Experimental Research on the particle composition of flowing mud in Shenzhen Port

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Abstract. Based on the particle analysis, mineral composition analysis and chemical composition analysis of the flowing mud in Shenzhen port, it is found that the flowing mud in Shenzhen port has fine particles, a lot of colloidal particles, and an obvious increase of colloidal particles after salt washing. The clay mineral content is large, and the highest content is I/M mixed layer, which makes the flowing mud have higher plasticity, greater compressibility and lower permeability. The content of Cl− and Na+] in the mud of Shenzhen port is high, which belongs to Cl−-Na+] type, which has strong corrosiveness to steel and medium corrosiveness to concrete.

1. Introduction

Shenzhen port is located in the south of the Pearl River Delta in Guangdong Province, the estuary of the Pearl River, the East Bank of Lingdingyang, adjacent to Hong Kong. By the end of 2012, Shenzhen port had invested more than 60 billion yuan to build the port, and had successively built 10 port areas including Shekou, Chiwan, Mawan, Yantian, Dachan Bay, shayuyong, Xiadong, dongjiaotou, Fuyong and Neihe, with 172 berths of 500 tons and above. Shenzhen port has a water area of 106 square kilometers and a land area of 16 square kilometers. Shenzhen has a coastline of 260 kilometers, which is divided into East and west parts by the Kowloon Peninsula. The western port area is located on the East Bank of Lingdingyang, with wide water depth and good natural barrier. It is 20 nautical miles away from Hong Kong in the South and 60 nautical miles to Guangzhou in the north. It can be connected with the cities and counties in the Pearl River Delta water network area through the Pearl river system, and can reach the domestic coastal ports and ports around the world through the Hong Kong’s Preston waterway. The eastern port area is located in Dapeng Bay, with a water depth of -12m--14m, open sea and calm waves. It is an excellent natural harbour in South China. As of October 2018, Shenzhen port had opened 239 international container liner routes, covering the world’s 12 major shipping areas and reaching more than 300 ports in more than 100 countries and regions. In 2018, the cargo throughput of Shenzhen port was 251 million tons, and the container throughput of Shenzhen port was 25.74 million TEUs, ranking the fourth in the world.

Shenzhen port is located at the estuary of the Pearl River. There are deep sediment and large area of flowing mud. Flowing mud is a kind of soil with water content more than 85% and pore ratio more than 2.4. This kind of foundation is difficult to be reinforced, high cost and poor effect[1]. It is difficult to build a port on such a foundation[2].
2. Soil sample for test

Soil is composed of soil particles with different properties, sizes and materials. The size of soil particles and the proportion of each particle group have a certain relationship with the permeability, plasticity, compressibility and shear resistance of soil, especially for fine-grained soil, the mineral composition, particle shape and rubber content have a greater impact on its physical and mechanical properties [3]. Therefore, the particle and material composition of the flowing mud in Shenzhen port were studied.

In the experiment, the flowing mud was sampled at random in Shenzhen port, the specific gravity was 2.759, the liquid limit was 51.2%, the plastic limit was 27.6%, and the plastic index was 23.6. Particle analysis by hydrometer, pipette, infrared spectrum and X-ray diffraction were carried out.

3. Particle size analysis

3.1. Hydrometer method

The analysis of particle size distribution by densitometer is based on two assumptions: the subsidence law of soil particles in water obeys the Stokes law, that is, the same soil particles decrease at the same speed, and the soil particles are evenly distributed in the suspension.

104 samples were divided into two groups. Before the test, all samples must be dried naturally. One group is subject to salt washing and the other group is not subject to salt washing. One group was not subject to salt washing, the other group was subject to salt washing to eliminate the influence of soluble salt on the particle size of soil.

The dispersant was 6% hydrogen peroxide, 1% sodium silicate and 4% sodium hexametaphosphate. Since the calibration of the densitometer is based on the density of pure water, when the suspension is added with dispersant, the specific gravity of the suspension increases, so the influence of the hydrometer on the dispersant was corrected before use.

The test results are shown in table 1 and figure 1. Compared with the two groups, the percentage of soil particles with particle size less than 0.002mm increased significantly after salt washing, from 26.3% before salt washing to 44.5%, with an increase of 69.2%. After salt washing, the increase of soil particles with particle size less than 0.005mm was smaller than that of soil particles with particle size less than 0.002mm, which indicates that the content of soil particles with particle size of 0.005-0.002mm was reduced. Similarly, the percentage of soil particles with particle size of 0.05-0.01mm and 0.01-0.005mm were also reduced.

Table 1. Grain distribution (%)

| Particle size (mm)  | 0.075~0.05 | 0.05~0.01 | 0.01~0.005 | <0.005 | <0.002 |
|--------------------|------------|-----------|------------|--------|-------|
| Desalting          | Avg        | 13.4      | 15.7       | 12.0   | 58.9  | 44.4  |
|                    | Max        | 14.7      | 18.7       | 15.2   | 63.4  | 47.6  |
|                    | Min        | 10.4      | 12.3       | 8.9    | 55.1  | 42.2  |
| Non desalting      | Avg        | 11.1      | 23.9       | 18.0   | 47.0  | 26.3  |
|                    | Max        | 14.1      | 31.9       | 26.4   | 55.2  | 43.3  |
|                    | Min        | 9.2       | 18.5       | 12.7   | 36.9  | 13.5  |
Figure 1. Cumulative grain distribution

3.2. Pipette method
The pipette method calculates the time and distance of absorbing suspension according to the relationship between particle size and settling distance and settling time. The soil particles were treated by the full dispersion method, and the test results are shown in Table 2. Compared with the method of a-densitometer, the content of 0.075mm-0.005mm particle size is close to the result of salt washing, and the content of colloidal particles is between the result of salt washing and salt washing.

