Study on macro-microscopic properties and separated technology of waste residue

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Abstract. The rapid growth of solid waste has posed a serious threat to the urban environment and the safety of groundwater. This paper relies on the land formation project of Shenzhen Marine emerging Industrial Base. Waste residue is used as filling material for landfilling. In this paper, macro and micro tests, heavy metal and organic matter content tests of waste residue and underground silt were carried out. The physical mechanics, microscopic properties and pollution degree were analysed. The separation technology of waste residue is also studied. The results show that the composition of the waste residue is complex. The contents of heavy metals and organic pollutants did not exceed the risk control standard of construction land. The physical properties and pollution requirements of waste residue used in landfilling are put forward. The technology of three-step separation and separation of waste residue is put forward.

1. Introduction

With the rapid development of economy and urbanization, the quantity of solid waste increases rapidly, including industrial solid waste, domestic solid waste, construction waste, residue and so on [1]. Cities and towns of all kinds of waste is still increasing at an annual rate of 5-8%. How to deal with these wastes has become a major problem hindering the development of cities and towns. At present, many cities and towns use waste incineration and local burial or stacking and other methods. This has brought serious threat to the safety of urban environment and groundwater, and even caused great loss and hidden danger to the safety of people's life and property [2-4].

With the increasing scope of human activities, the size and population of cities are expanding. Land resources are becoming increasingly scarce. Landfilling engineering becomes one of the main measures to solve this problem [5,6]. The long-term use of sea sand and river sand backfill will break the balance of river erosion and deposition. Make rivers, coastal instability, resulting in soil erosion, damage to the environment [7,8]. At present, various types of solid waste are rapidly accumulating, including industrial solid waste, domestic solid waste, construction waste, residue and so on, which need to be solved urgently. The solid waste residue is used as the filling material for landfilling. It not only deals with the excess solid waste, but also solves the limited problem of sea sand and river sand. It is both economical and environmentally friendly [9,10].

The composition of the residue is closely related to its origin, construction structure and construction technology. The composition of different types of residue varies greatly. Surplus soil, road reconstruction garbage and building materials production garbage, composition is generally relatively simple. Its regeneration and utilization or disposal is relatively easy. The composition of new building construction garbage and old building demolition garbage is relatively complex. At present, landfilling with waste residue is a simple landfill and then ground treatment. The residue was not separated and separated in advance [11]. The landfill effect of residue soil with different properties
is obviously different, and it is difficult to treat the foundation in the later stage, the cost increases, and the settlement is uneven.

This article relies on Shenzhen ocean emerging industry base land area formation project. Waste residue is used as filler for landfilling. In this paper, waste residue is taken as the research object. In order to realize green, healthy and sustainable development of land reclamation project from the two angles of environment and geotechnical engineering. Studies on macro-micro properties and separation technology of waste residue were carried out.

2. General situation of engineering

Shenzhen marine emerging industrial base land formation project, located at the top of Guangdong-Hong Kong-Macau Greater Bay Area Bay and Guangzhou-Shenzhen Hong Kong economic belt core position. It is the key area of Shenzhen's future economic and urban development. 1 the area of backfill land area and foundation treatment is 1.1598 million m². It is estimated that the amount of backfill for abandoned soil is 6.274 million m³. According to the approval of the State Oceanic Administration, it is preferred to adopt the landslide soil of Hongao residuum receiving ground in Guangming New District of Shenzhen City, which also contains a small amount of domestic waste and so on. And it is required to select the residue according to the environmental factors.

Shenzhen Marine emerging Industrial Base land formation project is located in the west side of Shenzhen City, Guangdong Province. The area south of the Dongbao River, north of Shenzhen Baoan International Airport and west of the Yangtze River Expressway. The original landform of the site is coastal beach. The site project includes two parts: embankment and backfill. The embankment contains new embankment, fish pond stem reinforcement and new landscape river embankment.

