A Study on the Manufacture of Rigid Pellets for the Dispersible Radioactive Waste by Roll Compaction

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Introduction

Dispersive(particulate) radioactive wastes, that are disposal nonconformity, can be subjected to solidification treatment by mixing them with an appropriate solidification agent. Since the existing solidification process using cement and asphalt involves mixing the particulate powder with a solidification agent, the volume of the finally disposed waste form will increase more than about three-fold. Therefore, the radioactive wastes are shaped into compressed pellets by using a roll compaction system and this method of solidification treatment for such pellets was devised. This will be highly advantageous from a volume reduction perspective by manufacturing high-strength pellets by maximally reducing the apertures between the particles and subjecting them to solidification processing by filling in the remaining apertures with medium. In this study, the selected powder particles were converted into pellets by finding the optimal conditions for the device using roll compaction technology. To confirm the extent of volume reduction through the final pellet product, the strength to volume reduction ratio of the shaped pellets was evaluated.

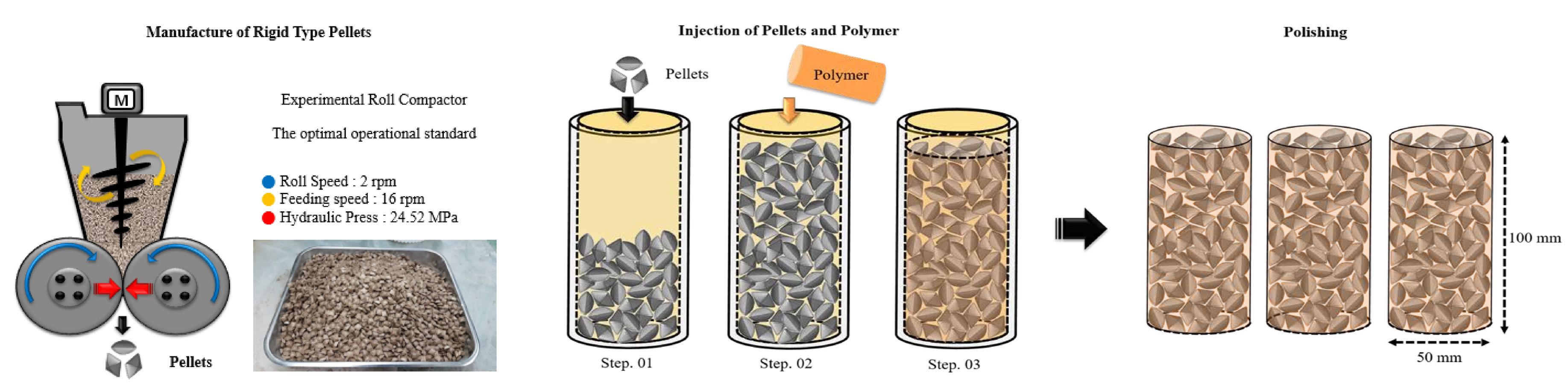

Fig. 1. Manufacturing process of polymer solidification.

Experiments

◆ Materials

- **Powdered materials** - Soil, concrete (disposal nonconforming radioactive wastes)
- **Physicochemical characteristics**
  - ✓ Inorganic chemical composition: contain relatively less iron content, mostly contained silica content
  - ✓ Particle size distribution: Less than 0.02 mm (used a sieve_500 μm or less)
  - ✓ Average particle size: Soil: 56.10 μm, Concrete: 99.53 μm (see in Fig. 2)
  - ✓ SEM image: Concrete particles had more irregular polygonal shapes than soil particles (see in Fig. 3)

