CHAPTER VI
TEST RESULTS ANALYSIS

This chapter correlates among the physical properties; shape and size, density, porosity, and mineral compositions for three types of rock specimens under each condition. The analyzation of calculated porosities are also included, based on their mineral volumes before and after test through 80 cycles. The values for calculated porosity are correlated with those obtained from the standard method (ASTM D7263-21). Each condition is analyzed further as the accumulated passing weight percents. The prediction equations from these results can express the estimation of test cycles for fragments to completely disintegrated through the drum, where this parameter can predict the erosive energy for each specimen under different conditions.

6.1 Physical properties

The variation changes of properties for PWSS, PPCS, and PPSS specimens from initial condition through 80 cycles are considered by their physical shape and size, mineral volume, density, and porosity. According to the obtained results, fragments of all test conditions show significantly increase in their roundness and sphericity after subjected to test cycles. Except for those of PPSS fragments under wet testing, the sphericity values are decreased between test cycle 40 and test cycle 80, as their shapes become flatten. However, these fragments are likely shown more roundness when passing though 80 test cycles.

The normalized fragment sizes are calculated. The results are summarized in Table 6.1 and illustrated in Figure 6.1. The reduction of fragments sizes tend to be linear for all test conditions. The PWSS and PPCS fragments are highly durable under both conditions, where less than 20% of their size has been losed after 80 test cycles. Rate of size reduction for PPSS specimens are highest. Their size are losed over 40% after dry testing and nearly 80% are losed after wet testing. Excepted for those of other specimens, PWSS fragments show the significant size reduction under dry testing than under wet testing.

Table 6.1 Normalized fragment sizes for PWSS, PPCS and PPSS specimens before testing and after test cycle 20, 40, 60, and 80.

	N	PWSS		PPCS		PPSS	
		Dry	Wet	Dry	Wet	Dry	Wet
Normalized size (%)	0	100		100		100	
	20	96.00	97.82	99.20	98.80	89.90	80.14
	40	89.82	92.00	98.80	97.60	79.22	62.37
	60	85.82	88.00	97.60	96.00	66.10	44.07
	80	82.55	85.09	96.00	94.00	52.54	23.73

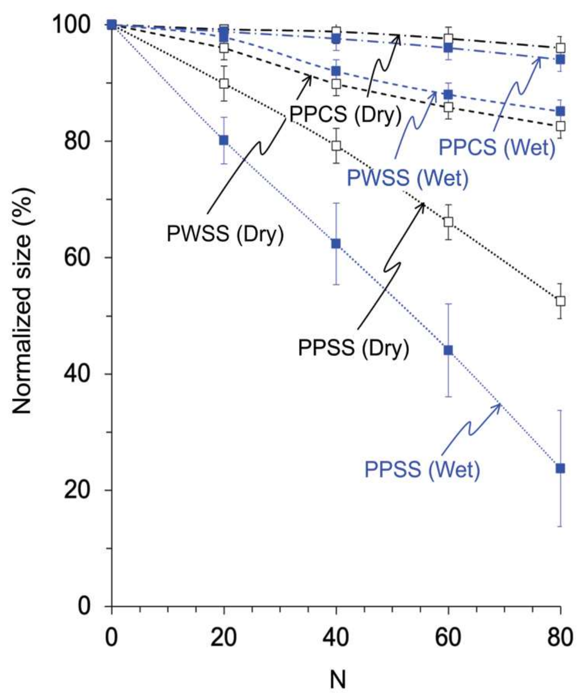

Figure 6.1 Normalized fragment sizes for PWSS, PPCS and PPSS specimens before testing and after test cycle 20, 40, 60, and 80.

The volumatic percent of fragments are correlated with the porosity, as shown in Figure 6.2. The porosities of rock fragments from initial condition through test cycles 80 are analyzed. The calculated porosity is expressed based on Chamwon et al. (2020) as:

$$n_c = \left\{1-\left[\sum_{i=1}^{n} \rho \cdot (W_i/100)/\rho_i\right]\right\} \cdot 100 \qquad (6.1)$$

where n_c represents calculated porosity (%) combining connective and non-connective voids. Porosity of PPSS specimens significantly increased after 80 test cycles, where nearly 15% is obtained under dry testing and 16% under wet testing (Table 6.2). The porosities of PWSS and PPCS specimens remain effectively unchanged from the initial condition through the end of 80 test cycles under both dry and wet conditions. This is reflected by total volumatic percent values of the mineral compositions, as illustrated in Figure 6.2.