The original geomorphology of the field area is the coastal shoal-intertidal geomorphology of the Pearl River Estuary, which belongs to the silt beach area. Its east side is the sea alluvial plain geomorphology. With the deepening of development, beach fill, development of aquaculture and other human activities are increasing. Great changes have taken place in the primitive landscape. The current situation of the site was filled with several embankments divided into different blocks. Form aquaculture fish pond area. The topography of the field area is more complicated. The site is mainly composed of fish ponds and rivers. The surface water body develops. The west side of the river and area C is connected to the sea water. This section is greatly affected by tides. The east side of the site is the land area, the west side is the sea area. The project site is located in the coastal soft soil area. The geographical environment is special, the engineering geology condition, the hydrogeology condition is complex. The development of rivers, part of the pond embankment, embankment vegetation luxuriant.

The strata distributed in the site are (Qml), Quaternary brand-new marine sedimentary layer (Q4mc), Upper Quaternary Upper Pleistocene marsh sedimentary layer (Q3h), Quaternary residual layer (Qel), Quaternary Upper Pleistocene marsh facies sedimentary layer (Q3h), Quaternary Upper Pleistocene marsh sedimentary layer (Q3h). The underground bedrock is the Great Wall gneiss (ChF).

Relying on the project in the State Oceanic Administration approval of temporary mud storage area. Combined with the present conditions of terrain and other construction conditions, land formation and foundation treatment projects are carried out. The main construction contents include embankment engineering, backfill land formation project and foundation treatment project. As shown in Figure 1, the heap filler formed in the land area is residuum. Mainly from Shenzhen Guangming New area residuum acceptance site and Shenzhen Convention and Exhibition Center residuum acceptance site. The waste residue is rich in source, complex in composition and different in engineering properties.
3. Soil properties

3.1. Silt properties
The original soft soil layer of the engineering site is 13 m thick. As shown in Figure 2, silt is dark ash, gray black, saturated, flow plastic to soft plastic state. The hand feels greasy. Easy to stain hands, slightly stink. The silt contains organic matter and a small amount of shell debris. A thin layer of fine sand is partially sandwiched. The physical and mechanical properties of the silt are as follows. The water content is 70%. The porosity ratio is 1.915 and the organic matter content is 6.01. The permeability coefficient is 4.3e-7cm/s. The compression coefficient is 1.929 MPa\(^1\), and the compression modulus is 1.77MPa. The pre-consolidation pressure is 28.1kPa, which belongs to under consolidation. The cohesive force is 9.2kPa and the friction angle is 6.4 °. It can be seen that the original site has high water content, high porosity ratio, high organic matter content, low permeability coefficient and high compressibility. It belongs to under consolidated soil.

3.2. Properties of residual soil
The waste residue of the site comes from various sources. Eight groups of representative residue samples were collected to analyze the physical and mechanical properties. The residue sample form is shown in Figure 3.

It can be seen that the waste residue samples are rich in source. As shown in Table 1, the residue contains clay and sand, some of which contain massive stones. The water content is about 20%. The
wet density is 1.23 g/cm³ and 2.08 g/cm³. The dry density is 1.00 g/cm³. The permeability coefficient is 8.4E-05 cm/s ~ 7.5E-03 cm/s. It shows low water content and low permeability coefficient.

Figure 3. Residue sample morphology.

Table 1. Geotechnical properties of residual soil samples.

| Residual soil sample | Average moisture content (%) | Specific gravity | Wet density (g/cm³) | Dry density (g/cm³) | Permeability coefficient (cm/s) | Morphological description |
|----------------------|------------------------------|------------------|--------------------|--------------------|---------------------------------|--------------------------|
| 1                    | 19.1%                        | 2.6              | 1.93               | 1.69               | 7.5E-03                         | It’s brick red, belong to silty soil, poor gradation. The sand content is large. It |
has viscosity.
Brick red clay mixed with construction waste. The outer cover is white gray cement ash. There are a few bricks.
Clayey soil containing a small amount of black organic matter. Poor particle gradation.
Silty clay, red brick, poor grading, a small number of bricks.
Grayish brown sticky soil, gradation difference, holding of stones of varying sizes.
Rust color, sand, gradation difference. Clayey soil, high moisture content, light black, fine particles, good grading.
Sand soil, yellowish brown, well-graded, partly covered with silt-like blocks wrapped in black matter.

