

EXPERIMENTAL PROCEDURES FOR ROCK SATURATION (B-VALUE TEST)

Experimental Set-up of B-value Tests

B-value tests were conducted in a custom water-pressurized chamber. B-value tests were performed on cylindrical rock specimens, Sierra White granite (SWG). The dimensions and mechanical properties of SWG specimens are summarized in Table 1. Saturation was accomplished following a two-step process, as discussed later: (1) vacuum saturation for 24 hours; and (2) back-pressure saturation until constant B-value. Vacuum saturation removes some air bubbles from the rock matrix and helps reduce the magnitude of back pressure needed for full saturation (ASTM D 4767). The following procedure was used:

- (a) Two desiccators were used: desiccator (D1) hosting the granite specimen, and (D2) containing deionized water (see Figure 1);
- (b) A vacuum pressure was applied to both desiccators for three hours. Then, the vacuum line of D2 was closed and vacuum in D2 was released;
- (c) The vacuum line of D1 was closed. The water line between the two desiccators was open, and so the deaired water in D2 moved to D1 until the specimen was entirely submerged in deaired water;
- (d) The water line was closed, the vacuum line of D1 was re-opened, and the rock specimen was immersed in deaired water under vacuum for 24 hours.

A vacuum pressure of 90 kPa was maintained for 24 hours to reduce air bubbles trapped inside the rock pores.

Figure 2 shows the experimental set-up for the B-value test and the pressure chamber where the test was performed. The vacuum-saturated specimen was mounted on a pedestal fixed to the bottom of the chamber. A stainless steel cap was placed at the top of the specimen. A latex membrane was used with O-ring seals

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to isolate the specimen from the chamber fluid. The O-rings were tightened with hose clamps (Hossain, 1995).

Figure 3 shows the complete setup for the B-value tests. Chamber pressure and back pressure were imposed independently through two syringe pumps. The syringe pumps had high-precision pressure transducers (0.1% linear accuracy) and were connected to controllers to maintain a constant pressure. A pressure transducer (Geotac PS2K) was installed on the back pressure line to monitor the pore water pressure during the B-value test. The pore pressure was recorded every second using a data acquisition (DAQ) system, consisting of an advanced digital I/O (ADIO) module, a network module, and a DAQ software (Geotac TestNet).

Test Procedure of B-value Tests

The procedure to check for the B-value was established based on ASTM D 4767 (2004). Because the tests were conducted on rock, the ASTM procedure was modified based on previous studies (Mesri et al., 1976; Chiu et al., 1983; Makhnenko and Labuz, 2013, 2018; Favero et al., 2018). The test procedure was as follows:

- (a) A cylindrical granite specimen was vacuum-saturated with deaired and deionized water for 24 hours, as pre-saturation;
- (b) All back pressure lines (drainage lines, pressure gauges, pressure transducer, and porous disc) were flushed with deaired and deionized water, prior to mounting the specimen in the chamber;
- (c) The porous disc, the vacuum-saturated specimen, and the top and bottom caps were mounted on a pedestal fixed to the bottom of the chamber. A latex membrane and O-ring seals were used to isolate the specimen from the chamber fluid;
- (d) The chamber was capped with the chamber lids, tightened by bolt systems and filled with water;
- (e) A small chamber pressure of 0.2 MPa was applied, so the specimen was subjected to a positive effective stress;

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- (f) The chamber and back pressures were simultaneously increased, following a stepwise process, while keeping the effective stress constant at 0.2 MPa (i.e. the chamber pressure was 0.2 MPa larger than the backpressure). During each step, the pressures kept constant for 10-15 minutes for stabilization;
- (g) The drainage valve connected to the specimen was closed and the change in pore pressure was measured over a 1-sec interval, to check if the pore pressure inside the specimen reached equilibrium; if the difference between the chamber pressure and the back pressure was less than 5%, the pore pressure was assumed to be equilibrated (ASTM D4767);
- (h) The Skempton's B-value was measured; this was done by applying an increment of 0.2 MPa to chamber pressure/confining stress. The B-value was calculated as follows:

$$B = \frac{\Delta u}{\Delta \sigma_c} \quad (1)$$

where $\Delta \sigma_c$ is the applied chamber pressure/confining stress and Δu is the change in pore water pressure measured at the base of the specimen;

- (i) The chamber and back pressures were simultaneously increased to the next pressure level. Steps (e) – (h) were repeated until successive values of the B-value did not change (Wissa, 1969; ASTM D4767, 2004).