Table 2. Cumulative grain distribution (%)

| Particle size (mm) | >0.25 | 0.25-0.075 | 0.075-0.005 | <0.005 | <0.002 |
|-------------------|-------|------------|-------------|--------|--------|
| Sample 1          | 2.73  | 8.33       | 45.16       | 43.79  | 38.29  |
| Sample 2          | 3.87  | 7.43       | 47.77       | 40.93  | 30.72  |
| Sample 3          | 3.20  | 7.59       | 41.29       | 47.92  | 37.31  |

4. Mineral composition
Mineral composition controls the size, shape and surface characteristics of soil particles. These characteristics and the interaction with the liquid phase determine the plasticity, expansion, compression, strength and other characteristics of the soil. Therefore, the study of mineral composition is very important to understand the properties of soil. In the experiment, infrared spectrum and X-ray diffraction were used to quantitatively analyze the mineral composition of the convective mud. The content of montmorillonite was determined by methylene blue selective attachment method. The results included not only montmorillonite of single mineral, but also montmorillonite of mixed layer mineral. The specific surface area was determined by glycol ether adsorption method, which was the total surface area. The experimental results are shown in Table 3 and Table 4. There are a lot of clay minerals in the mud of Shenzhen port. The total amount of clay minerals in the mud of Shenzhen port is 57.4%. The highest content is the I/S, whose engineering properties are between montmorillonite and illite, which makes the mud with high plasticity, high compressibility and low permeability. The content of illite, chlorite and montmorillonite are relatively low.
### Table 3. The results of the material composition of flowing mud

| Number | Mnt (%) | Surface area (m²) | Clay minerals Relative content (%) | Mixed layer ratio (%) | Clay minerals absolute content (%) |
|--------|---------|-------------------|-----------------------------------|----------------------|-----------------------------------|
|        |         |                   | I      | C    | K      |        | I      | I/S | C   | K   |
| Sample 1 | 5.45    | 109.22            | 6      | 49   | 7      | 38    | 45    | 2.30 | 18.76 | 2.68 | 14.55 |
| Sample 2 | 4.67    | 101.44            | 7      | 48   | 8      | 37    | 45    | 2.61 | 17.91 | 2.99 | 13.81 |

- I is a shorthand for Illite.
- I/S is a shorthand for illite / montmorillonite mixed layer mineral.
- C is shorthand for chlorite.
- K is a shorthand for kaolinite.

### Table 4. The results of the material composition of flowing mud

| Number | Colour | Organic matter (%) | CaCO₃ | Mnt (%) | Surface area (m²/g) | PH |
|--------|--------|--------------------|-------|--------|---------------------|----|
| Sample 1 | gray   | 2.17               | 1.63  | 5.45   | 109.22              | 7.50 |
| Sample 2 | gray   | 2.15               | 1.53  | 3.58   | 106.05              | 7.62 |
| Sample 3 | gray   | 2.12               | 2.11  | 4.67   | 101.14              | 7.67 |

### Table 5. Chemical composition and corrosivity evaluation of flowing mud

| Number | Chemical composition of water extract (1:5) (mg/100g/mg%) | Salt content (mg/100g) | Dry residue (mg/100g) | Chemical type | Saprophytic evaluation | Steels | Concrete |
|--------|----------------------------------------------------------|------------------------|-----------------------|---------------|------------------------|--------|----------|
|        | HCO₃⁻                                               | SO₄²⁻ | Cl⁻ | Ca²⁺ | Mg²⁺ | Na⁺ + K⁺ |        |          |          |                |        |          |          |
| Sample 1 | 31.64 | 1.40 | 1150.23 | 41.16 | 48.55 | 712.88 | 2164.67 | 2182 | Cl⁻ - Na⁺ | strong   | medium   |
| Sample 2 | 30.25 | 1.33 | 1158.75 | 41.16 | 50.72 | 712.91 | 2172.89 | 2192 | Cl⁻ - Na⁺ | strong   | medium   |
| Sample 3 | 33.04 | 1.44 | 1158.75 | 37.41 | 50.82 | 725.51 | 2198.79 | 2238 | Cl⁻ - Na⁺ | strong   | strong   |

- %me% is mg equivalent.

### 5. Chemical composition

The results of chemical analysis time are shown in Table 5. The content of Cl⁻ and Na⁺ + K⁺ in the mud of Shenzhen port is high, which belongs to Cl⁻ - Na⁺ type, which has strong corrosiveness to steel and medium corrosiveness to concrete.

### 6. Conclusion

1. The flowing mud in Shenzhen port has fine particles, a lot of colloidal particles, and an obvious increase of colloidal particles after salt washing.
2. The clay mineral content is large, and the highest content is I/M mixed layer mineral, which makes the flowing mud have higher plasticity, greater compressibility and lower permeability.
3. The content of Cl⁻ and Na⁺ + K⁺ in the mud of Shenzhen port is high, which belongs to Cl⁻ - Na⁺ type, which has strong corrosiveness to steel.

### References

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