CONTINUOUS DEWATERING SYSTEM FOR DREDGED SEDIMENT WITH HIGH WATER CONTENT

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ABSTRACT

The Eco-Screw system provides a new method of mechanical dewatering that allows volume reduction and reuse of dredged sediment. A screw press, which is a core tool of Eco-Screw system, has not been used frequently in soil treatment. However, it can be used for realizing a compact system that allows efficient and continuous dewatering. The system has been developed to allow continuous treatment of a wide range of soil, including fine dredged sediment with high water content. Two projects of dewatering dredged marine sediment have been conducted by using one of the largest machines in Japan with a screw diameter of 1350 mm.

Because the present system can perform dewatering while adding solidification material, the system is also effective for preventing the leaching of pollutant when dewatering polluted bottom sediment.

With its ability to reuse dredged sediment efficiently, extend the life of disposal sites, and treat polluted bottom sediment, the system can be a solution to various environmental problems.

Keywords: Screw press, dewatering, continuous-type, volume reduction, recycling

INTRODUCTION

A drastic shift has recently been considered necessary from a social and economic system based on mass exploitation, mass production, mass consumption and mass disposal of resources to a system for resources recycling from exploitation to production, consumption, disposal and recycling. Construction industry plays an important role in recycling resources and building a resources recycling social system. Greater efforts for recycling are essential.

Dredging as part of construction work at ports needs to be carried out continuously in the future not only for the construction of new port facilities or improvement of existing facilities but also for the maintenance to prevent navigation channels or berths from shoaling. The goals are to maintain and enhance port functions. Dredging has, however, been producing large quantities of sediment. Dredged sediment in fiscal 2002 amounted to approximately 40 million tons in Japan. The majority of sediment was disposed of in landfills. Greater efforts should therefore be made for recycling dredged sediment.

A decreasing number of landfill sites have recently been available. Reducing the volume of dredged sediment with high water content by dewatering has been studied everywhere to prolong the lives of landfill sites. Sediment is either treated before it is hauled to landfills or treated using drainage materials after dumping. For pre-hauling treatment, mechanical dewatering is generally adopted in which dredged sediment is consolidated under mechanically applied pressure for dewatering. In pre-hauling treatment, the mechanical properties of soils are enhanced because water is removed from dredged sediment with high water content. Studies are therefore being made to make effective use of dredged material without dumping to landfills after dewatering.

We focused on the screw press, a compact mechanical system that is capable of dewatering the sediment continuously, and developed the Eco-Screw system in 2003 for dewatering dredged sediment. We have been putting the system to practical use since 2004. This paper outlines the system and provides a case study.

WHAT IS THE ECO-SCREW SYSTEM

The Eco-Screw system refers to a dewatering plant with a compression-type squeeze dewatering device generally known as a screw press as a main component. No screw press has ever been adopted in the construction industry, but we have established the Eco-Screw system as a means of dewatering fit for construction work because the screw press has a simple mechanism and can be maintained easily.

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Dewatering Method

The screw press continuously removes water from sediment with rotating screw blades in the casing, a component of the filter, while transporting sediment. First, flocculant is added to the sediment before it is put into the dewaterer. Flocks of sediment are put into the hopper of the screw press. Then, the sediment is continuously transported with the rotation of screw blades, and compressed through the mechanical reduction of volume. The water squeezed out of the compressed sediment is drained to the bottom hopper via a screen that is made of punched metal and placed on the outer perimeter of the screw press. Filtered water is finally treated at an effluent treatment facility. Dewatered sediment is continuously pumped out through the outlet and removed on belt conveyors.

Figure 1 shows the principle chart. Photograph 1 shows a screw press owned by our organization.

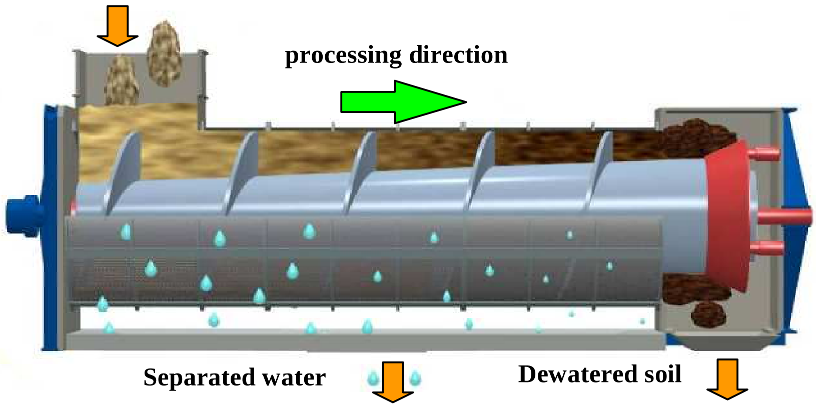

Figure 1. The principles of Eco-screw.

Photograph 1. Screw press of 1,350-mm diameter.

Characteristics of the System

The characteristics of the Eco-Screw system are described below.

(i) Continuous dewatering is possible.

(ii) Designated strength of dewatered sediment that meets the quality requirements can be obtained by adjusting the rate of rotation of screw blades.

(iii) Sediment containing certain quantities of gravel can be dewatered (allowable maximum gravel diameter: approximately 30 mm).

(iv) Punched metal instead of filter cloths is used for filtering, so maintenance is easier.

(v) Screw press is of a simple structure and screw blades rotate at a moderate rate. It operates quietly and consumes little electric power.

