Research on the Investigation Characteristics of the Re-Building Wharf Project at the Original Site

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Abstract. Taking the re-building fishing wharf project of Beira in Mozambique as an example, the investigation characteristics of the re-building wharf project at the original site are described, including the collection of the original wharf design data, the exploration of obstacles in the investigation area and the zoning statistics of the investigation results according to different regions. On the basis of the differences in different regions, the indexes such as soil indicator, vane shear strength and over-consolidation ratio should be provided by zone, so as to provide more practical parameters for the design.

1. Introduction

Beira port is the second largest port in Mozambique. The original fishing Wharf in the port is a high pile wharf, which has been seriously damaged after many years, so it is almost impossible to use. In consideration of the recovery and expansion of the fishing production capacity, the government of Mozambique has started the reconstruction of a new fishing wharf. The new fishing wharf is rebuilt on the original shoreline where the original wharf has been demolished, and the high pile wharf is still be used [1]. The investigation of the re-building wharf project at the original site is basically the same as that of the new wharf project, but it also has its own characteristics. Taking the re-building fishing wharf project of Beira in Mozambique as an example, this paper studies the key points that should be paid attention to in the investigation of the re-building wharf project at the original site, analyzes the engineering geological characteristics of the re-building site, and provides references for the investigation and design of the similar re-building projects at home and abroad.

2. Distribution and Main Properties of the Soil

For the controlling boreholes of the investigation on the re-building fishing wharf project in Beira, the final elevation should below -55m and drill into the soil layers, which SPT-N>50 blows, over 10m thick. The soil layer within the survey depth can be divided into 7 layers, and the engineering geological properties of each layer are as follows [2],[3].

The layer ① is Holocene man-made deposits, the surface of which is mainly block stone and the lower part is medium coarse sand. The layer ① is locally distributed and decreases from the bank slope to the wharf front, in a triangle shape, and the maximum thickness is about 6.4m.
The layer ② is Holocene marine deposits, mainly composed of silt, flow plastic, medium dry strength, with an average thickness of 6.7m.

The layer ③ is Holocene alluvial deposits, mainly composed of medium coarse sand, loose to medium dense, with an average thickness of 4.3m and standard penetration blows of 3-12.

The layer ④ is Holocene marine deposits, mainly composed of muddy clay, flow plastic, with an average thickness of 18.7m.

The layer ⑤ is Pleistocene alluvial deposits, mainly composed of medium coarse sand, dense, generally graded, with an average thickness of 1.1m and standard penetration blows of 25-46.

The layer ⑥ and layer ⑦ are Pleistocene fluvial deposits.

3. Investigation Characteristics of the Re-building Wharf Project at the Original Site

3.1 Collection of Design Data About the Original Wharf

Dredging of the harbor basin and backfilling of the revetment of the original wharf have great influence on the engineering properties of the foundation soil. In addition, the layout of exploration points should avoid some connecting components of the original wharf structure buried by mud. Therefore, on the basis of collecting data about regional basic geology, meteorology and hydrology, geological disasters, earthquake and earthquake damage in accordance with the requirements of the conventional investigation specifications, the re-building wharf project should focus on collecting the design data of the original wharf, including structural form, connection mode and location of components, dredging scope and depth of harbor basin, material and thickness of revetment, completion time of wharf, which provide basis for the arrangement of exploration points and the division statistics of survey results.

3.2 Exploration of Obstacles Before Investigation

In general, the original wharf has been in operation for decades, during which there will be falling of articles and components, even sinking of ships. After a long time, these will be buried under the mud surface and difficult to be detected by naked eyes. Moreover, some connecting components of the original wharf structure will also be buried by back silting. Therefore, before the arrangement of exploration points, the location of the connecting components buried under the mud should be basically determined through the collected original wharf design data, and the sonar, profiler or other instruments and equipment should be used for geophysical exploration to understand the location of the sedimentary obstacles below the mud surface within the survey scope. Before the investigation of re-building fishing wharf project in Beira, shipwrecks and a large number of unidentified obstacles were found through geophysical exploration, which were successfully avoided in the arrangement of exploration points.

3.3 Regional Statistics of Investigation Results

The dredging of the harbor basin and the backfilling of the revetment of the original wharf are the unloading and loading of the foundation soil, which have a great influence on the engineering properties of the original foundation soil. During the investigation results statistics, the investigation boreholes must be zoned according to the design data of the original wharf. According to the backfill thickness variation of the revetment and dredging scope of the wharf front, the survey boreholes are divided into three areas for the re-building fishing wharf project in Beira, as shown in Fig. 1.
3.3.1 Physical and Mechanical Indexes of Soil

The division statistics of physical and mechanical indexes of the main cohesive soil layers ② and ④ are shown in table 1. Due to dredging of the harbor basin, the soil layer ② in the front area of the quay is thin and the indexes of the soil layer ② weren't obtained. It can be seen from table 1 that the indexes of water content, density, void ratio, shear strength of silt layer ② in the backfill area of the revetment are obviously better than those in the slope toe area of the revetment, but the differences between them are not significant in terms of plasticity index, indicating that the silt in the two areas belongs to the same type of soil. In the decades of wharf operation, the soil in the backfill area of the revetment has been compressed and consolidated due to the influence of overlying loads such as backfill, resulting in the decrease of water content and void ratio, and the increase of density and shear strength. For the clay layer ④, the indexes of the soil in the backfill area of the revetment are slightly better, but it is not much different from the other two areas, because the clay layer ④ is deep, the load and scope of the backfill area of the revetment are limited, which has little impact on the deep soil.

