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

Sang Hyun Lim[1], Jun Yeol An[1], Jong Soon Song[1]* and Ki-Hong Kim[2]
[1]*Chosun University, 309 Pilmun-Daero, Dong-Gu, Gwangju, Republic of Korea*
[2]*Radin.Inc, 17, Techno 4-ro, Yuseong-gu, Daejeon, Republic of Korea*
**jssong@chosun.ac.kr*

1. 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 [1].

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.

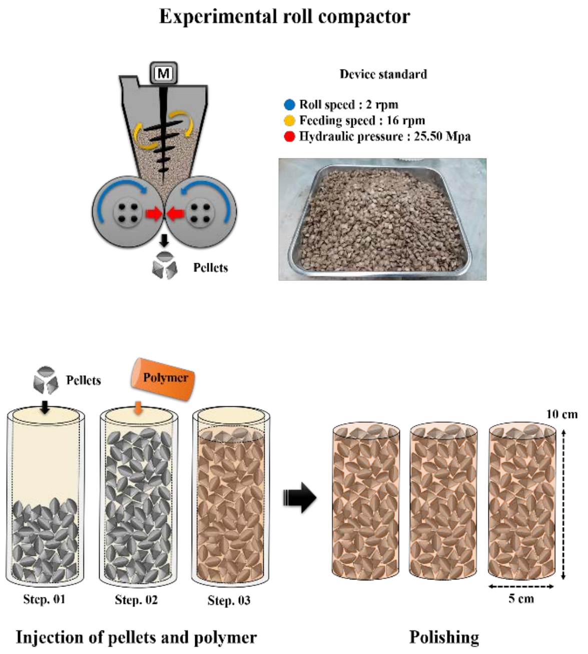

Fig. 1. Manufacturing process of polymer solidification.

2. Experiments

2.1 Materials

Among the waste acceptance criteria(WAC) for Korea waste disposal facility, it is prescribed that waste containing particulate material under the conditions of solidification(and stabilization) for packages be disposed of to be non-dispersible. Therefore, the particulate size for the powdered specimen used in this study was set at below 0.02 mm. The chemical compositions for each specimen, as show in Table 1.

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

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

2.2 Manufacture of rigid pellets by Roll Compaction

The roll compactor was designed and manufactured with application of the Johanson's model to produce rigid pellets of consistent sizes(H 6.5 mm x W 9.4 mm). Operating conditions for the device include hydraulic pressure, roll gap, roll speed, feeding speed. To select the optimal operating conditions for each specimen, the weight and density of pellets were checked in accordance with the change in the operating conditions.

2.2.1 Hydraulic pressure

The hydraulic pressure is an essential factor in the process of powder agglomeration within the roll tire (briquette). The hydraulic pressure varied in the range of 0 ~ 25.50 MPa to assess the state of the pellets. As a result, it could be confirmed visually that the agglomeration state of the pellets improved when hydraulic pressure was applied(Fig. 2). Therefore, hydraulic pressure was set at 28.44 MPa, which is the maximally designed value of the device, to execute roll compaction forming for each powdered specimen.

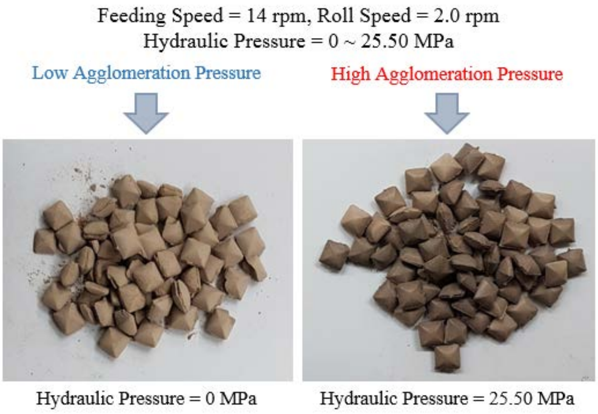

Fig. 2. Manufactured pellets according to change of hydraulic pressure.

2.2.2 Roll gap

Roll gap refers to the phenomenon of decreasing the powder supply speed while increasing the pressure applied to the roll. Currently, it is necessary to maintain narrow roll gap while increasing the pellet density. The hydraulic pressure was 28.44 MPa during the pellet forming process for concrete powder. And then, measurement of the roll gap accordance with changes in roll speed(see Fig. 3) and feeding speed(see Fig. 4). Through this, it was possible to confirm that the there is no significant effect on the roll gap in the range of –0.6 ~ +1.6 mm, even if the operating conditions change.

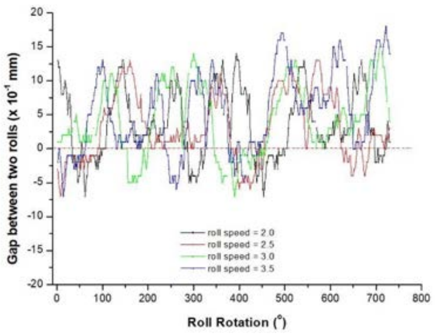

Fig. 3. Gap between two rolls according to the change of roll speed.

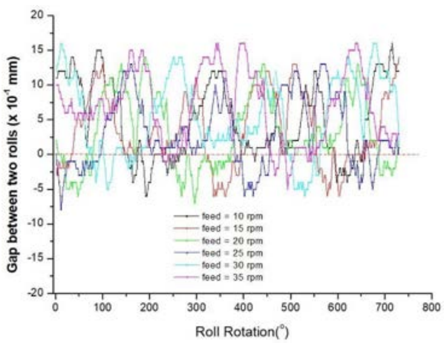

Fig. 4. Gap between two rolls according to the change of feeding speed.

