A Study on the Pelletization of Contaminated Fine Soil Waste Generated After Soil Washing

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Introduction

Radioactive materials may contaminate soil of a wide area when a nuclear power plant undergoes an accident or is decommissioned. In particular, the nuclides such as Cs-137, I-131 evaporated and released to the atmosphere when a nuclear accidents. They form radioactive clouds and trigger soil contamination with rainfall. Meanwhile, one of the methods for decontaminating of wide contaminated soil includes soil washing. Radioactive substances, however, usually get adsorbed on fine soil particles, creating secondary waste in the form of sludge after the soil washing process. These contaminated fine soil and powdered/particulate waste difficult to be decontaminated are classified as non-conformity waste. As a way to volume reduction and dispose of such waste, technology of compressing and forming them into high density pellets of a certain size to incorporate these pellets and solidify them in polymer is willing to apply. It can be to cut back on the volume of radioactive waste to some degree and enhance the filling rate in a drum. This is expected to contribute volume reduction of powdered/particulate waste. This study carried out pelletization of polluted fine soil generated after the soil washing process using the roll compaction technology. In order to look into the integrity of compression-molded pellets, their compressive strength was measured and the volume reduction factor of each pellet manufactured per different conditions was evaluated.

Experiment

◆ Materials

➢ Simulated waste

- **Simulated waste -** Mixed with less than 38 μm soil, J-AF(flocculating agent) and Cs aqueous solution.
- **Mixed rate** - Cs aqueous solution: 0.1 mmol/L, Soil : J-AF = 10 : 1
- **Process** - Simulated waste was dried for 48 hr in dry oven and moisture content was set at 7%.

Fig. 1. (a) Cumulative distribution (Q3) and density distribution (q3) according to particle size of soil. Real image of simulated waste. (a) Powder, (b) Pellet.

Table 1. Chemical composition of soil.

Component	Fe_2O_3	Al_2O_3	SiO_2	K_2O	MgO	Total
Soil	4-9	16-24	50-65	1-3	0.6-2.5	100

◆ Manufacture of rigid pellets by Roll Compactor

➢ Pre-compressibility test

- **Used device -** Uniaxial compressor
- **Range of pressure -** 10 to 30 MPa
- **Results**
  - ✓ As shown in Fig. 1, compressibility was even high at the pressure range of 10 to 25 MPa.
  - ✓ Compressibility was remarkably high at 350 % (Table 2).
  - ✓ It was judged that highly probable to form the soil sample into pellets.

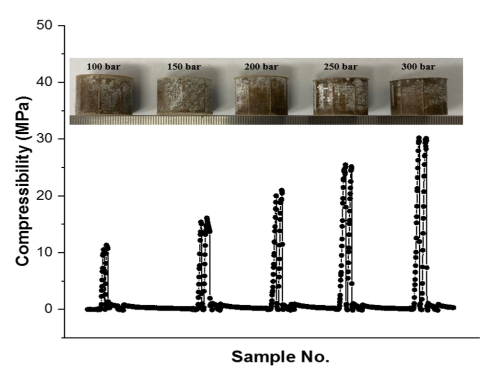

Fig. 2. Pre-compressibility test of contaminated soil waste according to change of pressure.

Table 2. Results of measuring the compressibility.

Sample	Pressure (MPa)	Density before/after compression		Compressibility (%)
		Before (g·cm⁻³)	After (g·cm⁻³)	
soil[a)]	10	0.6479	2.0839	322
	15		2.2200	343
	20		2.2402	346
	25		2.2491	347
	30		2.2706	350

a) soil, contaminated by adding cesium solution and flocculating agent.

➢ Operating condition of device

- **Used device** - Roll compactor (Fig. 3)
- **Results**
  - ✓ It was already checked in advance whether it was possible to turn ordinary soil into pellets in preliminary experiment.
  - ✓ However, as the soil particles composing the samples were smaller than 38 μm in size, it was deemed inappropriate to directly apply the above conditions.
  - ✓ To this end, as shown in Fig. 4, the optimum conditions were arranged to compression-forming the soil samples into pellets as follows.
  - ✓ The Roll Speed(RS) was fixed at 1.5 rpm, the Hydraulic Pressure(HP) and Feeding Rate(FR) were shifted to 27.45-28.44 MPa, 20-25 rpm, respectively.
  - ✓ The weight of pellet was the highest at 0.6549g when the HP, RS, FR were set at 28.44 MPa, 1.5 rpm, and 25 rpm respectively (Table 3).

