An Innovative Approach for Recycling the Subway Construction Waste in Shenzhen, China

Jian Liu¹, Dehan Xue², Chaonan Lin³*, Zengwen Bu⁴ and Heng Liu⁵

¹Ecological Technology Institute of Construction Engineering, Shenzhen University, China
²Sino-Australia Joint Research Center in BIM and Smart Construction, Shenzhen University, Shenzhen, China
³Zhubo Design Group Co., Ltd., China
⁴Shenzhen Jindian Construction Science & Technology Co., Ltd., China
⁵China Railway Southern Investment Group Co., Ltd., China
*E-mail: 395537202@qq.com

Abstract. Large volumes of construction waste have been produced with the rapid development of subway projects in Shenzhen, China. To solve the problems of difficult storage and low resource utilization of the subway construction waste, Shenzhen government has required the contractors to reduce the subway construction waste by onsite and offsite treatment processes since May 2019. This study introduces an offsite treatment process of the subway construction waste in Shenzhen. Some improvement measures such as replacing drum-type sand screening and settling tanks with centrifugal solid-liquid separation equipment and inclined plate sedimentation equipment are proposed to recycle fine sand and heighten treatment efficiency.

1. Introduction
The storage and treatment of construction wastes have become serious environmental problems with rapid urbanization in China. To promote the reduction and recycling of construction waste, the General Office of the State Council issued the Zero Waste City Construction Pilot Work Scheme to carry out construction waste treatment and improve the level of source reduction and resource utilization in pilot cities in January 2019. The zero-waste city construction will be implemented nationwide after 2021. The revised Law of the People's Republic of China on the Prevention and Control of Solid Waste Pollution approved on April 29, 2020, encouraged enterprises to promote the reduction of construction waste at source and establish a construction waste recycling and utilization system [2]. On November 1, 2019, the Technical standard for construction and demolition waste treatment (CJJ/T 134-2019) was put into effect, which can guide the collection, transfer deployment recycle, and landfill for construction waste [3]. Shenzhen also has launched a series of policies, standards, and guidelines such as the Regulations of Shenzhen Special Economic Zone on promoting the circular economy, the Regulations on emission reduction and utilization of construction waste in Shenzhen, the Standard for construction & demolition waste discharge quota of construction engineering (SJG62-2019), the Technical standard for construction & demolition waste reduction and comprehensive utilization of construction engineering (SJG63-2019). These policies, standards, and guidelines all stipulate the discharge and resource utilization of construction waste in Shenzhen.
According to the 2018 Annual Residual Soil Drainage Field Implementation Plan in Shenzhen, the total amount of construction wastes generated in Shenzhen from 2017 to 2020 is about 397 million m³, in which more than half of them are the subway construction waste. However, there is only one construction waste acceptance field with a residual storage capacity of 3.3 million m³ in Xinwuwei, Nanshan District, Shenzhen [4]. At present, only a few construction wastes are used for landfill, reclamation, and land levelling. The recycling system of construction waste has not been established until the present [5].

There are two methods used for treating the subway construction wastes in Shenzhen. One is the onsite treatment process mainly to dehydrate the subway construction waste to the water content of 40%, so as to meet the transportation standard of Shenzhen engineering mud; the other is the offsite treatment process, which is mainly used for recycling the subway construction waste in Shenzhen suburbs. According to the authors’ field surveys implemented from December 2019 to April 2020 on four onsite construction waste treatment projects of Shenzhen Metro Lines 6, 12, 13, and 16, the subway construction waste is divided into gravel, sand, and clay on the project sites by mechanical equipment. The water contents of dehydrated clay components are 21.07% to 24.25%, which are much less than the required value of 40% of Shenzhen engineering mud. The mud contents of the sands from the subway construction wastes range from 3.56% to 7.48% (by mass). The national standard, the *Sand for construction* (GB/T14684 – 2011), stipulates that the mud content of Class I sand shall not be larger than 1.0%, that of Class II sand shall not be larger than 3.0%, and that of Class III sand shall not be larger than 5.0%. The recycled sands of only two projects among four projects meet the requirements of Class III sand of the *Sand for construction* (GB/T14684 – 2011). Therefore, the onsite treatment process maybe not suitable for recycling the construction waste treatment from viewpoint of resources use.

This study addresses the present offsite treatment process of subway construction waste taking the offsite construction waste treatment plant built by the Zhongshentu Environmental Protection Technology Co., Ltd. as an example.

2. Project Overview

To recycle the construction waste, the Zhongshentu Environmental Protection Technology Co., Ltd. built an offsite construction waste treatment plant in Longgang Avenue, Pingxi Community, Pingdi Street, Longgang District, Shenzhen during July-September 2020. The plant area is about 9000m² and the daily treatment capacity is about 3000m³ as shown in Figure 1. The construction waste treatment plant is generally divided into the raw material stacking area, production area and finished area as shown in Figure 2. The construction waste of this treatment plant is mainly from Shenzhen Metro Line 16.