Table 1. Zoning statistics on physical and mechanical properties index of soil

| Soil name | region                | ω (%) | ρ (g/cm³) | e  | I₁ | Iₚ | a₁-₂ (MPa⁻¹) | cₗ (kPa) | φq (°) |
|-----------|-----------------------|-------|-----------|----|----|----|---------------|----------|-------|
| ② silt    | backfill area of revetment | 78.8  | 1.53      | 2.15 | 1.36 | 31.7 | 2.41           | 28.6     | 1.3   |
|           | slope toe area of revetment | 91.9  | 1.45      | 2.57 | 1.73 | 33.9 | 3.99           | 17.8     | 0.2   |
| ④ clay    | backfill area of revetment | 63.7  | 1.60      | 1.80 | 0.81 | 32.5 | 0.79           | 50.8     | 0.5   |
|           | slope toe area of revetment | 64.2  | 1.59      | 1.82 | 0.84 | 32.3 | 0.90           | 48.5     | 0.5   |
|           | front area of quay     | 65.3  | 1.59      | 1.85 | 0.81 | 33.6 | 0.94           | 44.0     | 0.9   |

3.3.2 Field Vane Test

The index of the vane shear strength obtained from the field vane shear test is an important parameter needed to analyze the stability of the bank slope [5]. The curves of the vane shear strength of the silt layer ② at the same elevation in different areas are compared, as shown in Fig. 2. The lower part of the curve increases significantly due to the approach to the medium coarse sand layer. From Fig. 2 and Table 2, it can be seen that the strength of undisturbed soil in the backfill area of the revetment is significantly higher than that in the slope toe area of the revetment. When analyzing the stability of the bank slope, the average value cannot be used. It is necessary to adopt the index of the vane shear strength in different zones so as to make the calculated partial coefficient of resistance more practical, reduce unnecessary reinforcement measures and save engineering cost.
Figure 2. Vane shear strength curves of silt in different regions

Table 2. Vane shear strength comparison of clay in different regions

| Test area                  | Test position elevation (m) | Undisturbed soil (kPa) | Remolded soil (kPa) | sensitivity |
|----------------------------|-----------------------------|------------------------|---------------------|-------------|
| Backfill area of revetment | -12.4                       | 82.0                   | 23.1                | 3.58        |
|                            | -14.3                       | 94.1                   | 24.2                | 3.89        |
| Slope toe area of revetment| -12.3                       | 74.0                   | 22.8                | 3.25        |

3.3.3 Over-consolidation ratio (OCR)

Special attention should be paid to the over-consolidation ratio (OCR) of the soil, especially the cohesive soil in the investigation of the re-building wharf project at the original site. It can be seen from Table 3 that although the overburden load increasing due to backfilling, the cohesive soil in the area of the riprap is still in the under consolidated state after several decades in the case of lack of drainage channel. It should be paid special attention to that the soil under consolidated will produce negative friction on the piles of wharf [6]. However, the cohesive soil of the other two areas in the scope of dredging of the original harbor basin is basically in the state of over-consolidation because the overburden load is reduced. It can be seen from the statistical results that the over-consolidation ratio OCR of the re-building wharf project at the original site cannot take the average value of the whole area for each layer, so it is necessary to make statistics in different areas in order to find out the under consolidated area and provide basis for the design consideration of the negative friction.

Table 3. Statistics of over-consolidation ratio in different areas

| Soil name | elevation (m) | Backfill area of revetment | Slope toe area of revetment | Front area of quay |
|-----------|---------------|-----------------------------|-----------------------------|--------------------|
| silt      | -3.1～-3.9    | 0.89                        | 0.90                        | 1.29               |
|           | -5.8～-6.3    | 0.97                        | 0.99                        | 1.52               |
| clay      | -15.7～-18.0  | 0.97                        | 1.17                        | 1.66               |
|           | -19.2～-22.2  | 0.9                         | 0.96                        | 1.44               |
|           | -25.9～-28.0  | 0.74                        | 1.41                        | 1.11               |
|           | -29.6～-29.8  |                            |                            | 1.23               |
4. Conclusion
There are not only the same contents but also the key points that need special attention between the investigation of the re-building wharf project at the original site and the conventional investigation. Before the investigation, it is necessary to pay attention to the collection of the original wharf design data and the exploration of obstacles, so as to provide basis for the rational arrangement of the exploration points and the avoidance of the hidden obstacles.

The investigation results cannot be counted together according to the whole survey area, but should be distinguished according to the different areas of the original wharf. The division statistics of the foundation soil indicators should be provided to improve the accuracy of the design.

The shear strength of the vane on the site of the cohesive soil in the backfill area of the wharf revetment is higher than that in other areas, so the area should be divided in detail, during the stability analysis of the bank slope. It is necessary to adopt the index of the vane shear strength in different zones so as to make the calculated partial coefficient of resistance more practical and reduce unnecessary reinforcement measures.

It is important to pay attention to the over-consolidation ratio of soil, especially to analyze whether the soil in the backfill area of the original wharf revetment is under consolidated, so as to provide a basis for whether negative friction is considered in the design of pile foundation.

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