Report on “Radiation Disaster Recovery Studies”

Course: Radioactivity Environmental Protection Course
Name: Ooki Kurihara

○Regarding “Radiation Disaster Recovery Studies”

Deposition of radioactive materials occurred due to the Fukushima Daiichi Nuclear Power Plant accident in March 2011. Decontamination has been carried out where the radiation dose rate is higher than the reference value in order to reduce the air dose rate in the living environment by removing and shielding radioactive materials. The amounts and the radioactivity concentration of soil and waste generated by decontamination in Fukushima Prefecture as of January 2016 are estimated; 10 million m^3 of soil less than 8,000 Bq/kg, 10 million m^3 of soil more than 8,000 Bq/kg and less than 100,000 Bq/kg, 10 thousand m^3 of soil more than 100,000 Bq/kg, and 1.6 million m^3 of incineration ash[1)]. The removed soil by decontamination in Fukushima Prefecture is stored in flexible containers at temporary storage sites in each municipality, and then transported to the intermediate storage facility from March 2015[2)]. The removed soil contained in the flexible containers transported from the temporary storage sites to the intermediate storage facility is crushed first and landfilled in the soil storage facility in the intermediate storage facility. Regarding the removed soil, it is decided by a law to take necessary measures to complete the final disposal within 30 years after the start of interim storage[1)], and final disposal method will be discussed in 2019-2024[3)]. Based on the above, the construction of the final disposal facility will be an important social and engineering problem in the near future.

In Japan, disaster waste disposal using a coastal disposal facility that can dispose of huge amounts of waste exceeding 10 million m^3 at a place has been operated in the recovery from the Great Kanto earthquake of 1923 and the Great Hanshin Awaji Earthquake of 1995. Unlike in the land disposal facility, most of the waste in the coastal disposal facility is submerged. In case of constructing a coastal disposal facility, impervious seawall structure is constructed at the beginning, which makes inner water isolated from the outside sea. And then, waste is reclaimed into the isolated inner water. After water surface of the coastal disposal facility disappears and a land appears, the final soil covering is conducted, and the landfill is over.

In my doctoral thesis, I considered a possibility that the coastal disposal facility will be an option of the final disposal method for the removed soil and developed sealing geomaterial used for the bottom shielding of the offshore disposal facility intended for the final disposal of the removed soil. The cost of the construction of the offshore disposal facility and the disposal of the removed soil was also examined.

In the Phoenix program, I have learned that radiation disaster recovery in a short time is very important, while enough time is required for security of local residents, which is result of reduction of the air dose rate due to natural attenuation of radioactivity and decontamination. I had many opportunities to hear the voice of the residents of the evacuation zone and the construction area of the intermediate storage facility. Among the people whose residential areas were designated as the site of the intermediate storage facility, some built new houses in new places and have reconstructed the lives of their families, while others are still waiting for return of their land by the government 30 years later in order to leave their lands as their living marks to the next generation. I got an impressive word from a resident in the evacuation zone, "Five years until returning was very long and it was an enough time for many people to loss the desire to restart the farming." I thought that, for the affected people, evacuation for a long time would make their reconstruction more difficult. My research theme is the offshore disposal facility, and the site of the offshore disposal facility is not individual lands, therefore, it is easier to reach an agreement than land disposal sites which is located in or near private land. Thus, I believe that my research can contribute to the smooth implementation of the final disposal. While learning radiation disaster recovery, I strongly felt that government decisions such as policies and criteria, including the decontamination and the disposal of the removed soil, have a great influence on residents' lives and cultures over a long period of time. In addition, I also learned the beginning of risk communication, but I could not mention it in my doctoral thesis. However, considering the method of final disposal of the removed soil, it is important to consider not only technical aspects but also risk communication with stakeholders.

○Title of Doctoral Thesis

Study on Offshore Disposal Facility for Soils and Wastes Contaminated with Radioactive Cesium

○Summary of Doctoral Thesis

Due to the decontamination work carried out after the Fukushima Daiichi Nuclear Power Plant accident, approximately 22 million m^3 of the removed soil and waste are generated, and the disposal of the removed soil has become an issue of the recovery from the Great East Japan Earthquake. In this study, I discussed the offshore disposal facility for the final disposal of the removed soil and developed the sealing geomaterial used for the bottom shielding of the offshore disposal facility. The cost of the construction of the offshore disposal facility and the disposal of the removed soil was also examined.

In Chapter 1, the background and related research were summarized as an introduction.

In Chapter 2, the structure of the offshore disposal facility and the necessary performance concerning the permeability and adsorptivity of the sealing geomaterial used for the bottom shielding were describe.

In Chapter 3, the permeability of the sealing geomaterial made with marine clay, bentonite, sand and zeolite was investigated. The consolidation test was carried out on the sealing geomaterial of various composition to determine the hydraulic conductivity. With addition of sand to marine clay, the hydraulic conductivity for flow in pores k_{pore} was increased due to the reduction of the void ratio compared with that without the addition. By the addition of bentonite and zeolite, k_{pore} decreased due to the addition of bentonite. With addition of the same amount of bentonite, k_{pore} decreased as the zeolite addition ratio increased. At the end, the hydraulic conductivity was predicted from the change of porosity by adding bentonite, zeolite and sand.