![Figure 1. Location of the construction waste treatment plant in Longgang, Shenzhen.](image-url)
3. Treatment Process

3.1. The Present Treatment Process

The subway construction waste for this treatment plant is from Shenzhen Metro Line 16, which is composed of stone, sand, silt and clay, and the water content is 25% to 70%. For this treatment, the main equipment and facilities are shown in Table 1. Two production lines are designed in the treatment plant, and each production line has almost the same treatment process. Through field surveys, the treatment process includes the following steps as shown in Figure 3.

| Equipment                        | Quantity |
|----------------------------------|----------|
| Three-layer vibrating screen     | 2        |
| Crushers                         | 2        |
| Tipping bucket feeders           | 4        |
| Ball mill                        | 2        |
| Drum-type sand screening          | 4        |
| Sand washers                     | 6        |
| Settling tanks                   | 6        |
| Belt pressure filter             | 6        |
| Spray equipment                  | 30       |
| Tail water pond                  | 1        |

1) Transporting the subway construction waste to a three-layer vibrating screen by using tipping bucket feeders to separate garbage, stone, and clay mixture with particle size larger than 50mm. The residual sludge after screening flows into a mud pit;

2) The separated stone and clay mixture are transported into a crusher to crush and mix into the sand;

3) The remaining sand, clay mixture, and crushed stone are transported into a ball mill to further crush;

4) The mixture from the ball mill is transported into a drum-type sand screening to separate sand, and remaining slurry flows into a mud pit;

5) The separated sand is transported into a sand washer to further clean to meet the requirement of the Sand for construction (GB/T14684 – 2011), and the remaining slurry flows into the mud pit;
6) The slurry in the mud pit is pumped in the settling tanks to separate clay from the slurry. To accelerate clay settlement, flocculants are added into the settling tanks;

7) The separated clays from the settling tanks are transported into the belt pressure filters to further dewater;

8) The tailwater from the settling tanks and belt pressure filters flows into a tailwater pond for further reuse. The tailwater can be turned into clean water through tertiary treatment.

Figure 3. Flow chart of the construction waste treatment process.

3.2. Resource Utilization
According to the Construction Waste Resource Utilization Industry Standard Conditions [6], the recycling process shall follow the requirements of environmental protection standards, and the recycling rate of construction waste should not be lower than 95%. After the treatment process, the subway construction waste can be decomposed into sand and mud cake. The treated sand which meets the requirement of the Sand for construction (GB/T14684 – 2011) can be transported outward as building aggregate, and the mud cake can be made into backfill soil, planting soil, mixture soil of sponge city, ceramic clay and materials for bricks. They can meet the requirements of national standards of the Soil Environmental Quality Risk Control Standard for Soil Contamination of Agricultural Land (GB15618-2018), the Soil Environmental Quality Risk Control Standard for Soil Contamination of Development Land (GB36600-2018) and the Planting Soil for Greening (CJ/T340-2016).

The tailwater can be reused for the flushing equipment and dilution, and the excess tailwater through tertiary treatment can be turned into clean water which meets the requirement of the Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant.

4. Improvement Measures
The present treatment process was designed based on the traditional river sand washing process. There are the following problems to be improved:

1) The crushed stone is transported into the ball mill with the mixture of sand and clay, which is not necessary to further crush, and it shall be directly sent to the drum-type sand screening for saving electricity;

2) The drum-type sand screening cannot separate fine sand from the mixture of sand and clay;

3) The efficiency of the settling tanks is low and a lot of flocculants are needed to accelerate clay settlement;
According to these existing problems, the following suggestions are proposed to heighten the treatment efficiency and recycle fine sand.

1) Only crushed stone is transported into the ball mill, and the mixture of sand and clay is directly sent to the sand and clay separation equipment for saving electricity and heightening the treatment efficiency.

2) To recycle fine sand, the drum-type sand screening can be replaced by the containerized centrifugal solid-liquid separation equipment as shown in Figure 4. The advanced technology of hydrocyclone (centrifugation) solid-liquid separation could easily separate the sand and the silt with particle diameters greater than 0.075mm and 0.025mm respectively from the slurry. It can treat 454.25m$^3$ of slurry per hour with a solid content of 15% by mass. The remaining slurry with clay less than 0.025mm is treated by a subsequent process.

3) To accelerate clay settlement, the settling tanks can be replaced by inclined plate sedimentation equipment such as Containerized High Speed Suspended Solids Separation System (CH5S) made in Dongguan, China, as shown in the Figure 5. It can treat 5000m$^3$ of slurry with a solid content of 3% to 5%, and 150m$^3$ clay with the moisture content of 80% per day. CH5S utilizes the self-gravity of the slurry to flow into the inclined plate, through the physical absorption settlement of the inclined plate, it can swiftly separate the clay from the slurry. The separated water will pump to the tailwater pond for further recycling. In terms of treatment efficiency, CH5S is four times higher than the traditional inclined plate sediment equipment [7].

![Figure 4. Containerized centrifugal solid-liquid separation equipment (ES2000C).](image)

![Figure 5. Containerized high speed suspended solids separation system (CH5S).](image)

5. Conclusions
The subway construction waste treatment process in Shenzhen was introduced in this study. The present treatment process was designed based on the traditional river sand washing process to meet the requirements of the engineering mud treatment stipulated by Shenzhen Housing and Construction Bureau. To heighten the treatment efficiency and recycle fine sand, some new equipment such as
centrifugal solid-liquid separation equipment and high speed suspended solid settlement system are suggested to replace the drum-type sand screening and settling tanks. The technology of centrifugal solid-liquid separation can accurately separate the sand and silt. The technology of high speed suspended solid settlement by gravity and polymeric flocculants can improve the separation speed of clay in the slurry. The improved treatment process is planning to be used in new construction waste treatment plants in Shenzhen, and it can be also used to treat the polluted river sediment.

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