Test Results: Evolution of B-value with Back Pressure

B-value tests were conducted on three cylindrical granite specimens: SWG-C-1, SWG-C-2, and SWG-C-3. All tests started at an initial chamber pressure of 1.2 MPa and an initial back pressure of 1.0 MPa, corresponding to an effective stress of 0.2 MPa. Pore pressure responses during B-value tests on the three granite specimens are shown in Figure 4. The “bumps” in the graph are the increments of the pore pressure induced by an increase in chamber pressure of 0.2 MPa. The numbers inside the graph are the measured B-values. The figure shows that the B-values increased with increasing back pressure and became constant

beyond a back pressure of 5.0 ~ 5.5 MPa.

Figure 5 plots the evolution of the B-values for three granite specimens with increasing back pressure. The figure shows that low B-values increased with back pressure until they became constant (0.84 ~ 0.87) beyond a back pressure of 5.0 ~ 5.5 MPa. Thus, full saturation was achieved at back pressures greater than 5.0 ~ 5.5 MPa.

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Table 1. Dimensions of Sierra White granite (SWG) specimens and B-value test results.

Specimen	SWG-C-1	SWG-C-2	SWG-C-3
Diameter (mm)	50.72	50.92	51.51
Height (mm)	75.24	74.77	75.33
Density (g/cm ³)	2.67	2.63	2.63
Back pressure for full saturation (MPa)	5.0	5.5	5.0
Corresponding B-value	0.84	0.87	0.85

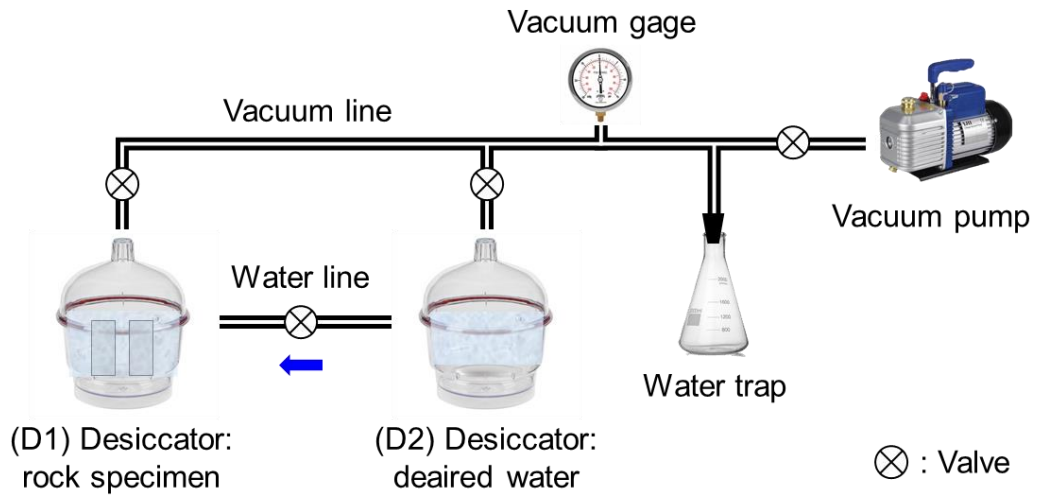


Figure 1. Configuration for vacuum saturation.