| Sample | Moisture (%) | Plastic limit (PL) | Liquid limit (LL) | LIQUID LIMIT | GRADE |
|--------|--------------|-------------------|------------------|--------------|-------|
| 2      | 19.5         | 2.6               | 1.23             | 1.00         | 4.8E-03 |
| 3      | 18.7         | 2.6               | 1.89             | 1.51         | 2.9E-03 |
| 4      | 23.6         | 2.6               | 1.68             | 1.37         | 1.9E-03 |
| 5      | 11.1         | 2.6               | 2.08             | 1.76         | 4.9E-04 |
| 6      | 12.1         | 2.6               | 2.08             | 1.75         | 5.2E-04 |
| 7      | 16.9         | 2.6               | 1.62             | 1.43         | 6.3E-04 |
| 8      | 24.2         | 2.6               | 1.48             | 1.26         | 8.4E-05 |

3.3. Analysis of microscopic properties
The microstructure of silt and waste residue was analysed by scanning electron microscope (SEM). Microscopic photographs are shown in Figure 4 and Figure 5. The silt is mostly flaky. The residuum needle-like grain is dominant, and part is flake. The kinds and contents of trace elements in waste residual soil were analysed by energy spectrometer. The energy spectrum is shown in Figure 6. The EDS results show that the content of O element is the highest. The second is the Si element. The contents of heavy metals are relatively small.

**Figure 4.** Site sampling of silt.

**Figure 5.** Site sampling of silt.
3.4. Analysis of pollution properties
Field sampling of silt and waste residue was carried out. The pollution properties of soil samples were analysed, including heavy metal analysis and organic pollutants analysis. The results are shown in Table 2 and Table 3.

### Table 2. Heavy metal concentration.

| Sample  | Cd (mg/kg) | Cr (mg/kg) | Pb (mg/kg) | Cu (mg/kg) | Ni (mg/kg) | Zn (mg/kg) | Hg (mg/kg) | As (mg/kg) |
|---------|------------|------------|------------|------------|------------|------------|------------|------------|
| sludge  | 0.605      | 196        | 97.3       | 500        | 170        | 314        | 0.253      | 26.9       |
| muck    | 0.0618     | 80.3       | 73.5       | 34.7       | 28.6       | 59.4       | 0.00225    | 15.8       |

### Table 3. Organic pollutant analysis results.

| Sample          | BHC (μg/kg) | DDT (μg/kg) | PCB28 (μg/kg) | PCB52 (μg/kg) | PCB101 (μg/kg) | PCB118 (μg/kg) | PCB153 (μg/kg) | PCB138 (μg/kg) | PCB180 (μg/kg) |
|-----------------|-------------|-------------|---------------|---------------|----------------|----------------|----------------|----------------|----------------|
| sludge          | 8.20        | /           | /             | /             | /              | /              | /              | /              | /              |
| Waste soil      | /           | /           | /             | /             | /              | /              | /              | /              | /              |

The concentration levels of major pollutants (including heavy metals and organic pollutants) in silt and waste residue were analysed. The results were compared with soil pollution risk control standard and soil heavy metal background value. The results are as follows:

The content of heavy metal (Cd, Cr, Pb, Cu, Ni, Zn, Hg, As) and the main organic pollutants in the waste residue were not higher than the soil pollution risk control standard of construction land. According to the current construction land soil pollution risk control standards, the detection of residual soil cannot need to repair or risk management. It is used directly as soil for construction. However, compared with the background value of heavy metals in Guangdong Province, the content of Cd, Cr, Cu, Ni in most samples was close to the background value. It is manifested as light pollution. The concentration of Pb, Zn in most of the fill samples is much higher than the background value. Its effects on ecological environment (especially ocean) and human health pollution need further study.

The content of heavy metals in silt is much higher than that in fill. There are potential environmental risks. Silt is the sediment, the carrier, the fate and the storage bank of heavy metal ions in the environment. The implementation of reclamation activities will also cause great disturbance to the silt in this area. The dissolution equilibrium of heavy metals between silt and water will be broken.
4. Waste residue separated technology

4.1. Basic requirements of waste residue for landfilling

The backfill soil for landfilling can generally be filled with dredged material. It includes backfilling of sand and stone, backfilling of construction residue or abandoned soil, etc. The requirements of land formation on soil quality include plasticity index, organic matter content, particle size distribution, water content, industrial and domestic pollutants, etc. The project is used as a temporary mud storage area after construction. At the same time also as a new marine industrial base in Shenzhen construction land. In order to reduce the cost of foundation treatment, to ensure the reliability of environmental treatment and to satisfy the capacity of abandoned soil as far as possible, the basic requirements of the quality of abandoned soil are determined as follows.