The submerging porosity for each specimen is measured follows the standard method, ASTM D7263-21 (ASTM, 2021) comparing with the calculated porosity, where all techniques are measured before and after 80 test cycles. The standard porosity are not measured while testing because of their internal structures that might be loss during subjected to vacuum. The obtained results are shown in Table 6.2. The diagram from Figure 6.3 shows that the calculated porosity seems to be more than that obtained from the submerging method. According to their non-connective voids that the submerging method might take a longer time reaching into the matrix of rock fragments. The results for calculated porosity agree with the fragments density. The normalized densities are analyzed comparing between each rock specimen and condition. Figure 6.4 shows that PWSS and PPCS fragments slightly loss their density less than 2%, where the calculated porosity remained effectively changed only in a few percents after testing through 80 cycles. PPSS fragments under wet testing significantly loss their density more than 10% down to 89.72, where those under dry condition also loss nearly 10% of their density.

Table 6.2 Calculated porosities (n_c) and porosities (n) for PWSS, PPCS and PPSS specimens before testing and after testing through 80 cycles. The n_c is measured with an interval of 20 test cycles.

	N	PWSS		PPCS		PPSS	
n_c		Dry	Wet	Dry	Wet	Dry	Wet
	0	12.35		1.52		6.37	
	80	12.91	12.57	2.22	2.63	14.67	16.05
n	N	PWSS		PPCS		PPSS	
		Dry	Wet	Dry	Wet	Dry	Wet
	0	11.69		1.24		5.17	
	80	12.04	11.76	2.01	2.45	14.53	16.01

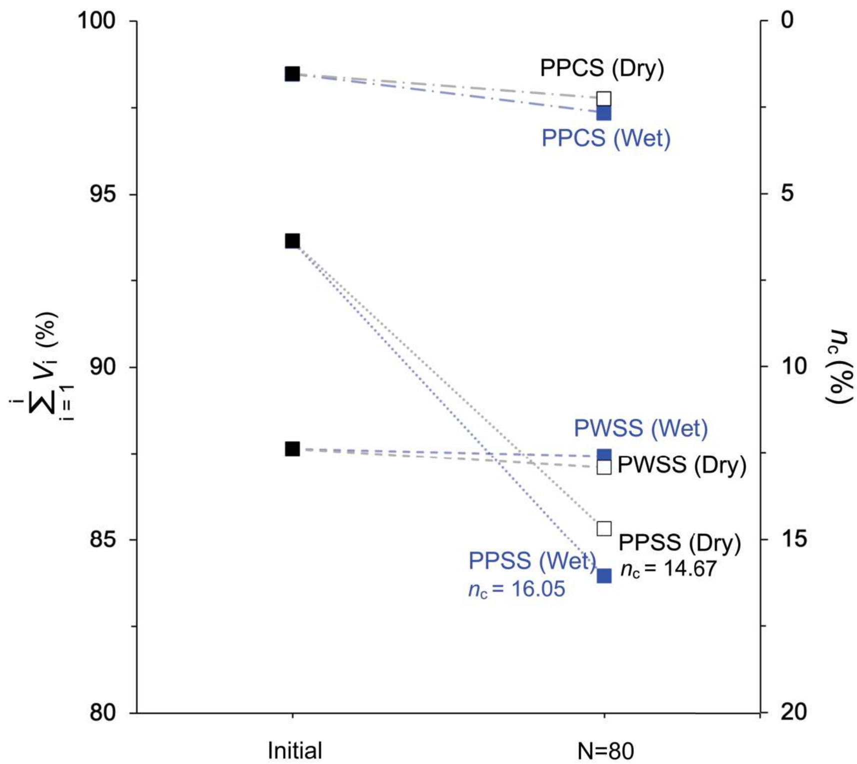

Figure 6.2 Total volumatic percent and calculated porosity (n_c) as function of test cycle (N) for PWSS, PPCS, and PPSS after test through 80 cycles. Open points represent dry testing and solid points represent wet testing.