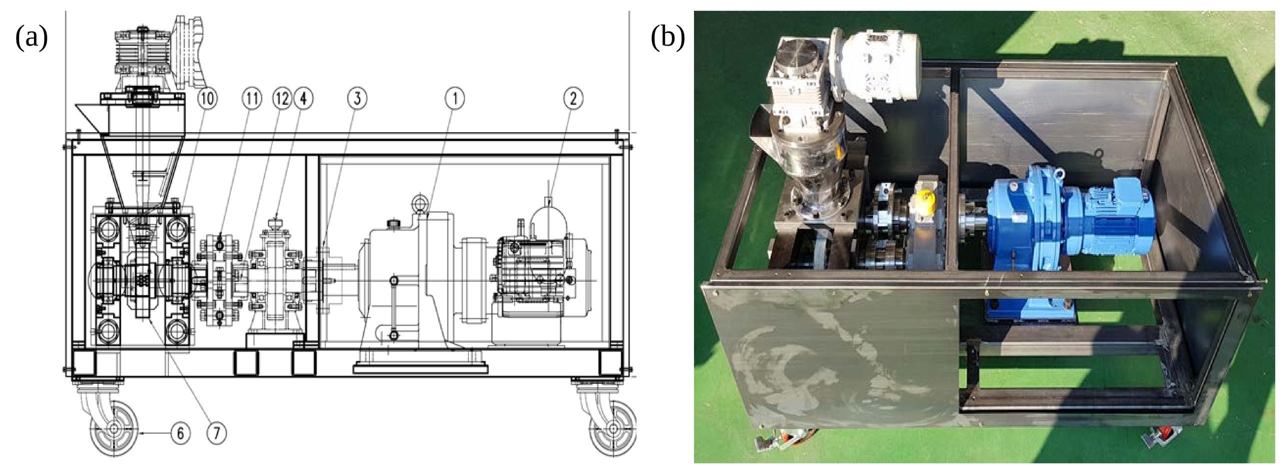

Fig. 3. (a) Design drawing of device, (b) Appearance of device.

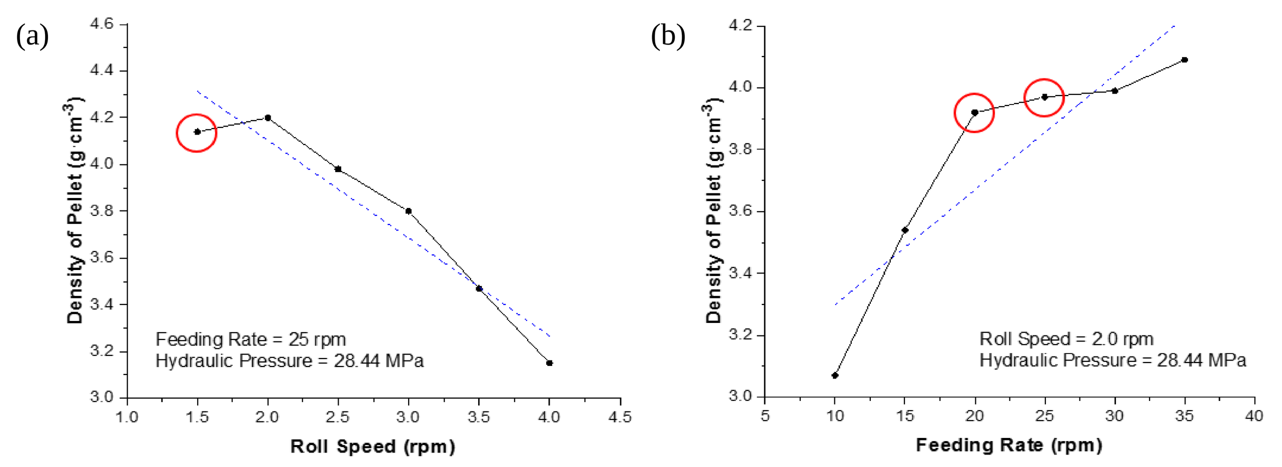

Fig. 4. Density of pellet according to (a) Roll speed, (b) Feeding rate.

Table 3. Weight of pellet according to operating condition.

Sample	Operating condition[a,b)]		Weight of Pellet (g)	Density of pellet (g·cm⁻³)
	FR (rpm)	HP (MPa)		
Soil (J-AF)	20	27.45	0.6116	2.4079
	25	27.45	0.6318	2.4874
		28.44	0.6549	2.5783

a) Roll Speed (RS), Feeding Rate (FR), Hydraulic Pressure (HP).
b) Roll Speed (RS) is fixed at 1.5 rpm.

