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Study on the maximum dry density of sea mud modified clay as the anti-seepage layer material in petrochemical field

J J Ye¹, G M Zhu*¹,², ³, M Q Zhang¹, X H Zhang¹ and J K Shen¹

¹School of Petrochemical and Energetic Engineering, Zhejiang Ocean University, Zhoushan 316022, China
²United National-Local Engineering Laboratory of Harbor Oil&Gas Storage and Transportation Technology, Zhoushan 316022, China
³School of Naval Architecture and Mechanical-electrical Engineering, Zhejiang Ocean University, Zhoushan 316022, China

E-mail: huobiterr@163.com

Abstract. As the pollution of the ground water and soil in the petrochemical field area is becoming more and more serious, the anti-seepage layer is an effective way to eliminate the pollution of the ground water and soil, and has received extensive attention. As the natural anti-seepage material resources which can meet the specification requirements are limited, it is imperative to study artificial modification of natural anti-seepage materials. Compaction degree is the main factor affecting the permeability of materials. It’s quite necessary to determine the compactness parameters of materials before the study of permeability. In this paper, the maximum dry density and the best water content of the mixture are measured by mixing local clay and sea mud in a variety of proportions, and the maximum dry density of the mixture is analyzed, and the optimum mass ratio of the material used as the material of the anti-seepage layer is determined. The test shows that when the mass ratio of clay to clay is 1:4 and the water content is 16%, the maximum dry density is close to the maximum and the compaction characteristic is the best and the maximum dry density reaches 1.78g×cm⁻³. The results provide sufficient data support for the follow-up study.

1. Introduction

In the process of storage and transportation of petrochemical products, leakage occurs easily. When the pollutants are infiltrated from the ground into the groundwater layer, it will lead to groundwater pollution in this area[1]. The construction of anti-seepage layer is an effective way for petrochemical enterprises to prevent pollutants from infiltrating the groundwater, rivers and ocean environment, so as to fight against groundwater, rivers and ocean from being contaminated.

At present, the commonly used anti-seepage materials in petrochemical enterprises include natural anti-seepage materials, synthetic organic anti-seepage materials and cement-based infiltration crystalline anti-seepage materials. The cost of material is not the same because their different laying specifications. For example, the cost of natural calcium bentonite clay mixture is about 80 RMB per square meter, the cost of laying a single layer synthetic HDPE anti-seepage membrane is about 140 RMB per square meter, and the cost of cement-based permeable crystalline anti-seepage material is about 240 RMB per square meter. It can be seen that the natural anti-seepage material is simpler and easier to maintain and repair than other materials, and the cost is lower than other materials. However,
there are limited natural anti-seepage materials to meet the requirements of specifications, so the modification of natural anti-seepage materials is the focus of current researches[2].

With the continuous expansion of China's coastal petrochemical industry, the large-scale petrochemical bases and the national petroleum reserve bases are constantly planned and constructed. For example, the first-phase national petroleum reserve bases of 16 million 400 thousand cubic meters in Zhoushan, Zhenhai, Dalian and Huangdao. The sea mud in these coastal area has the characteristics of high porosity, high water content, strong compressibility and strong anti-seepage[3], abundant, widely distributed and easily accessible. It’s significant to use sea mud as the clay modification material to reduce the cost of foundation construction in the petroleum reserve bases and to improve the environmental friendliness of the petrochemical bases.

2. Research purposes

Many scholars in China have studied the characteristics of sea mud as the modified material, such as Z W Jiang [4] explored whether the sand and sea sand mixture can be used as seawall packing filler, by light compaction test and relative density test, the maximum dry density of the mixture is determined and compared. The influence of the maximum dry of the mixture of sea sand and water content of the mixture is studied. X J Xu [5] studied the dynamic strength characteristics of sea sand sea mixture in the different proportions, and determined the optimal quality ratio of sea sand sea mud from the consideration of the variation rule of the strength of the mixture and the dynamic strength index. Above research papers used sea mud mixed with sea sand as seawall packing filler. With the construction of large petrochemical reserve bases in the coastal area, if the sea mud could us as anti-seepage layer of modification material applied in petrochemical projects and meet the engineering requirements, which can both meet the urgent needs of the petrochemical enterprises for the natural anti-seepage material, and can make full use of regional resources, improve the environment and save investment.

In the anti-seepage layer of petrochemical area, whether modified clay can be used as filler, compaction degree is one of the important parameters that must be considered. Requirements in the specification: the relationship between the optimum water content, the maximum dry density and the permeability coefficient must be measured before the construction of impermeable layer; the construction of the clay layer should be layered and compacted, and the compactness degree of the clay layer should be tested by the circular knife method[6]. The higher the compaction degree, the smaller the porosity in the clay, the higher the cohesion and the higher the compactness. Under the best compaction degree, the permeability of clay is the best. The maximum dry density and the optimum water content are the apparent parameter[7] of the compaction degree. They are also the most intuitionistic validation parameter for the feasibility of sea mud modified clay as the impermeable layer in the petrochemical field. In this paper, the test of the maximum dry density and the optimum water content of a variety of sea mud are carried out. The properties of the modified clay as the material for the impermeable layer in the petrochemical plant is verified, and the data support is provided for the research of the subsequent permeability tests.