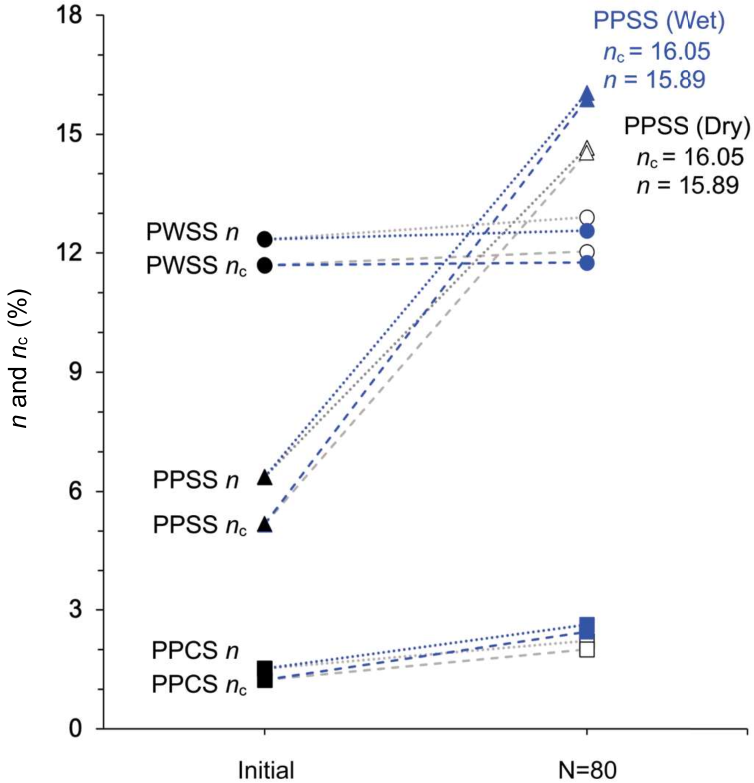

Figure 6.3 Calculated porosities (n_c) compared to submerging porosities (n) for PWSS, PPCS, and PPSS at initial condition and after 80 test cycles. Open points represent dry testing and solid points represent wet testing. Significant increasing of PPSS porosities are shown with the labels.