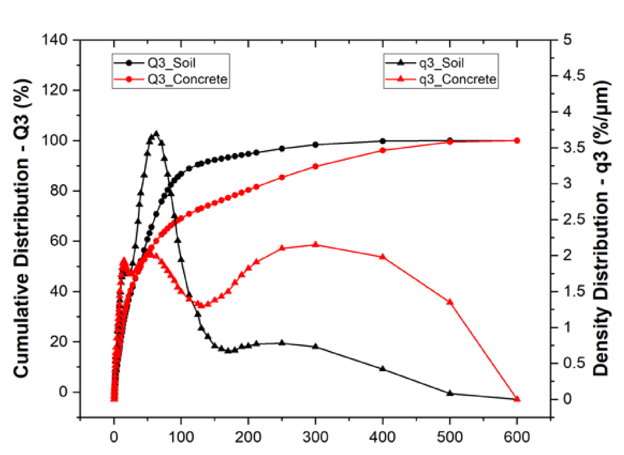

Fig. 2. Cumulative distribution (Q3) and density distribution (q3) according to particle size of soil and concrete.

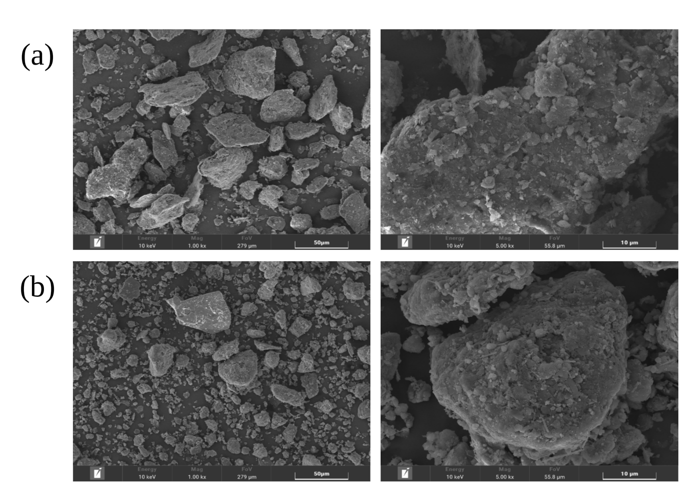

Fig. 3. SEM micrographs of powdered waste. (a) soil (1,000×, 5,000×), (b) concrete (1,000×, 5,000×).

Table 1. Chemical composition of each specimens (wt.%).

	Fe_2O_3	Al_2O_3	SO_2	SiO_2	CaO	Na_2O	K_2O	MgO	Total
Soil	4 – 9	16 – 24	-	50 – 65	-	-	1 – 3	0.6 – 2.5	100
Concrete	5.61	5.31	2	21.03	63.38	0.07	-	2.6	100

◆ Manufacture of rigid pellets by roll compaction

- **Equipment** - Roll compactor (see in Fig.4)
- **Type of fabricated** - Rigid type pellets (roll pocket size - H 6.5 · W 9.4 mm)
- **Forming method** - Compress the selected bentonite powder into pellets
- **Operating conditions** - Hydraulic pressure (HP), roll gap (RG), roll speed (RS), feeding speed (FS)
  - ✓ Optimal condition selected by checking the agglomeration state: 28.44 MPa (maximum design value)

Fig. 4. Actual appearance of the roll compactor for pellet forming.

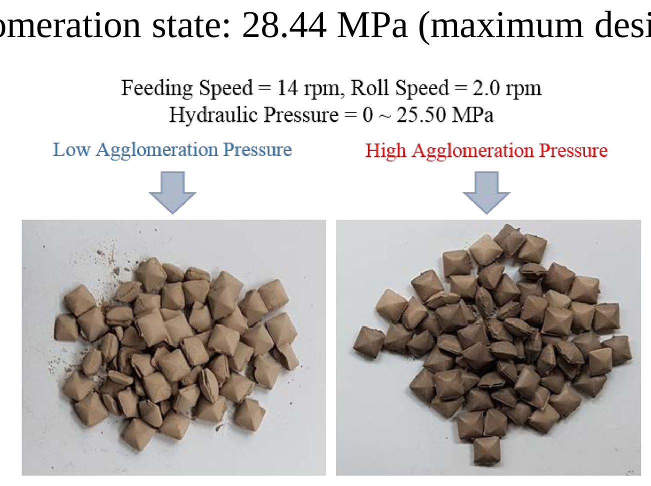

Fig. 5. Manufactured pellets according to change of hydraulic pressure.

