Compaction Property Of Integrated Backfilling Materials

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Abstract : Nuclear industry production would produce large amounts of nuclear waste.How to safely dispose of the nuclear waste especially high level radioactive waste (HLW) became increasingly serious problem at present. This article turned out that compaction energy was an important factor of the impact compaction performance through the light and heavy compaction experiments . Adding a certain amount zeolite or attapulgite could get larger maximum dry density and smaller optimal moisture content. In zeolite or attapulgite added to 0%-20% of dry density increased mixed materials, compaction curve was relatively tame. With zeolite or attapulgite increased to 20% to 50%, the pressure increased sharply. But when zeolite or attapulgite increased more than 50%,the pressure of the compaction needed higher. Thus the content of zeolite or attapulgite in 20% to 30% was easier to compact.

Introduction

In order to relieve the effect of the pressure of the surrounding rock on the waste cans in the geological repository of high-level radioactive waste, the gap between the surrounding rock and the waste tank were closed effectively block the leakage of radioactive waste material to the environment. A buffer/backfill material must be filled between surrounding rock and the waste tank [1] . It was as the last artificial barrier in the repository of high level waste disposal, needed the function of the engineering barrier, the function of the hydraulic barrier, chemical barrier and thermal conductivity. In deep geological disposal, the heat released by the nuclear waste diffused back to the backfill material, which would be subjected to high temperatures, high stresses and strong air currents, may create fissures. Then groundwater was dipped into the backfill material along the fracture. Furthmore, the untreated bentonite was difficult to meet the performance requirements of the high-level waste repository. It must be treated and compacted before it could be used as buffer / backfill material. The compaction properties of high compacted backfill materials were studied in China. Most of them were single bentonite or sand mixture.So it was necessary to study the compaction properties of the composites.The compaction experiments in this paper focused on the relationship between the maximum dry density and the optimal moisture content under different compaction energy (light and heavy) of ZB and AB mixtures.

Experiment

Sample

Raw materials used in the experiment were Xinjiang Altai bentonite (Na +), Xinjiang zeolite, Sichuan Jiangyou pyrite . Xinjiang Altai bentonite was light gray and white. Its deposit was located

in the northern edge of Xinjiang Junggar Basin. The main mineral of bentonite in Xinjiang Altai was Na - montmorillonite, and its content was high and contained a small amount of α - quartz. Since it had good cation exchange capacity, Expansion properties in this experiment, so it was as the substrate of the experiment. The physico-chemical and engineering properties of bentonite in Xinjiang are refered with table 1.

Tab. 1   The Physico-chemical and Engineering Index of Xinjiang Bentonite

Swelling Capacity (mL/1g)	Swelling Value (mL/3g)	pH	Absorption of Blue (Meq/100g)	CEC (mmol/100g)	Liquid Limit (%)	Plastic Limit (%)
28	42	6.4	139	82	82.3	27
Dry Moisture Content	Bulk Density (g/cm^3)	Proportion	Dry Density (g/cm^3)	Porosity (%)	Plasticity Index	Thermal Conductivity (W/m·℃)
14.47	2.23	2.52	1.89	24.10	51.1	0.21

Xinjiang zeolite was mainly plate, sheet, needle. From the X-ray diffraction test, it was found that the main mineral composition of the zeolite was mordenite, clinoptilolite, zeolite, quartz, montmorillonite, feldspar and hydrous mica. Because the CEC value of zeolite(98mmol /100g)was much higher than that of Xinjiang bentonite ore, it showed that the cation exchange capacity of the zeolite was better than that of Xinjiang bentonite. But zeolite had porous characteristics, poor water barrier, and needed   to add bentonite to prevent groundwater into the waste container tank.It also needed to prevent the radionuclide with the groundwater migration, diffusion.

The cation exchange capacity of attapulgite was 0.295 mmol / g, which was smaller than that of bentonite and zeolite. The porosity was larger and the thermal conductivity(0.277 W/m·℃) was the biggest, which was mainly due to the higher siliceous content. According to previous studies [2], attapulgite for some nuclides such as cesium adsorption performance was better than bentonite, and easy expansion properties of water was good, so this article also tried to explore the attapulgite as one of the candidate materials to optimize integrated backfill material.

Backfill material into the ground a few kilometers, the release of radionuclide energy was difficult to heat out from the waste filling, and pyrite had a good thermal conductivity to solve this problem.Therefore, according to the complementary properties of different mineral materials, depending a certain combination ratio on better developing the superior performance of the there materials to achieve optimal integration. According to the pre-required dry density and moisture content of the sample configuration, several natural samples were naturally air-dried, crushed into 100 mesh, bentonite, zeolite (or attapulgite), pyrite (additive) mixed by a certain proportion. A few groups of backfill materials are found in Table 2.