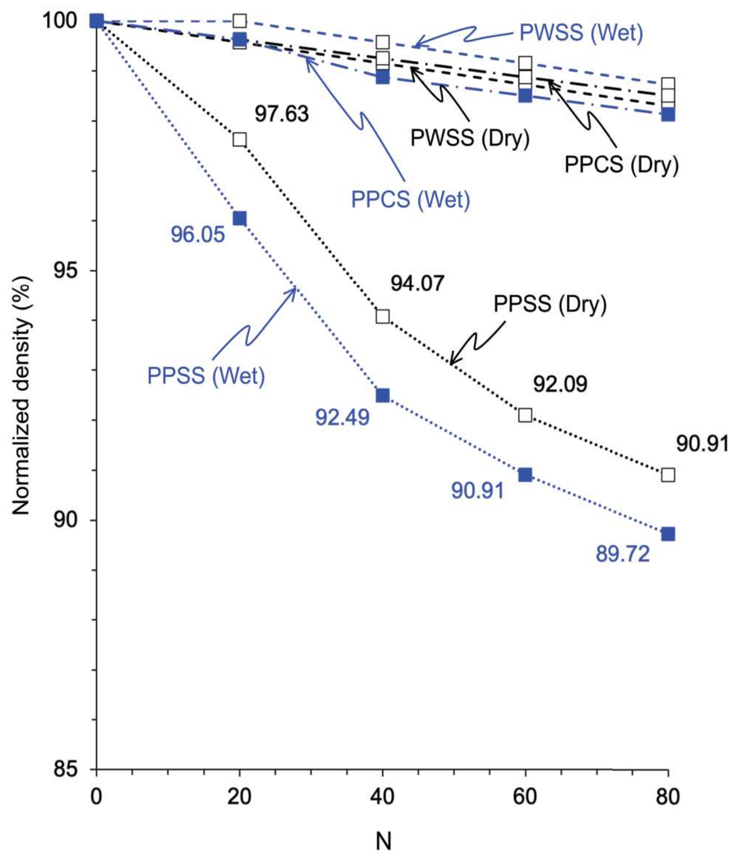

Figure 6.4 Normalized densities as function of test cycle (N) for PWSS, PPCS, and PPSS after subjecting to 20, 40, 60, and 80 test cycles. Open points represent dry testing and solid points represent wet testing. Significant reduction of PPSS densities are shown with the percentage labels.

6.2 Accumulation of passing materials

To clearly show how the specimens from three rock types have passed the drum openings, Figure 6.5 plots accumulated weight percent of passing materials (P_A) from the initial condition through the end of 80 test cycles. Exponential equation is proposed to represent the increase of P_A in a function of test cycle (N) for each test condition and rock specimen:

$$P_A = \alpha \cdot N + [1-\exp(-\delta \cdot N)/\beta] \quad (6.2)$$

where α, β and δ are empirical constants. Their numerical values are given in Figure 6.5. Good correlations are obtained ($R^2>0.9$). According to Figure 5.5b, the passing weight percents for PWSS specimens under wet and dry conditions tend to be similar. Both PPCS and PPSS specimens show slightly different percentages of passing materials between wet and dry conditions. The passing of PPSS fragments are relatively high within the first 20 cycles (up to 10-20%). They rapidly decreased toward 0.2% near test cycle 80. For PPCS specimens, those with dry testing tends to show slightly less passing materials comparing to the wet testing.

Extrapolation of the aforementioned equation to the condition at which all fragments pass through the drum openings (P_A=100%) can predict the number of test cycles needed. The results as summerized in Table 6.3 show that dry and wet testing would require N=219 and 391 for PWSS, 454 and 257 for PPCS, and 135 and 116 for PPSS fragments. These predicted test cycles are later used to calculated the energy required to disintegrate the rocks.

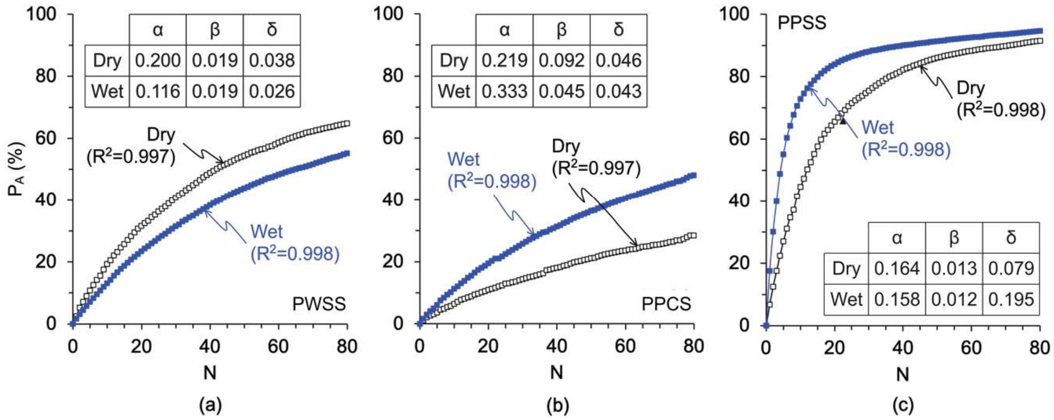

Figure 6.5 Accumulative passing weight percent (P_A) as a function of test cycle (N). Dry testing (open points) and wet testing (solid points). Lines are fitted by $P_A = \alpha \cdot N + [1-\exp(-\delta \cdot N)/\beta]$.

Table 6.3 Test cycle (N) required to obtain 100% passing materials.

Rock type	Condition	N
PWSS	Dry	219
	Wet	391
PPCS	Dry	454
	Wet	257
PPSS	Dry	135
	Wet	116