The natural moisture content is not more than 50%. The organic matter content is not more than 10%. If there is a block stone, the size of the block should be less than 30 cm. The particle size is in 2cm~30cm. The content shall not exceed 10. If the size of a block does not meet the requirements, it can be eliminated or crushed. No industrial or domestic waste of any kind shall be contained. Contaminated soil containing heavy metals or radioactive substances shall not be allowed.

Prior to the backfilling of the waste residue in the site of the project, the composition of the abandoned soil should be inspected. Ensure that the backfill soil meets the plastic index, organic matter content, particle size distribution, water content, industrial and household pollutants as shown in the above table. At the same time, the material composition of the abandoned soil must meet the limit value of the third type of fill material in the reclamation project (GB30736-2014). Ensure that the abandoned soil does not contain substances prohibited at sea from disposal at sea as set out in the Annex to the London Convention 1972 and substances listed in the National list of Hazardous wastes. Materials containing radioactive substances or easily dissolving toxic and harmful substances shall not be permitted.

4.2. Classification of residual soils

The waste residue is divided into six categories: pure residual soil, construction waste of new buildings, demolition garbage of old buildings, garbage from road reconstruction, garbage from building materials production and decoration. Among them, pure residual soil can also be called engineering abandoned soil. The latter five categories can be collectively called construction waste.

4.2.1 Engineering disposal. Pure residual soil refers to the remaining soil in the process of urban construction due to the excavation of the land or mountain. It mainly includes foundation pit and large municipal engineering. The abandoned soil of foundation pit is the residual earth in the course of excavation of building foundation pit. The abandoned soil of large-scale municipal engineering refers to the remaining earth in the construction process of rail transit, road, port and other large-scale municipal projects. Pure residual soil is basically pure earth. It can be divided into gravel, sand, mud, weathered debris and gravel mixture, etc. It is generally possible to backfill directly.

4.2.2 Construction waste.

(1) New building construction waste

The construction waste of new buildings refers to the surplus concrete and building debris produced in the process of building new buildings. Mainly composed of gravel, concrete, mortar, pile head and packaging materials. It cannot be recycled directly.

(2) Refuse for road reconstruction

Road reconstruction garbage refers to the waste concrete block and abandoned asphalt soil produced in the process of expansion and reconstruction of urban roads, municipal roads, residential areas and industrial areas. In general, it cannot be directly reused. The waste concrete produced in the process of municipal pipe network construction and reconstruction can also be classified as road reconstruction refuse.

(3) Demolition of old buildings
The demolition of old buildings refers to the waste concrete blocks, roof wastes, waste bricks, wood, plastics, gypsum, mortar, iron and steel and non-ferrous metals produced in the process of the old city transformation, the old industrial area transformation or other old buildings. In general, it cannot be directly reused. The demolition of old buildings is the most complex of the residue. But it is also a kind of high reuse value. It has the typical pollution and the resources dual attribute.

(4) Waste material for producing building material

Building materials production waste refers to all kinds of construction waste materials generated by the waste, waste. It also includes building materials finished products in the process of processing and handling of the production of fragments, etc.

(5) Decoration garbage

Decoration rubbish refers to the waste produced by house decoration. It’s mainly by gravel, concrete, mortar and decorative materials and so on. And the construction of new construction garbage is more similar. But paint, paint and other ingredients are more. In general, it cannot be directly reused.

4.3. Waste residue separated

According to the rules of "quality Standard and Test method of Sand used in ordinary concrete" (JGJ52-92) and "quality Standard and Test method of Pebble after crushed Stone" (JGJ53-92) for ordinary concrete, the particle size of recycled aggregate is regenerated fine aggregate between 0.16mm~5mm. The grain size larger than 5mm is regenerated coarse aggregate.

According to the different sources of waste residue, the basic requirements of landfilling and the particle size of recycled aggregate are required. In order to make better use of waste residue and to form better foundation structure after landfilling, the waste residue should be separated before landfilling.

