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

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1. 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.

2. Experiments

2.1. Materials

In this experiment, simulated waste samples were manufactured and used instead of fine soil that occurred after soil washing process. First, cesium solution was mixed with soil and a flocculating agent (J-AF, Jeon Tech.Co.,Ltd) was injected to be agitated. Here, the concentration of the cesium solution was 0.1 mmol/L, and the ratio of the soil to the flocculating agent was 10:1. As for the soil, only particles smaller than 38 μm were used and a sieve shaker (Daewha Tech, Analysette 3 Pro) was used to divide particle size. Then, the soil samples were dried for 48 hours in a dry oven (Jongro Industrial CO., LTD, VTEC-75), and the moisture content was set at around 7 %. Then, the samples were crushed into powder to form them into high compressed pellets. Table 1 shows the chemical composition of the soil samples.

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

2.2. Manufacture of rigid pellets by Roll Compactor

2.2.1 Pre-compressibility test

Prior to this experiment, compressibility was evaluated to find out about the possibility of making the sample into pellet using a uniaxial compressor. Used compressor has the maximum capacity of 35 MPa, but the range of pressure applied onto the powder during the compression process was set between 10-30 MPa. And the soil sample was made to free-fall into the cylindrical die of a certain volume and the powder was compressed by pushing down the upper pressure plate.

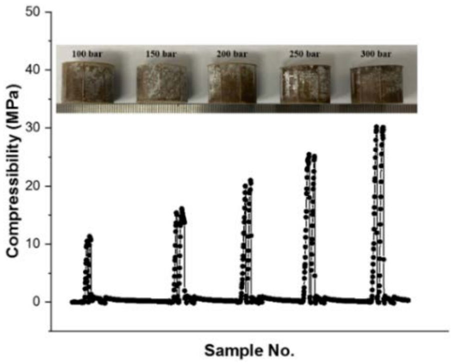

Fig. 1. Pre-compressibility test of contaminated soil waste according to change of pressure.

Table 2. Results of measuring the compressibility.

Sample	Pressure (MPa)	Density before/after compression		Compress-ibility (%)
		Before ($g\cdot cm^{-3}$)	After ($g\cdot cm^{-3}$)	
	10		2.0839	322
	15		2.2200	343
soil[a)]	20	0.6479	2.2402	346
	25		2.2491	347
	30		2.2706	350

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

As shown in Fig. 1, compressibility was sufficiently high even at the pressure range of 10-20 MPa. When a pressure similar to the compressive force applied by roll compactor (30 MPa) was imposed, the compressibility was confirmed to be remarkably high at 350 % (refer to Table 2). Therefore, it was judged that highly probable to form the soil sample into pellets using roll compactor.

2.2.2 Operating condition of device

It was already checked in advance whether it was possible to turn ordinary soil into pellets in preliminary experiment. And then, the concept diagram of roll compactor used and the actual pellets produced were shown in (a) and (b) of Fig. 2 respectively. The data which is derived the density of soil pellets according to change of operating conditions of the roll compactor was possessed (refer to Fig. 3). 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.

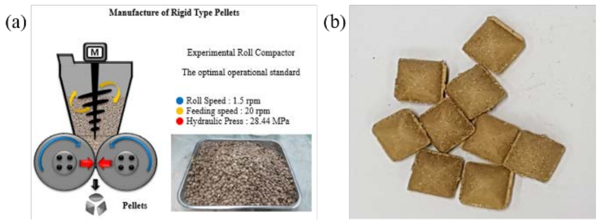

Fig. 2. Pelletization of soil samples using a roll compactor, (a) Concept diagram, (b) Appearance of soil pellet.

To this end, as shown in Fig. 3 and 4, the optimum conditions were arranged to compression-forming the soil samples into pellets as follows. The roll speed was fixed at 1.5 rpm, the hydraulic pressure and feeding rate were shifted to 27.45-28.44 MPa, 20-25 rpm, respectively. While manufacturing, the higher feeding rate and hydraulic pressure were, the higher density of pellets. Especially, the weight of pellet was the highest at 0.6549g when the hydraulic pressure, roll speed, and feeding rate were set at 28.44 MPa, 1.5 rpm, and 25 rpm respectively. The density of polluted soil pellet was 2.5783 g·cm^{-3}, much lower than that of ordinary soil. This is estimated to be attributed to an extremely low density of soil with particle size smaller than 38 μm used to produce the soil samples. Additionally, it is estimated necessary to look into the effects on pellet formation based on an analysis on chemicophysical properties of the flocculating agent (J-AF).