➢ Hydraulic pressure

- **Changed condition** - 0 ~ 25.50 MPa
- **Results** - State of pellets: The visible agglomeration state was great (see in Fig. 5).
  - ✓ Selected optimal operating condition: 28.44 MPa

➢ Roll gap

- **Fixed condition** - Hydraulic pressure: 28.44 MPa
- **Changed condition** - Roll speed, feeding speed(see in Fig. 6)
- **Results** - Range of roll gap: - 0.6 ~ + 1.6 mm (There is no significant effect on the roll gap)

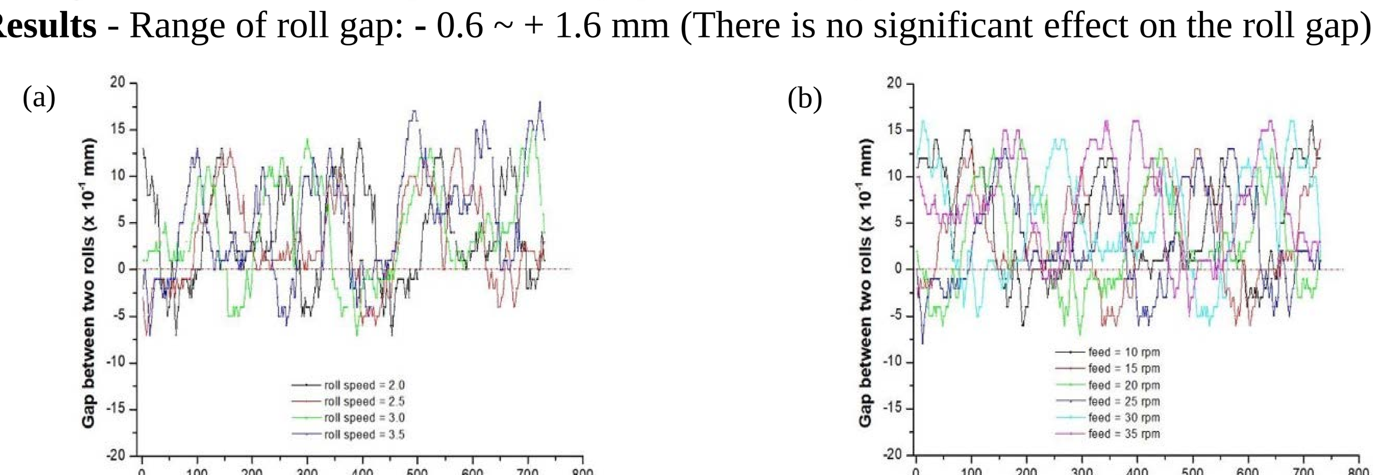

Fig. 6. Gap between two rolls according to each condition. (a) roll speed, (b) feeding speed.

➢ Roll speed

- **Fixed condition** - Hydraulic pressure: 28.44 MPa, feeding speed: 25 rpm
- **Changed condition** - Roll speed: 1.5 ~ 4.0 rpm
- **Results** - When optimal condition is 2.0 rpm, density of pellets was 4.21 $g \cdot cm^{-3}$ (Soil), 3.78 $g \cdot cm^{-3}$ (concrete).

➢ Feeding speed

- **Fixed condition** - Hydraulic pressure: 28.44 MPa, roll speed: 2.0 rpm
- **Changed condition** - Feeding speed: 10 ~ 35 rpm
- **Results** - When optimal condition is 25 rpm, density of pellets was 3.98 $g \cdot cm^{-3}$ (Soil), 3.60 $g \cdot cm^{-3}$ (concrete).