Results

◆ Characteristic evaluation for manufactured pellets

➢ Compressive strength

- **Standard** - KS F 2405
- **Criteria** - Waste Acceptance Criteria for the disposal facility, ≥ 3.45 MPa
- **Condition** - Jigs were used to parallel the top and bottom of pellets (Fig. 5)
- **Results**
  - ✓ Compressive strength was 4.03 - 19.28 MPa.
  - ✓ All of pellets were satisfied with Waste Acceptance Criteria.

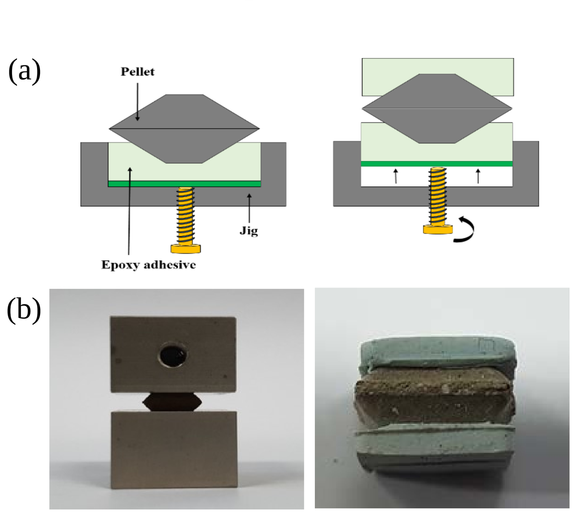

Fig. 5. Real image of jigs.
(a) Concept diagram of jigs, (b) manufactured jigs.

Table 4. Compressive strength of each pellet.

Sample	Operating condition[b)]			Compressive strength (MPa)
	RS (rpm)	FR (rpm)	HP (MPa)	
Soil[a)] Pellet	1.5	20	27.45	11.14 10.12 15.43
	1.5	25	27.45	4.46 19.28 10.48
	1.5		28.44	5.89 13.37 4.03

a) soil, contaminated by adding cesium solution and flocculating agent.
b) Roll Speed (RS), F eeding Rate (FR), Hydraulic Pressure (HP).

➢ Volume reduction Factor (VRF)

- **Measured specification of pellet -** Density, volume, weight (see in Table 5)
- **Formula -** $\frac{Density\ of\ Powder\ (g{\cdot}cm^{-3})}{Density\ of\ Pellet\ (g{\cdot}cm^{-3})} = Volume\ reduction\ Factor$
- **Results**
  - ✓ VRF was 0.25-0.27 and 0.35-0.37 when the gap was 0 mm and 1 mm gap, respectively
  - ✓ This means that volume reduction ratio is amounted to 2.78 and the volume of waste was reduced to 1/2.78 times when the powdered waste was formed into pellets.

Table 5. Volume reduction factor of the waste powder at pelletizing.

Sample	Weight of pellet (g)	Density of pellet (g·cm⁻³)		VRF	
		Gap[b)] 0 mm	Gap[c)] 1 mm	Gap[b)] 0 mm	Gap[c)] 1 mm
Soil[a)] Pellet	0.6116	2.4079	1.7524	0.2691	0.3697
	0.6318	2.4874	1.8103	0.2605	0.3579
	0.6549	2.5783	1.8765	0.2513	0.3453

a) soil, contaminated by adding cesium solution and flocculating agent.
b) Volume of a pellet = 0.254 cm^3 at roll gap = 0 mm.
c) Volume of a pellet = 0.349 cm^3 at roll gap = 1 mm.

Conclusion

This study carried out the pelletization of fine soil the form of sludge occured after the soil washing. A compressibility test was conducted on the soil samples to see if it was possible to compress before forming into pellet. The results show highest compressibility at 350% when a pressure of 30 MPa was applied. Pellet density was measured at 2.5783 g·cm-3 when the operating conditions of the pellet roll compactor were as follows. The hydraulic pressure, roll speed, and feeding rate set at 28.44MPa, 1.5 rpm, and 25 rpm respectively. In addition, the compressive strength of pellets turned out to be outstanding as it was estimated to be 13.37 MPa under the above described conditions. Lastly, VRF was averaged at 0.36 when the gap was 1 mm from the conservative perspective. This signifies that volume reduction ratio was 2.78 and the volume of waste was reduced to 1/2.78 times. This study confirmed that it was possible to process fine soil particles generated after the soil washing process into high-density / high-strength pellets. Furthermore, if additional experiments and research are conducted on this technology to supplement it, it is considered to be a technology that can economically treat the fine contaminated soil generated in the wide area during nuclear accident and decommissioning.