Experimental research on cement-soil mixture ratio of track foundation cement mixing pile

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Abstract. In order to ensure the feasibility and economy of the construction scheme of cement mixing piles for track foundation, a cement-soil indoor mix ratio test was carried out. Selected ordinary Portland cement and sulfate-resistant cement, groundwater and tap water, three mixing ratio experiments were carried out. The experimental study found that the cement-soil has high strength, which can fully meet the bearing capacity requirements of the track foundation, and the cement content can be appropriately reduced. The strength of the solidified soil increases with the increase of the cement content, and the groundwater has no adverse effect on the strength of the cement-soil. The strength of solidified soil with P.HSR 42.5 cement is not significantly higher than that of P.O42.5 cement. Even in BDQ1 and BD4 track foundations, the strength of solidified soil with P.O42.5 cement is significantly higher than that of P.O42.5 cement.

1. Introduction

Cement mixing pile is a kind of pile that uses cement or cement-based materials as curing agent, and mixes in-situ soil and curing agent deep in the foundation through a special deep mixing machine[1]. After cement and other admixtures are mixed with the soil, a series of physical and chemical reactions will occur to form the cement solidified soil, which has certain strength and forms the composite foundation with integrity, water stability and certain strength[2-3]. It can also be made into continuous groundwater soil wall and cement soil block to bear the load or water insulation[4]. It has been more than 40 years since cement mixing piles were used to strengthen soft soil foundations in the 1970s.

In order to meet the construction requirements and save raw materials, it is necessary to determine the proportion of cement mixing pile through laboratory test before construction[5]. According to the properties of the foundation soil to be treated on site, the appropriate cement and its content are selected to provide the strength results of different ages and ratios for the project. Based on laboratory tests and analysis of the results, the variation law of soil-cement mixing strength in the composite foundation scheme of cement mixing pile to be adopted for ore wharf foundation is studied in this paper.

2. Project introduction

The first phase of the ore terminal consists of four-track foundations, the length of BQ4 and BQ5 track foundation is 1,087.6m, and the length of BD4 and BDQ1 track foundation is 1,151.6m. In 2013, the site was treated by vacuum combined heap loading preloading, and the bearing capacity of the
foundation basically reached 140kPa. Cement mixing pile composite foundation is adopted under the track foundation, and the cement mixing pile is arranged with grid type, with the diameter of 600mm, pile top elevation of 4.8m~5.2m, pile bottom elevation of -7.0m~-8.3m, and pile length between 12.2m~13.5m. The construction technology of mixing pile is to adopt uniaxial bidirectional mixing technology.

3. Cement-soil mix ratio test

3.1. Test method

The mixing ratio test adopted wet method to prepare samples. Removed debris from the soil sample and stir with a blender to make the soil sample as uniform as possible. The cement and water were quickly mixed to form a uniform cement slurry, which was poured into the already mixed slurry. The slurry was stirred at a low speed first and then quickly, so that the cement slurry and slurry were fully mixed. The mixing time should not be less than 10min or more than 20min from adding water to mixing evenly.

The mixed cement soil was poured into the square test mold with the size of 70.7mm × 70.7mm × 70.7mm in layers. After manual filling, it was vibrated to make the air in the test mold fully exhausted, and the surface of the test mold was scraped flat with a trowel. After 24 hours curing in the molding room, removed the mold and put samples into the curing box. The temperature range of the curing room should be (20 ± 2) ℃, the relative humidity should be more than 90%, and the curing time should be at least 24 hours. The curing method of solidified soil samples after molding was water curing, and the temperature range of water is (20 ± 1) ℃

3.2. Test materials

3.2.1. Soil. The soil used in the test was taken from the track foundation of the first phase project of the ore terminal, with a depth of 16.00m. The statistics of water content of soil samples for different track foundations are shown in Table 1. Soil samples with water content of 25% ~ 36% accounted for more than half of the total, soil samples with water content of more than 36% accounted for one fifth of the total, and soil samples with water content of less than 20% accounted for the least.

| Location | ≤20% | 20%~25% | 25%~36% | >36% |
|----------|------|---------|---------|------|
| BQ4      | 3    | 6       | 30      | 10   |
| BQ5      | 2    | 5       | 36      | 14   |
| BD4      | 6    | 17      | 28      | 11   |
| BDQ1     | 8    | 12      | 21      | 8    |
| Total    | 19   | 40      | 115     | 43   |

Through soil identification, it was found that silty and sandy were less in content, while cohesive soil was the most, accounting for 83.9% of the total. Statistics of soil properties are shown in Table 2.

| Location | Sandy | Silty | Cohesive soil |
|----------|-------|-------|---------------|
| BQ4      | 6     | 2     | 41            |
| BQ5      | 2     | 1     | 54            |
| BD4      | 5     | 10    | 47            |
| BDQ1     | 7     | 2     | 40            |
| Total    | 20    | 15    | 182           |

3.2.2. Water. In order to be consistent with the project, groundwater and tap water were selected for the mixing water. The type of curing water was the same as the mixing water.
3.2.3. Cement. The types of cement were specified and provided by the client. The P.O42.5 cement of Company A, the P.O42.5 cement of Company B with 19% slag and 4.5% desulfurized gypsum, and the P.HSR 42.5 cement of Company C were used. Moisture-proof treatment was carried out during the preservation of cement.