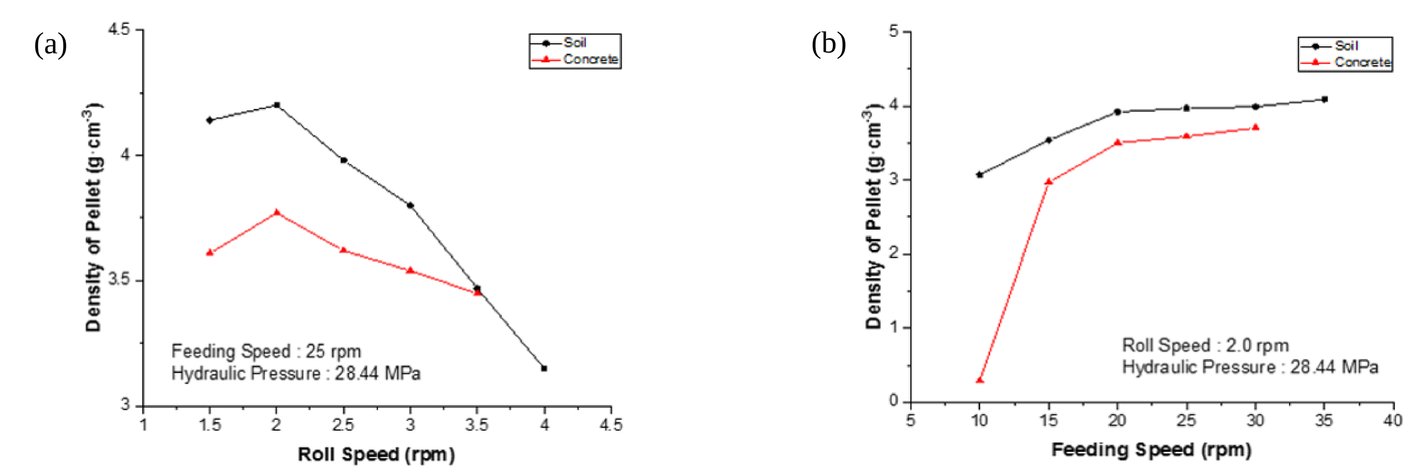

Fig. 7. Change of density of pellet according to each condition. (a) roll speed, (b) feeding speed.

◆ Evaluation for manufactured rigid pellets

➢ Manufactured pellets

- **Optimal Operating Conditions** - HP: 28.44 MPa, RS: 2.0 rpm, FS: 25 rpm
- **State of pellets** - Pellets takes the shape of combination of two tetrahedrons (see in Fig. 8)

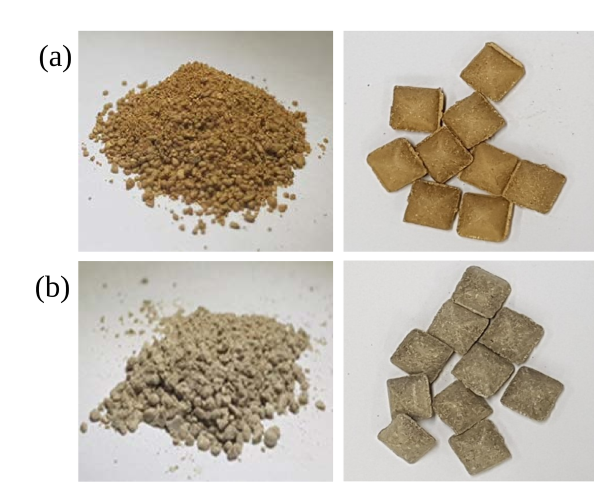

Fig. 8. Real image of powder materials and pellets. (a) soil, (b) concrete.

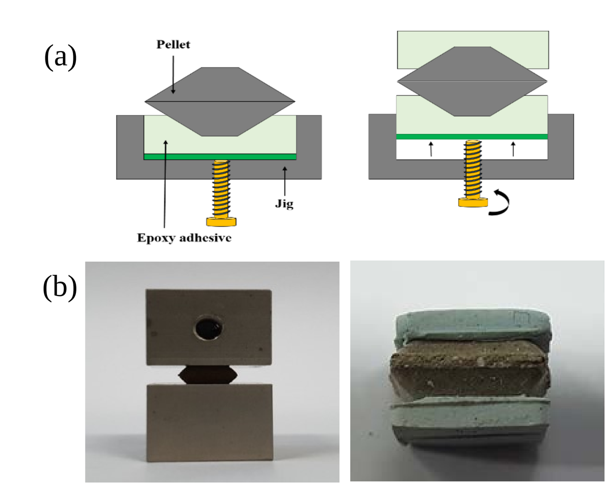

Fig. 9. Real image of jigs. (a) Concept diagram of jigs, (b) manufactured jigs.

