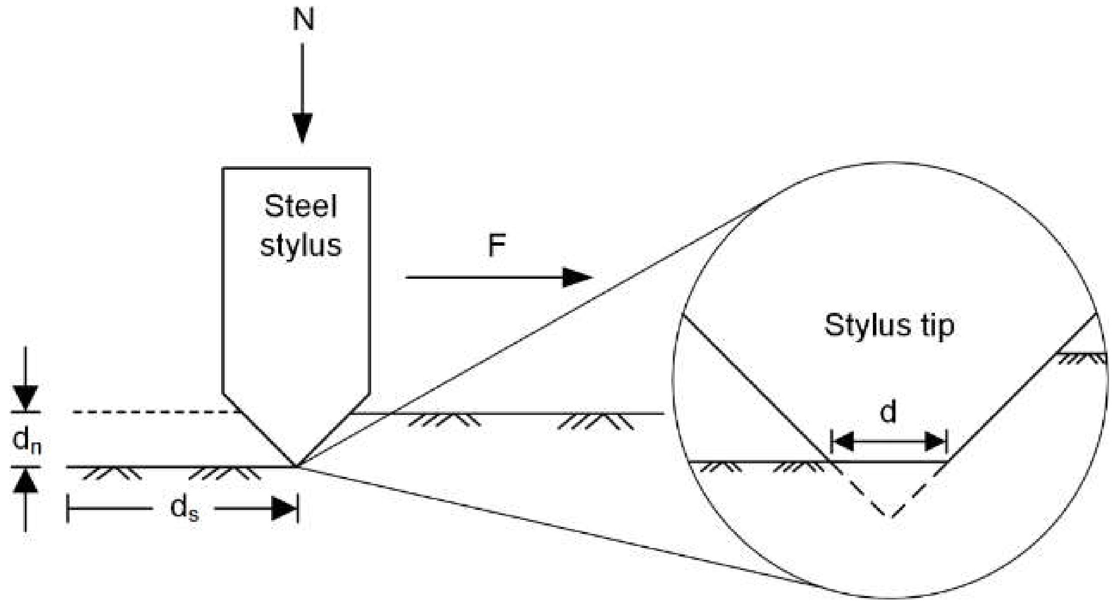

Figure 4.4 Steel stylus test variables, N is normal load (N), F is horizontal force (N), d_n is vertical displacement (mm), d_s is scratching distance (mm), and d is wear flat width of stylus tip.

4.3 X-ray diffraction (XRD) analysis

After CERCHAR test, certain specimens undergo preparation for X-ray diffraction analysis, conducted using the Bruker D8 Advance, as depicted in Figure 4.8. The testing methodology adheres to the ASTM D5357-19 (2019) standard practice. These specimens are ground to produce powder with particle sizes smaller than 0.25 mm (able to pass through mesh #60). Approximately 5 to 10 grams of this powder are utilized. The DIFFRAC.EVA software is employed to ascertain the weight percentage of mineral compositions within the specimens. These mineral compositions serve to elucidate the results of the CAI testing.

Figure 4.5 X-ray diffraction Bruker, D8 advance (Center for Scientific and Technology Equipment University of Technology).