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.

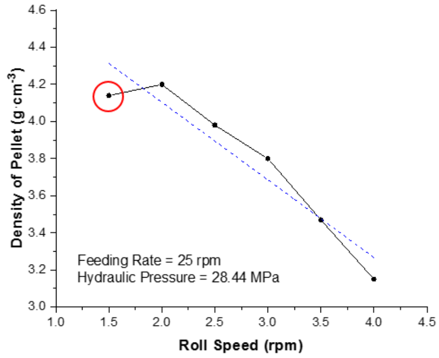

Fig. 3. Density of pellet according to roll speed (RS).

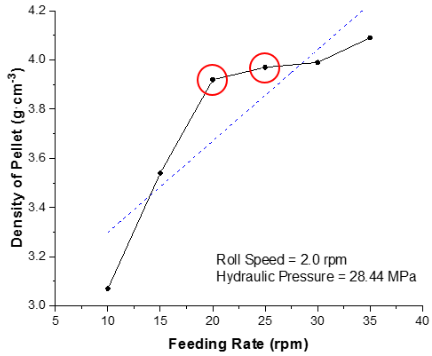

Fig. 4. Density of pellet according to feeding rate (FR).

2.3. Characteristic Evaluation for manufactured pellets

2.3.1. Compressive strength test

A compressive strength test was conducted to check the integrity of the manufactured pellets. The shape of the pellets produced looks like two tetrahedrons being joined together. However, both the upper and lower surfaces of the samples should be horizontal to make it possible to measure the compressive strength. Therefore, as shown in Fig. 5, a specially-produced surface processing jig was utilized to fixate the upper and lower surfaces with solid epoxy adhesive, with a pellet being placed between them.

And then, pellets were processed into samples for measuring compressive strength, and the compressive strength of each of the three pellets (12 in total) which is manufactured each operating condition was measured. The measurements of their compressive strength are shown in Table 4, and was measured between 4.03 and 19.28 MPa. The strength of the pellet was highest at 19.28 MPa, when the hydraulic pressure, roll speed, and feeding rate of device were set at 27.45 MPa, 1.5 rpm, and 25 rpm, respectively.

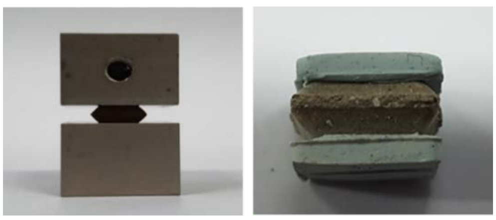

Fig. 5. Real image of manufactured jigs.

Table 4. Compressive strength of each pellet.

Sample	Operating condition[b)] RS (rpm)	FR (rpm)	HP (MPa)	Compressive strength (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), Feeding Rate (FR), Hydraulic Pressure (HP).

2.3.2. Volume Reduction Factor (VRF)

The ultimate purpose of this study is volume reduction of powdered waste. The volume reduction factor (VRF) of powdered waste was calculated by dividing the density of powder by that of pellet as shown in Equation (1). As indicated in Table 5, VRF was 0.25–0.27 when the gap was 0 mm, whereas with a 1 mm gap, it was estimated at 0.35–0.37. In the conservative perspective, VRF was calculated at 0.37 when the gap is 1 mm. 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.

$$\frac{Density\ of\ powder\ (g{\cdot}cm^{-3})}{Density\ of\ \ pellet\ (g{\cdot}cm^{-3})} = Volume\ reduction\ Factor\ (VRF) \quad (1)$$

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

Sample	Weight of pellet (g)	Density of pellet ($g{\cdot}cm^{-3}$) Gap[b)] 0 mm	Gap[c)] 1 mm	VRF Gap[b)] 0 mm	Gap[c)] 1 mm
Soil[a)] Pellet	0.6116	2.41	1.75	0.27	0.37
	0.6318	2.49	1.81	0.26	0.36
	0.6549	2.58	1.88	0.25	0.35

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.

3. 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 $g{\cdot}cm^{-3}$ when the operating conditions of the pellet roll compactor were as follows. The hydraulic pressure, roll speed, and feeding rate set at 28.44 MPa, 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.

ACKNOWLEDGEMENT

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