The separated technology of waste residue is to separate the waste residue from each source for the first time, the second separation, and the third separation. The screening instrument used for each separation is attached with a strong magnet. The metal can be easily separated for backfilling.

Primary separation refers to the selection of plastics, wood, rubber, bamboo, glass, paper, metal, packaging waste and other organic materials at the site. Secondary separation refers to simple screening and sorting at the source site. Residue with natural particle size smaller than 25mm was separated. The third separation refers to the crushing of bulk residue with crusher for the residue whose diameter is larger than 25mm. Sift again after completion. Sift the residue smaller than 25mm and fill it with earthwork. The residue larger than 25mm is broken again, and the residue whose diameter is smaller than 25mm is screened out. This is repeated until all the pieces are broken. The separation process of waste residue is shown in Figure 7.
According to the classification of waste residue, the separation process of different types of waste residue can be further refined. The specific separation techniques are as follows:

Pure residual soil, pure earth from foundation pit and large municipal engineering. After the initial separation, it can be directly backfilled.

New building construction resulted in broken brick, mortar, concrete, pile head, packaging materials, roof materials, steel, wood and other wastes. Through the first simple sorting selection. Separate packaging materials, wood, steel and other wastes. After secondary separation, the garbage with particle size less than 25mm was screened out. Layered backfill with pure earth. Then through three levels of separation, crushing, screening, separation. Until all large-size concrete, pile heads, broken bricks and so on are up to the standards of backfill.

Road reconstruction garbage mainly refers to the waste concrete block and waste asphalt soil produced by road reconstruction. All waste bituminous soil needs to be separated separately. For remote human sites, such as remote subgrade backfill, underground pipelines around the earth backfill. Can be broken, with pure earth layered backfill. It can also be transported to a dedicated site for recycling. To avoid pollution. Abandoned concrete can be directly separated by two or three stages. Crushing, screening and separation. After reaching the basic standard of residual soil backfill, it can be layered backfill with pure earth.

Demolition of old buildings includes scrap concrete, roof waste, waste bricks, wood, plastics, gypsum, mortar, steel and non-ferrous metal. At the site of garbage generation, primary separation of all old buildings is first carried out. Separate wood, plastics, gypsum, mortar, iron and steel, and non-ferrous metals. Then the remaining waste is separated by two-level separation and three-level separation. After crushing and screening, reach the standard of residue backfill. Layered backfill with pure earth.

Building materials production waste refers to all kinds of construction waste materials generated by the waste, waste. Also includes building materials finished products in the process of processing and
handling of the production of fragments, etc. The output of this type of garbage is relatively low. Through the three-stage separation method, the residue can be recovered.

Decoration refuse is mainly composed of gravel, concrete, mortar and decorative materials. And contains more paint, paint. Although the yield is small, the pollution is relatively large. It cannot be backfilled directly, need to be dealt with separately.

5. Conclusions
Waste residue refers to the soil and other wastes produced during the construction process. In this paper, the macro-microscopic and pollution properties of waste residue are analysed. The separation technology of waste residue is put forward. The conclusions are as follows.

(1) The soil in original site has high water content, high porosity ratio, high organic matter content, low permeability coefficient, high compressibility, and belongs to under consolidated soil.

(2) The waste residue samples are rich in species. The residue contains clay and sand, some of which contain massive stones. The water content is about 20%. The wet density is 1.23 g / cm3 and 2.08 g / cm^3. The dry density is 1.00g / cm^-3. The permeability coefficient is 8.4E-05~7.5E-03cm/s. It shows low water content and low permeability coefficient.

(3) The content of heavy metals and organic pollutants in the waste residue was not higher than the soil pollution risk control standard of construction land. It can be directly used as soil for construction.

(4) The natural moisture content of waste residue landfill is not more than 50%. The organic matter content is not more than 10%. The particle size of block stone should be less than 30 cm. The particle size should not exceed 10% in 2cm~30cm content. Industrial waste or domestic waste shall not be contained. Contaminated soil containing heavy metals or radioactive substances shall not be allowed.

(5) Waste residue can be used for landfilling, and the technology of three times separation and separation of waste residue is put forward. The separation technology of different residue types was put forward.

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