In Chapter 4, the compression and consolidation characteristics of sealing geomaterial made with marine clay, bentonite, sand and zeolite were examined. Relationships between the change ratio of compression index C_c/C_{c0} and the addition rate of each material were shown, and C_c/C_{c0} of the sample adding bentonite and sand or zeolite was predicted. The prediction based on the relational expression of the change rate of consolidation coefficient c_v/c_{v0} and the addition rate of each material was also investigated.

In Chapter 5, the cesium adsorption characteristics of the sealing geomaterial made with marine clay, bentonite, sand and zeolite was studied. The cesium adsorption characteristics of the sealing geomaterial was

investigated by a batch adsorption test and a consolidation and seepage test. The influence of the layer thickness on the adsorption breakthrough property of cesium was considered, and a target value of Pore Volume of Flow (PVF) was proposed. It was shown that PVF at the breakthrough point can be predicted from the composition of each material. In addition, X-ray diffraction analysis showed that layered silicate minerals with cesium adsorption effect were present in each material.

In Chapter 6, the method of composition design based on the results of Chapter 3, 4, and 5 was explained. The method of adding bentonite and zeolite in consideration of hydraulic conductivity and cesium adsorption characteristics was shown by using the prediction of hydraulic conductivity examined in Chapter 3 and the prediction of PVF at the breakthrough point examined in Chapter 5. In addition, I showed the method of adding sand considering compressibility using the prediction of the change rate of compression index discussed in Chapter 4 and confirmed the time required for consolidation using the prediction of the change rate of consolidation coefficient.

In Chapter 7, I discussed the permeability and adsorption properties of the clay with the addition of a small amount of cement (CASC). Vane shear test, consolidation test and hollow cylinder torsional permeability test were performed on CASC contains about 2-4%of cement. CASC appears to have strength of several kPa with curing, and it is considered that CASC will be an option of the sealing geomaterial from the viewpoint of giving necessary strength for construction. As a result of investigation of the change of the hydraulic conductivity before and after giving the shear deformation, cracks occurred due to shearing deformation of 20% in the lean-mix cement-treated clay (LCTC) and the hydraulic conductivity of LCTC was increased, however there was no increase in the hydraulic conductivity of CASC. In addition, studying the cesium adsorption characteristics showed that PVF at the breakthrough point was not significantly different from that without the addition.

In Chapter 8, construction method of the offshore disposal facility and disposal method of the removed soil were shown, and the cost of construction and disposal was examined. When the transportation distance of the removed soil and dredged soil used for the sealing geomaterial was set to 5 to 200 km, direct construction costs including the construction cost and transportation cost were 477.6 billion yen to 549.2 billion yen, and it was found that the same amount of cost as the intermediate storage facility[4)] would be required for final disposal of the removed soil by the offshore disposal facility. In addition, the estimated construction cost per 1 m^3 of disposal capacity, including construction cost and transportation cost of dredged soil, was 25,600 to 26,500 yen. It was found that when the offshore disposal facility was used for the final disposal of the removed soil, disposal capacity of 20 million m^3 is allocated to a place, and there was a possibility that the construction cost per 1 m^3 could be reduced compared with land disposal facilities.

In Chapter 9, the findings obtained in each chapter were summarized as a conclusion, and future tasks were mentioned.

1) Ministry of the Environment. (2016). Development strategy for volume reduction and recycling technology for intermediate storage removal soil. (in Japanese)
http://josen.env.go.jp/chukanchozou/facility/effort/investigative_commission/pdf/investigative_commission_text.pdf
2) Ministry of the Environment. (2016). On the verification report on pilot transportation. (in Japanese).
http://josen.env.go.jp/chukanchozou/action/investigative_commission/pdf/pilot_transportation_160331_01.pdf

3) Ministry of the Environment. (2016). Strategic process chart of volume reduction and recycling technology development of intermediate storage removal soil. (in Japanese). http://josen.env.go.jp/chukanchozou/facility/effort/investigative_commission/pdf/investigative_commission_process.pdf

4) Yasutaka, T., & Naito, W. (2016). Assessing cost and effectiveness of radiation decontamination in Fukushima Prefecture, Japan. Journal of environmental radioactivity, 151, 512-520.

○Other theses published in academic research journals

1. Kurihara, O., Tsuchida, T., Takahashi, G., Kang, G. O., & Murakami, H. (2018). Cesium-adsorption capacity and hydraulic conductivity of sealing geomaterial made with marine clay, bentonite, and zeolite. Soils and Foundations, 58, 1173-1186. (In Press) (Peer Reviewed)
2. Kurihara, O., Takaoka, Y., Tsuchida, T., Shiraga, T., Hashimoto, R., & Kumagai, T. (2018). Sealing geomaterial for coastal disposal facility using marine clay with the addition of a small amount of cement. International journal of GEOMATE, 15(51), 132-139. (In Press) (Peer Reviewed)
3. Kurihara, O., Tsuchida, T., Takahashi, G., & Murakami, H. (2018). A study on the permeability of geomaterials made with marine clay, bentonite, sand, and zeolite. Journal of Japan Society of Civil Engineers, Ser. B3 (Ocean Engineering), 74(2), I_874-I_879. (In Japanese) (Peer Reviewed)
4. Tsuchida, T., Murakami, H., Kurihara, O., Athapaththu, A. M. R. G., Tanaka, Y., & Ueno, K. (2017). Geotechnical sealing material for coastal disposal facility for soils and wastes contaminated by radioactive cesium. Marine Georesources & Geotechnology, 35(4), 481-495. (Peer Reviewed)