➢ 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 (see in Fig. 9)
- **Results** - Compressive strength was 5.20 ~ 19.70 MPa (Soil pellets), 7.70 ~ 28.20 MPa (concrete pellets)

Table 2. The results of compressive strength of pellets.

Sample	Operating Condition			Compressive strength (MPa)
	Hydraulic pressure (MPa)	Roll speed (rpm)	Feeding speed (rpm)	
Soil Pellet	28.44	2.5	20	11.40
			25	10.80
			30	5.20
		2	25	19.70
		2.5		13.10
		3		8.50
Concrete Pellet	28.44	2.5	20	15.30
			25	12.00
			30	7.70
		2	25	28.20
		2.5		17.00
		3		24.40

➢ Volume reduction ratio

- **Measured specification of pellet -** Density, volume, weight (see in Table 3)
- **Formula -** $\frac{Density\ of\ pellet\ (g \cdot cm^{-3})}{Density\ of\ powder\ (g \cdot cm^{-3})} = Volume\ reduction\ ratio$
- **Results -** Average of volume reduction ratio(roll gap: 1 mm) was 2.9 (soil pellet), 2.8(concrete pellet)

Table 3. The results of the volume reduction ratio according to pelletization of powder.

Sample	Operating condition			Weight of pellet (g)	Density of pellet ($g \cdot cm^{-3}$)		Volume reduction ratio	
	Hydraulic pressure (MPa)	Roll speed (rpm)	Feeding speed (rpm)		Gap 0 mm	Gap 1 mm	Gap 0 mm	Gap 1 mm
Soil	28.44	2.5	15	1.06	4.16	3.03	3.57	2.60
			20	1.17	4.61	3.35	3.95	2.88
			25	1.19	4.67	3.40	4.01	2.92
			30	1.19	4.70	3.42	4.03	2.93
			35	1.22	4.81	3.50	4.13	3.00
Concrete	28.44	2.5	15	0.89	3.49	2.54	3.26	2.37
			20	1.05	4.12	3.00	3.84	2.79
			25	1.07	4.23	3.08	3.94	2.87
			30	1.11	4.35	3.17	4.06	2.95
			35	1.05	4.14	3.01	3.86	2.81

Conclusion

In this study, powdered radioactive wastes that are disposal nonconformity were manufactured into pellets by using a roll compaction system. The optimal operating conditions for this device were set as follows; hydraulic pressure: 28.44 MPa, roll speed: 2.0 rpm, and feeding speed: 25 rpm. The compressive strength of the pellet manufactured under the above conditions are in the ranges of 5.20 - 19.70 MPa (soil) and 7.70 - 28.20 MPa (concrete). Particularly, these are values that substantially exceed the waste acceptance criteria (WAC) for Korea waste disposal facility (3.45 MPa = 500 psi). As such, it can be interpreted that these pellets satisfy the handing over standards regardless of which solidification medium is utilized. Moreover, regarding the result of the volume reduction cost computation, the average volume reduction costs per specimen were found to be 2.9 (soil) and 2.8 (concrete). This can be interpreted as a volume reduction by approximately 1 / (2.8 - 2.9) when powder is roll compaction formed into pellets. Therefore, it was confirmed through this study that rigid pellets with high density (high strength) can be manufactured through conversion of powder into pellets. Through the additional experimentation, improvements of the volume reduction and solidification technology are to be made. In the future, it is considered that this technology may be applied to the treatment of wastes that are judged disposal nonconformity.