3. Experimental materials and scheme

3.1. Experimental materials
The clay used in the test is taken from the Zhoushan national oil reserve bases around. The sea mud is taken from Ao Shan Island tidal flats. The basic physical properties of the materials are shown in Table 1. After the sea mud and clay were air-dried and dried through 2mm aperture sieve to remove the shells, leaves and other debris. The amount of sea mud was set as 10%, 15%, 20%, 25% and 30% respectively. According to the plastic limit of the soil, the optimum water content of the modified clay is estimated, and then 5 samples are prepared in accordance with the water content difference of 2% in turn. The modified clay is mixed with water into the plastic bag, and the test is carried out after 24h.
3.2. Experimental scheme

Compaction test refers to the method of hammering the solid soil to understand its compaction characteristics. The soil of different water content was hammered with different hammer force and the corresponding dry density was measured. Then the relation curve between different water content and dry density was obtained. The maximum dry density and the optimum water content of the soil sample were obtained through the curve, which provided the basis for the design and construction. According to the standard of geotechnical test method[8], the compaction test is carried out with the standard light compaction tester. The size specifications of the test model are shown in Table 2.

### Table 1. The physical properties of materials

|       | Specific gravity | Water content (%) | Liquid limit (%) | Plastic limit (%) | Plasticity index |
|-------|------------------|-------------------|------------------|------------------|-----------------|
| clay  | 2.07             | 10                | 25.0             | 19.1             | 5.9             |
| Sea mud | 2.69            | 68                | 48.4             | 31.4             | 17.0            |

### Table 2. Specifications of light compaction test apparatus

| type    | Hammer bottom diameter(mm) | Hammerer quality(kg) | Drop height (mm) | Internal diameter-r (mm) | Tube height (mm) | Volu-me(cm³) | Numb-er of plies | Stroke number-per layer | Hammerer energy(k J/m⁴) |
|---------|-----------------------------|-----------------------|------------------|--------------------------|-----------------|--------------|------------------|--------------------------|--------------------------|
| light   | 51                          | 2                     | 305              | 100                      | 116             | 947          | 3                | 25                       | 592.2                    |

Different water content of each kind of clay was prepared. In the prepared samples, three homogeneous soil was poured into the compaction cylinder, three layers were struck and 25 times hit each layer. The sample surface of each layer should be "drawing" after processing the compaction, and the total mass of the weighing cylinder and soil sample after compaction was measured.

### Table 3. Dry density of different sea mud admixture and different water content (g×cm⁻³)

| Admixture of sea mud(%) | Water content(%) |
|-------------------------|------------------|
|                         | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 10                      | 1.68 | 1.69 | 1.76 | 1.72 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.68 | 1.66 | 1.67 |
| 15                      | 1.71 | 1.76 | 1.77 | 1.74 | 1.72 | 1.70 | 1.70 | 1.70 | 1.70 | 1.68 | 1.66 | 1.67 |
| 20                      | 1.71 | 1.78 | 1.75 | 1.71 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.68 | 1.66 | 1.67 |
| 25                      | 1.70 | 1.75 | 1.72 | 1.68 | 1.66 | 1.66 | 1.66 | 1.66 | 1.66 | 1.66 | 1.66 | 1.66 |
| 30                      | 1.71 | 1.74 | 1.73 | 1.69 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.66 | 1.66 | 1.66 |
4.1. The effects of sea mud admixture on maximum dry density of modified clay

Taking 10%, 15%, 20%, 25%, 30% modified clay as the research object, the influence of different sea mud content on the maximum dry density of modified clay was explored. When the amount of sea mud is 10%, the maximum dry density is 1.76 g×cm⁻³, and the maximum dry density is 1.77 g×cm⁻³ when the amount of sea mud admixture is 15%. The maximum dry density is 1.78 g×cm⁻³ when the amount of sea mud admixture is 20%. Thus, the maximum dry density of the modified clay increases with the increasing of sea mud admixture, because the mud and clay particles are smaller than clay, and the clay and sticky are tightly bonded so that the pores in the modified clay are filled with and the dry density increases. The maximum dry density is 1.75 g×cm⁻³ with the addition of sea mud to 25%, and the maximum dry density is 1.74 g×cm⁻³ when the amount of sea mud admixture is 30%. This is because the composition of clay soil is changed after the amount of mud admixture exceeds a certain limit. The stability is reduced, and the maximum dry density is reduced.

From the above analysis, the maximum dry density of the modified clay increases with the increasing of mud admixture, but when the amount of mud admixture reaches a certain limit, it has a great influence on the soil composition of the modified clay, and the maximum dry density decreases with the increase of mud admixture.