Tab.2   Composite Mineral Constituent Content

Name of the mineral	Zeolite content（%）	Bentonite content（%）	Name of the mineral	Attapulgite content（%）	Bentonite content（%）
Z_5B_5	50	50	A_5B_5	50	50
Z_3B_7	30	70	A_3B_7	30	70
Z_2B_8	20	80	A_2B_8	20	80
Z_0B_{10}	0	100	A_0B_{10}	0	100

Note: The compound mineral No. Z_5B_5 stand for Zeolite was 50% of the total mass mixture(zeolites and bentonite) , which was added 10% of pyrite as an additive. A-Attapulgite, B-Bentonite, Z- Zeolite ,P - Pyrite, the rest of the ratio and so on.

Experimental facilities

Compaction equipment was DJS-2 type digital display standard electric compaction instrument producted in Nanjing Soil Instrument Factory. Light and heavy compaction test compaction instrument main components specifications were refered with Table 3. Stripping equipment used DTM-2 automatic stripping machine was producted in Nanjing soil instrument production. Oven and dryer were DZ-1BC type, Tianjin Tester Instrument Ltd . The others were balance ,round hole screen, metal plate, Soil shovel, Disc, bulb, bulldozer, aluminum box, ring knife, earth knife, Vaseline, dial indicator and so on.

Tab.3　The Standard of Compaction Apparatus

Test method	Hammer Diamete-r (mm)	Heavy hammer (kg)	High fall (mm)	The compaction cylinder			Protecting tube height (mm)
				Inner diameter (mm)	Tube of high (mm)	volume (cm^3)	
Light	51	2.5	305	102	116	947.4	50
Heavy	51	2.5	457	152	116	2103.9	50

Dynamic compaction test method

In this paper, lightweight and heavy-duty experiments carried out on backfill material mixture of different proportions were studied. We needed to put the material over the 5mm screen and they were dried under 105℃ to get constant weight. Then each sample was added to a certain distilled water and sealed for 24 hours by the spray method, and t each ratio was formulated with 5 diferent water contents. The water content of the backfill material was reduced by 2%. In the light compaction test, the soil sample under the electric hammer was divided into three times, each time 25 times, and the sample was divided into 5 layers, 56 times/layer in heavy compaction. Finally, the sample was introduced into the cylinder, and the water content of the sample was measured from the center of the sample,and the water content was calculated to 0.1%. We could draw the curve of the relationship between dry density and water content and got the maximum dry density and the most water content through the curve.That was the maximum dry density of the corresponding was optimal moisture content. The dry density of each point after compaction was calculated as follows：

$$r_d = \frac{r}{1+0.01w}$$

(1)

ρ_d—dry density（g/cm^3）, calculated to 0.01, ρ—wet density（g/cm3）, w—water content（%）。

Experimental results and discussion

Effect of Bentonite Proportion

Through the table4, Fig.1, Fig.2, it was showed that with the decrease of bentonite content, the maximum dry density increased and the optimal water content decreased . In this paper, the dry density of a single mineral Xinjiang Altai bentonite maximum was 1.271g / cm3, the optimum moisture content of 42.96%. Abidin [3] and other studies had shown that the bentonite content of 3%

-20%, with the bentonite content increased, the optimal moisture content increased, the maximum dry density decreased.

Kayabali[4] and Hou Li[5] also studied the compaction properties of ZB mixtures. The results showed that the optimal water content decreased with the increase of bentonite content in the same compaction work. The conclusion was opposite to the results in this paper . Theoretically, under the same compaction energy, soil particles after expansion would increase due to the water absorption of more bentonite . But the maximum dry density should be reduced, and the optimal moisture content should be increased. It Indicated that the more bentonite soil content was, the more difficult compaction was . In this paper, adding a certain amount of zeolite or attapulgite could make the plasticity index of backfill material significantly reduce, and plasticity reduce. The compaction test could achieve greater maximum dry density and smaller optimal moisture content, thus we could get a clear peak compaction curve though original pure bentonite nature of "conditioning" was improved.

Tab.4 The dry density and water content of ZB and AB mixture under the low compaction

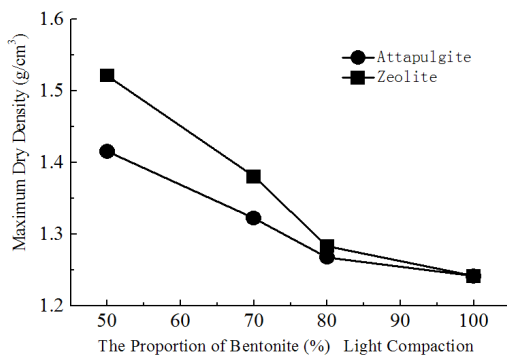| Sample	Water Content (%)	Dry density (g/cm^3)	Sample	Water Content (%)	Dry density (g/cm^3)
Z_5B_5	31.27	1.52	A_5B_5	36.72	1.42
Z_3B_7	35.55	1.38	A_3B_7	38.43	1.32
Z_2B_8	37.79	1.31	A_2B_8	40.88	1.28
Z_0B_{10}	42.96	1.27	A_0B_{10}	42.45	1.26