2.2.3 Roll speed

The feeding speed and hydraulic pressure were consistently maintained to compute the optimal roll speed. And the result, density of pellets in accordance with the roll speed are illustrated in Fig. 5. As shown in Fig. 5, the densities of pellets was the highest when the roll speed was 2.0 rpm. And then, the densities of pellets were measured, 4.21 g·cm^{-3}(soil) and 3.78 g·cm^{-3} (concrete).

2.2.4 Feeding speed

The roll speed and hydraulic pressure were consistently maintained to compute the optimal feeding speed. And the result, densities of pellets in accordance with the feeding speed are illustrated in Fig. 6. As show in Fig. 6, the density of pellets was the increased alongside the feeding speed increase. In addition, roll rotation stopped due to reaching the device performance limit once the rate of the quantity of powder supplied reached the prescribed value. Through this, the densities of pellets were the best when the feeding speed was 25 rpm. And then, the densities of pellets were measured, 3.98 g·cm^{-3}(soil) and 3.60 g·cm^{-3}(concrete).

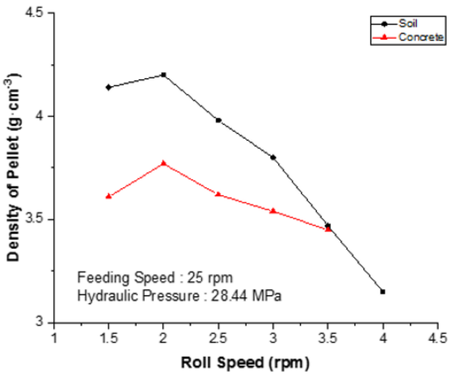

Fig. 5. Change of density of pellet according to roll speed.

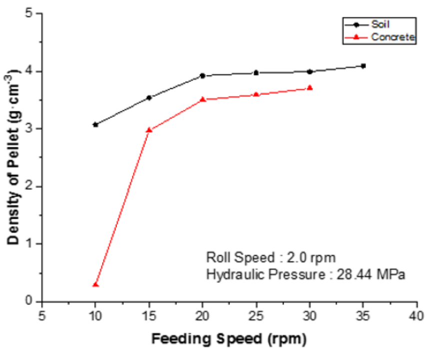

Fig. 6. Change of density of pellet according to feeding speed.

2.3 Evaluation for manufactured rigid pellets

2.3.1 Compressive strength

The Rigid pellets were manufactured under the optimum operating conditions of the roll compactor(see

Fig. 7). This is a machined measurement specimen to evaluate the integrity of the pellet by measuring its compressive strength. The configuration of the formed pellets takes the shape of combination of two tetrahedrons. Therefore, the surface of the specimen was treated to ensure that the top and bottom surfaces are parallel to each other to measure the compressive strength(see Fig. 8). As such, the results of the compressive strength of pellets manufactured for each of the operating conditions are given in Table 2.

(a) (b)

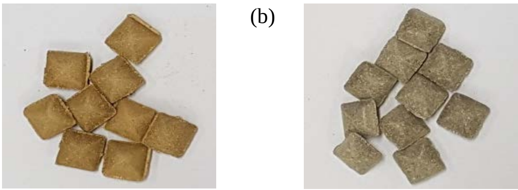

Fig. 7. Real image of soil pellets(a) and concrete pellets(b).

(a) (b)

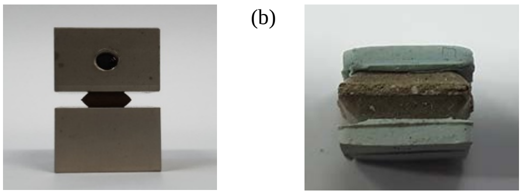

Fig. 8. Real image of soil pellets(a) and concrete pellets(b).

Table 2. The results of compressive strength of pellets.

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

*Hydraulic pressure = 28.44 MPa

2.3.2 Volume reduction ratio

The density and volume of the pellets were measured precisely to evaluate the volume reduction ratio of the powder to confirm the extent of the volume reduction achieved through pellet production. At this time, the weight, density, and volume of each pellet were measured, and the volume reduction ratio was computed by referring to formula (1). As show in Table 3, the average volume reduction ratio of a conservative 1 mm roll gap of were computed to be 2.9 and 2.8 for soil and concrete, respectively. This signifies that the powder can be compressed by 1 / (2.8 - 2.9) when powder is formed into pellets.

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

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

Sample	Operating condition* Feeding Speed (rpm)	Weight of pellet(g)	Density of pellet ($g{\cdot}cm^{-3}$) Gap 0 mm	Density of pellet ($g{\cdot}cm^{-3}$) Gap 1 mm	Volume reduction ratio Gap 0 mm	Volume reduction ratio Gap 1 mm
Soil	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	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

*Roll speed = 2.5 rpm, Hydraulic pressure = 28.44 MPa

3. Conclusions

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.

ACKNOWLEDGEMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education(2018M2B2B1065636)

REFERENCES

[1] J.S. S, et al., “A Study on the Pelletization of Powdered Radioactive Waste by Roll Compaction”, Journal of Nuclear Fuel Cycle and Waste Technology, 17(2), 203-212 (2019).
[2] J.S. S, et al., “Roll Compaction of Powdered Radioactive Wastes”, Waste Management, 978-1-5108-6764-2 (2018)