4.2. The effects of water content on the maximum dry density of modified clay

To analyze the effects of different water content on the maximum dry density of modified clay under the condition of constant sea mud admixture. From the analysis of Table 3, when the water content of the modified clay is 14%, the dry density is 1.71 g×cm⁻³. When the water content increases to 16%, the dry density increases to 1.78 g×cm⁻³. This is because when the water content is low, the water film on the surface of the particles is relatively thin, the interparticle bonding force is relatively large, and it is not easy to be compacted, when the water content increases gradually. When the water film on the surface of the particle is relatively thin, the intergrain bonding force is reduced, and the lubrication of the intergranular water increases, the frictional resistance of the particles is reduced. So, it is easily compacted under the action of external force. At the same time, the water is filled with the soil gap between the clay and the clay to a certain extent, thus increasing the density. When the water content reaches 16%, the dry density begins to decrease with the increase of water content, mainly because more and more compaction work is absorbed by free water, the pores between sea mud and clay gradually become larger and the water film is gradually thickening, so the dry density of the modified clay is reduced accordingly.
According to the above analysis, when sea mud admixture is 20%, water content of the modified clay is 16%, the dry density reaches the maximum, and the maximum dry density is at this time. Then the dry density decreases with the increase of water content.

5. Conclusion

The most important part of the anti-seepage engineering in petrochemical enterprises is the material of anti-seepage layer. Constructing the anti-seepage layer is a feasible and effective way to prevent underground pollution in petrochemical field. The artificial modified natural anti-seepage material has been favored by the majority of enterprises for its good development background and low cost. As one of the important parameters to test the anti-seepage layer, compaction degree plays an important role in the research of modified anti-seepage materials. In this paper, the maximum dry density and the optimum water content of clay modified clay were measured by light compaction test, and the maximum dry density of clay with different water content and different sea mud content was analyzed. The study shows that the maximum dry density of the modified clay reaches the maximum value of $1.78\text{g}\times\text{cm}^{-3}$ when the content of sea mud is 20% and the water content is 16%, the compaction state is the best. Therefore, it is determined that the most compacted content of the clay modified clay is 20%, and the maximum dry density of the modified clay decreases with the increase of mud admixture when sea mud admixture more than 20%. From the results we could infer that sea mud as modified material influence the clay plasticity, so sea mud admixture should not be too high.

References

[1] Hao Niu. Selection and application of anti-seepage schemes in refinery projects 2014 J. Petrochemical Safety and Environmental Protection Technology, 30(3): 23-27.
[2] Lei Chen, Libing Liao, Xiuli Zhang. Bentonite, zeolite and red mud used as the mineral lining of the bottom of the landfill site 2014 J. Environmental Engineering, 28(S1): 209-213.
[3] Xuchao Shi, Nen Wang, YuanYu Hu. Study on deformation characteristics of marine silt 2014 J. Journal of Yangtze River Academy of Sciences, 20(1): 17-19.
[4] Zhiwei Jiang, Tugen Feng, Haiyang Song. Determination method of maximum dry density of sea mud and sea sand mixture 2017 J. Science and technology and Engineering, 17(8): 248-251.
[5] Xiaojie Xu. Sea sand sea mud mixture dynamic strength characteristics 2017 J. Science and Technology Engineering, 17(2): 273-277.
[6] GB/T 50934-2013. Code for Seepage Control of Petrochemical Engineering 2013 S. Ministry of Housing and Urban Rural Development, PRC. Beijing: China Planning Publishing House.
[7] Weimin Lin. Study on maximum dry density and optimum water content under different compaction functions 2008 J. Highway and Motor Transportation, 15(4): 142-143.
[8] GB/T 50123. Geotechnical Test Method Standard 1999 S. Ministry of Water Resources of People's Republic of China. Beijing: China Planning Publishing House.
[9] Jianhua Song. Physicochemical properties of aeolian sand with different silt contents 2011 J. Shanxi Architecture, 37(12): 125-127.
[10] Yulu Wei, Jichang Han, Yang Zhang. The study of the maximum dry density after the combination of sandstones and sand into soil 2015 J. Journal of China Three Gorges University (NATURAL SCIENCE EDITION), 37(5): 54-57.
[11] Ming Cai, Zirun Yue, Zhaoliang Ye. Study on the maximum dry density and compactness of coarse granular soil mixture 2013 J. Journal of Shijiazhuang Railway University (NATURAL SCIENCE EDITION), 26(3): 103-106.
[12] FROST R J. Some testing experiences and characteristics of bouldas gravel bouldas.
[13] STEPHENSON R J. Relative density tests on rock fillat Carter dam 1973 J. ASTM(9)
[14] Cheng Xue, Hongwen Li, Hu Bing. Characteristics and compaction mechanism of aeolian sand in desert subgrade 2013 J. Highway, 18(6): 20-24.
[15] Zhiquan Zhang, Zhiyong Wang. The accuracy of the maximum dry density and the optimal water content 2004 J. Journal of Chang'an University (Architecture and Environmental Science
Edition), 21(2): 7-10.