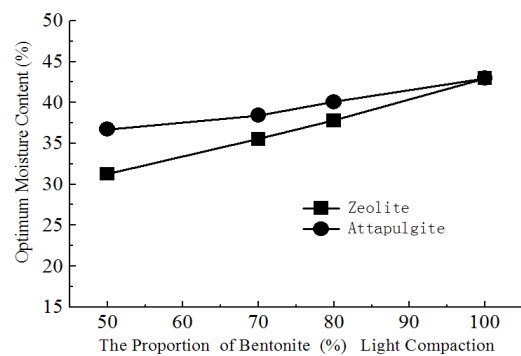Fig.3 The maximum dry density of different materials under the low compaction

Fig.4 The optimum moisture content of different materials under the low compaction

Influence of compaction energy

From tab4, tab5, fig.3 and fig.4, we also could see that the dry density of the mixed material obtained by the heavy compaction was larger than that of the light compact. Therefore, compaction energy was an important factor affecting the compaction effect of composite minerals. It was worth noting that when the zeolite or attapulgite was added in the range of 0% to 20%, the dry density of the mixed material increased little and the compaction curve was relatively gentle. When the zeolite or attapulgite was increased to 20% -50% , the compacted dry density increased sharply. It was because the mixture of bentonite accounted for most of the composition, which had large surface area, water absorption capacity, strong combination of water film changes in the scope of large. Then, in the external force, the particles moved not only to overcome the friction resistance within the zeolite and bentonite or attapulgite, but also overcomed by the water molecules cohesion . So the compaction range of the mixture was large and the relative change of the dry density was relatively small. However, the addition of 50% zeolite or attapulgite had a high dry density, which was difficult to control with light or heavy compaction during the actual construction, and the

construction time was long.

Tab.5   The dry density and water content of ZB and AB mixture under the heavy compaction

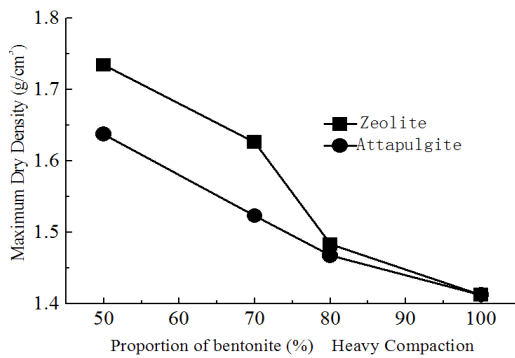| Sampl	Water Content (%)	Dry density (g/cm^3)	Sample	Water Content (%)	Dry density (g/cm^3)
Z_5B_5	30.77	1.73	A_5B_5	32.77	1.64
Z_3B_7	32.76	1.63	A_3B_7	34.95	1.52
Z_2B_8	35.79	1.48	A_2B_8	36.88	1.45
Z_0B_{10}	40.22	1.41	A_0B_{10}	40.22	1.41

Fig.3   The maximumu dry density of different materials under the heavy compaction
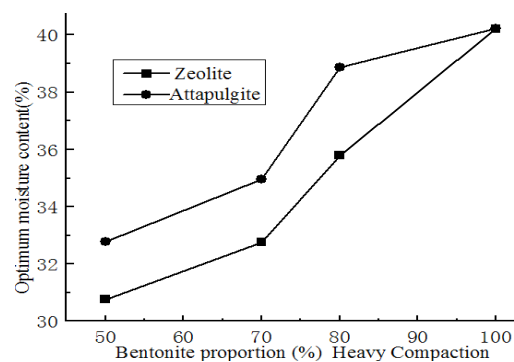

Fig .4   The optimum moisture content of different materials under the heavy compaction

From Fig. 1, Fig. 2, Fig. 3 and Fig.4, it could be seen that the maximum dry density of the ZB composite minerals under light and heavy compaction conditions was larger than that of the AB composite minerals, and the optimum moisture content was less than that of the AB composite minerals. In the same compaction power, a certain ratio of adding zeolite was easier to get a dry density of the larger minerals than the addition of attapulgite.

Conclusion

The compaction experiments in this paper focused on the relationship between the maximum dry density and the optimal moisture content under different compaction work (light and heavy) of ZB and AB mixtures. The experimental results showed that adding a certain amount of zeolite or attapulgite could work out that the plasticity index of backfill material was obviously reduced and the plasticity was reduced. However, the maximum dry density and the smaller optimum moisture content could be obtained in the compaction test. The original bentonite was difficult to be "conditioned", and the peak could be obtained obvious compaction curve.In addition, the dry density of the mixed material obtained by the heavy compacting was larger than that of the light compaction. Therefore, compaction energy was an important factor affecting the compaction effect of composite minerals. Overdose attapulgite or zeolite aggregated particles easily slide in the frame.It was difficult to obtain a higher maximum dry density even if too much high load . The results of dynamic compaction was the same, so the content of attapulgite or zeolite of 20% -30% easier to compact.

Acknowledgements

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