3.3. Mix ratio design
In order to study the relationship between cement and solidified soil strength, BQ4 track foundation and BQ5 track foundation used A company’s P.O42.5 cement, BD4 track foundation and BDQ1 track foundation used B company’s P.O42.5 cement, BQ4, BQ5, Both BD4 and BDQ1 track foundations used C Company’s P.HSR 42.5 cement.

In order to select the economic cement content, the mix proportion adopts 16%, 18% and 20% cement content.

In order to study the influence of water on the strength of solidified soil, groundwater and tap water were used.

The water cement ratio was a constant value of 1.0.

There were 83 groups of solidified soil, 81 of which were clayey soil, including 36 groups of 14 day old samples, 27 groups of 28 day old samples and 18 groups of 90 day old samples. In the other two groups, silt was used as the object soil, including silt mixed with 18% of 42.5 ordinary Portland cement and tap water, silt mixed with 18% of 42.5 ordinary Portland cement and groundwater. There were 6 samples in each group, a total of 498 samples. The test combination number is shown in Table 3.

| Soil  | Mixing Water | Maintenance Water | Cement    | No  |
|-------|-------------|-------------------|-----------|-----|
| clay  | tap water   | tap water         | P.O 42.5  | CO  |
|       | groundwater | groundwater       | P.O 42.5  | GO  |
|       | groundwater | groundwater       | P.HSR 42.5| GS  |
| silt  | tap water   | tap water         | P.O 42.5  | FCO |
|       | tap water   | tap water         | P.O 42.5  | FGO |

3.4. Test results and analysis
The mixing ratio strength of cement stabilized soil for four-track foundations is shown in Figure 1 to Figure 4. The cement-soil had high strength, which can fully meet the bearing capacity requirements of the track foundation, and the cement content can be appropriately reduced. The greater the amount of cement, the higher the strength, and the increase in strength varies to a certain extent depending on the mix ratio conditions. Due to the uneven sample preparation of the solidified soil when 18% cement was added to the track foundation BDQ1, the 14d unconfined compressive strength did not increase with the amount of cement.

The curing process of cement soil is different from concrete, the growth rate is slow, and it takes a longer process to complete the curing. As the age of cement soil increases, the degree of cement hydration becomes more adequate, and the strength of cement continues to increase. The solidified soil of track foundation BQ4, BQ5, BD4 and BDQ1 under different mix ratio conditions, within 90 days of curing time, as the age of the solidified soil is longer, its unconfined compressive strength continues to increase, and the increasing range varies with the aging and mix proportion.
Figure 1. Unconfined compressive strength of BQ4 track foundation specimen.

Figure 2. Unconfined compressive strength of BQ5 track foundation specimen.

Figure 3. Unconfined compressive strength of BD4 track foundation specimen.
By comparing the strength of the solidified soil of ordinary Portland cement from different manufacturers, it could be found that the compressive strength of the solidified soil of the P.O42.5 cement of Company A is higher under the premise of ignoring the difference in soil properties. The strength of cement-mixed soil with P.HSR 42.5 cement was not significantly higher than that of P.O42.5 cement. Even in the BDQ1 and BD4 track foundations, the strength of cement-mixed soil with P.O42.5 cement was significantly higher than that of P.HSR 42.5 cement.

4. Conclusion

Through the cement-soil mix test on the four-track foundations BQ4, BQ5, BD4, and BDQ1 of the first phase of the ore terminal project, the following conclusions can be drawn:

1. The cement-soil had high strength, which can fully meet the bearing capacity requirements of the track foundation, and the cement content can be appropriately reduced.
2. With the increase of cement content and the growth of age, the unconfined compressive strength of cement-mixed soil is increasing.
3. The compressive strength of the solidified soil of the P.O42.5 cement of Company A was higher under the premise of ignoring the difference in soil properties. The strength of cement-mixed soil with P.HSR 42.5 cement was not significantly higher than that of P.O42.5 cement.
4. Compared with tap water, the local groundwater of the project did not adversely affect the strength of cement soil. There was no obvious difference in the strength of solidified soil between different track foundations.

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