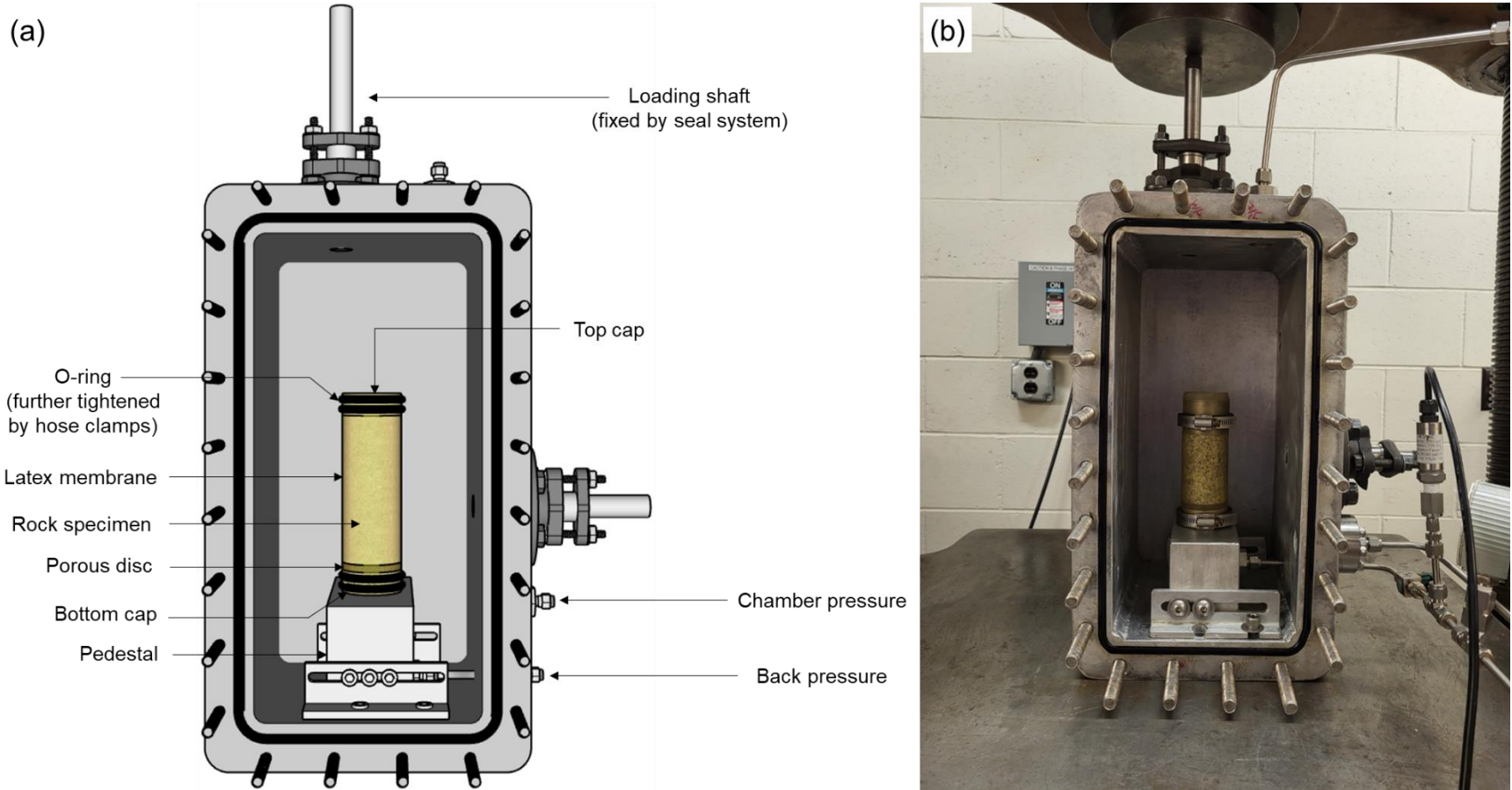


Figure 2. Pressure chamber with internal set-up: (a) Schematic drawing; (b) Photograph.

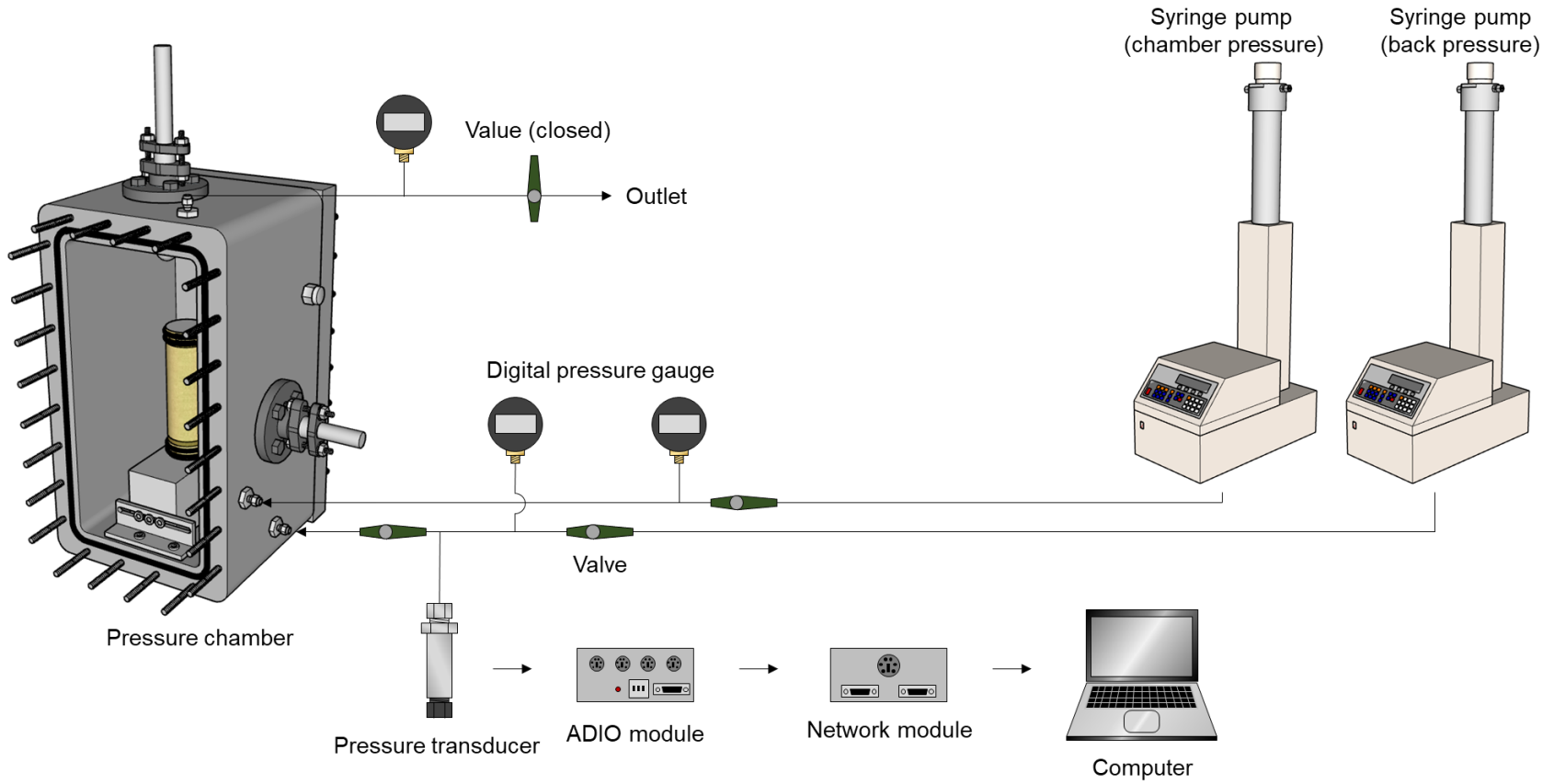


Figure 3. Complete configuration of B-value test.

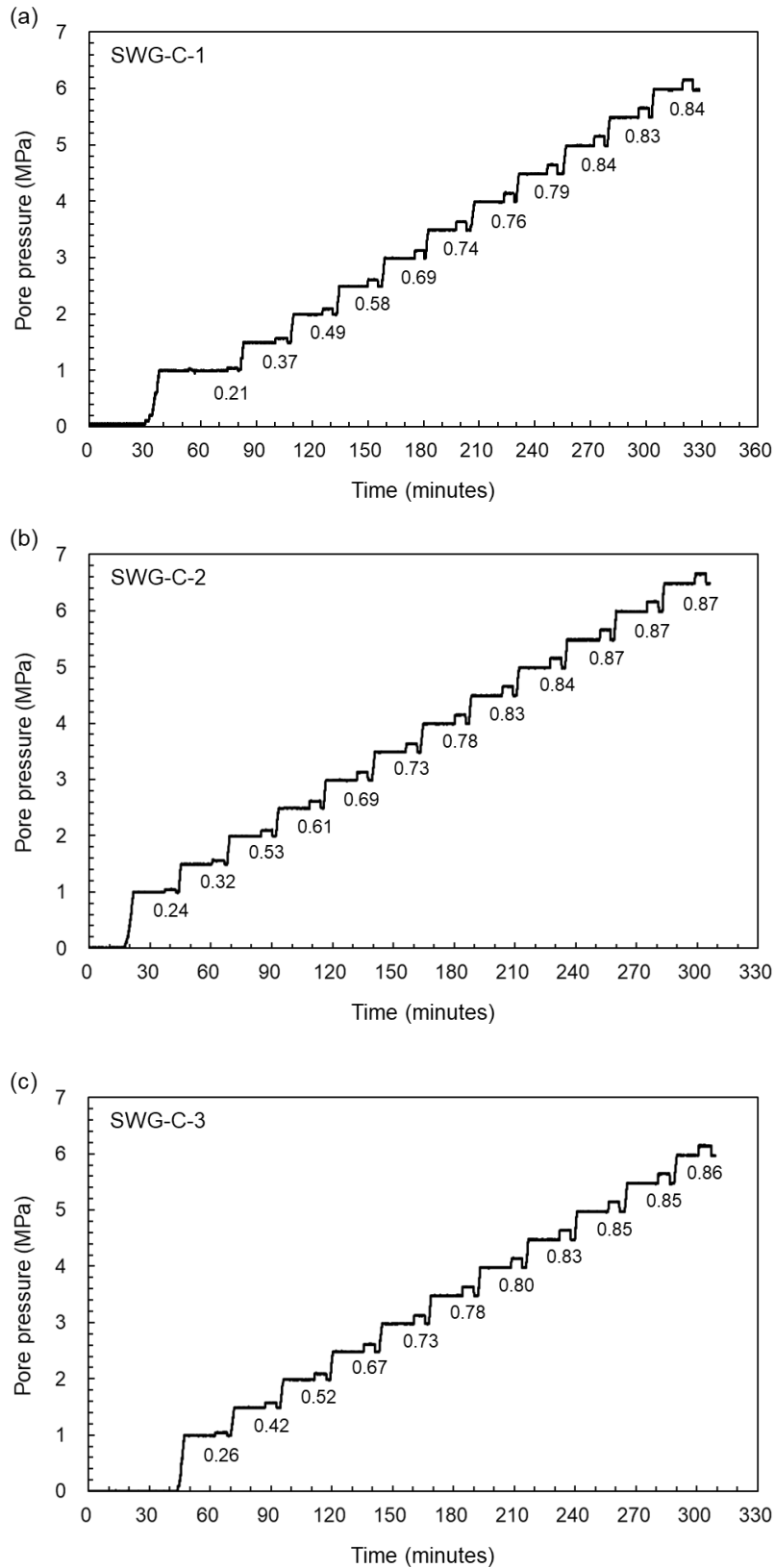


Figure 4. Results of B-value tests. Specimens: (a) SWG-C-1; (b) SWG-C-2; (c) SWG-C-3.

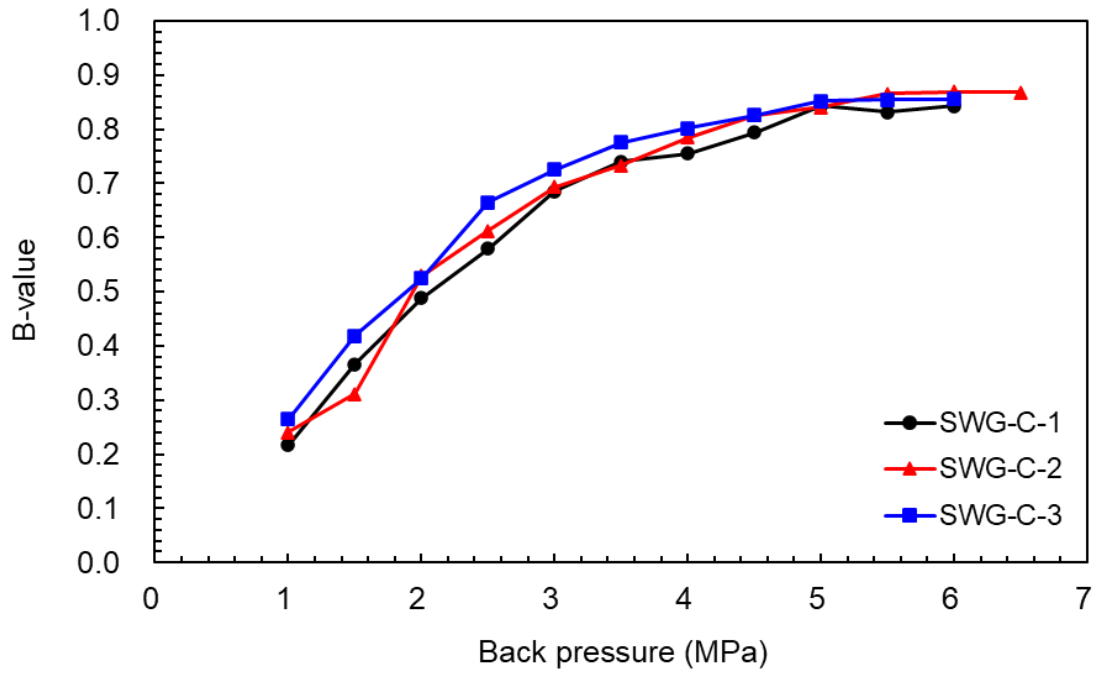


Figure 5. Evolution of B-value with increasing back pressure.