Procedure

The Eco-Screw system is operated in four phases including dewatering. Figure 2 shows a standard flow of steps. The objectives and characteristics of respective phases are described below.

(1) Sieving and removal

The objective of sieving and removal is to separate and remove large cobbles and garbages from the sediment using a shaking screen or other device. Particles with a diameter of more than 30 mm are basically separated. Particles with a diameter as small as 5 mm may sometimes be separated from sediment with a certain grain size distribution to reduce the load in the dewatering phase.

In the case where the sediment has a relatively high sand content and separated sand is used effectively for other purposes, hydration equipment and a shaking sieve equipped with a cyclone may be added to the system for separating sand.

The Eco-Screw system continuously handles slurry after sieving, so it requires no storage tank as in batch-type dewatering equipment including filter presses. Then, a compact plant can be built.

(2) Flocculation

Flocculation involves supplying the sediment with flocculant and agitating it to facilitate dewatering.

The sieved sediment is pumped to the flocculation tank. The chemicals described below are added to the sediment during pumping or in the tank. Flocculation is an important part of system operation. We have obtained a patent for the method of flocculation. The following types of chemicals are added.

-Dehydration promoter: Added to the sediment to enhance dewaterability and strength of dewatered sediment (e.g. hydrated lime or magnesium oxide)

-Polymeric flocculant: Added to form large flocks (e.g. anionic polymer)

-Inorganic flocculant: Added to provide hydrophobic property to facilitate the separation of soil from water (e.g. poly-aluminium chloride)

(3) Dewatering

The water content of sediment is reduced by compressing the sediment with a screw press to remove water. With the reduction of water content, the volume of sediment is reduced and the strength is increased. Filtered water is drained through holes of 1.0- to 3.5-mm diameter of the punched metal on the outer perimeter of the screw press. Sediment, however, hardly leaks owing to the effect of flocculation.

The water content of dewatered sediment can be controlled by varying the number of rotations of screw blades to adjust the duration of dewatering. Then , the strength of dewatered sediment (generally represented by the cone index) can be adjusted according to the objective of dewatering and the use of dewatered sediment. Where the sediment is recycled for use as a material for filling or other civil engineering work, for example, a cone index of 400 kN/m^2 or higher is required. For reducing the volume of sediment simply to facilitate handling, a cone index of 200 kN/m^2 or higher is sufficient.

Sediment can also be heated by sending vapor to the screw axis to enhance the dewaterability of sediment. Then, the temperature of pore water in the sediment rises and the coefficient of permeability increases, so more water can be removed from the sediment.

(4) Effluent treatment

Filtered water discharged in the dewatering phase is treated to meet the effluent quality standard and released to surrounding sea areas.

A turbid water treatment system that meets the local effluent quality standards is selected. Soil particles and other solid components that settle and are collected in the turbid water treatment system are returned to untreated sediment for re-processing.

Filtered water is used for cleansing in the plant, dissolving polymeric flocculant, adjusting the density of untreated mud or other purposes.

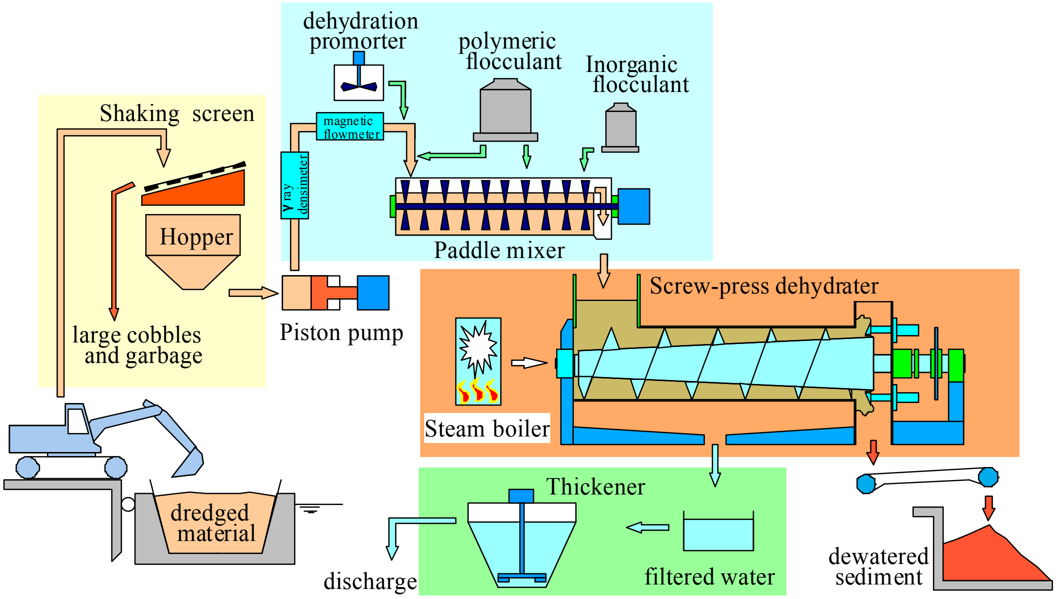

Figure 2. Standard operation steps for the Eco-Screw system.

CASE STUDY

This chapter provides a case study of dewatering of dredged material in a project implemented in 2005 (dredging of navigation channel and berths to a depth of 12 m, amount of earthwork for reference: 10,000 m^3).

Figures 3 show the project site and locations where construction took place, respectively.

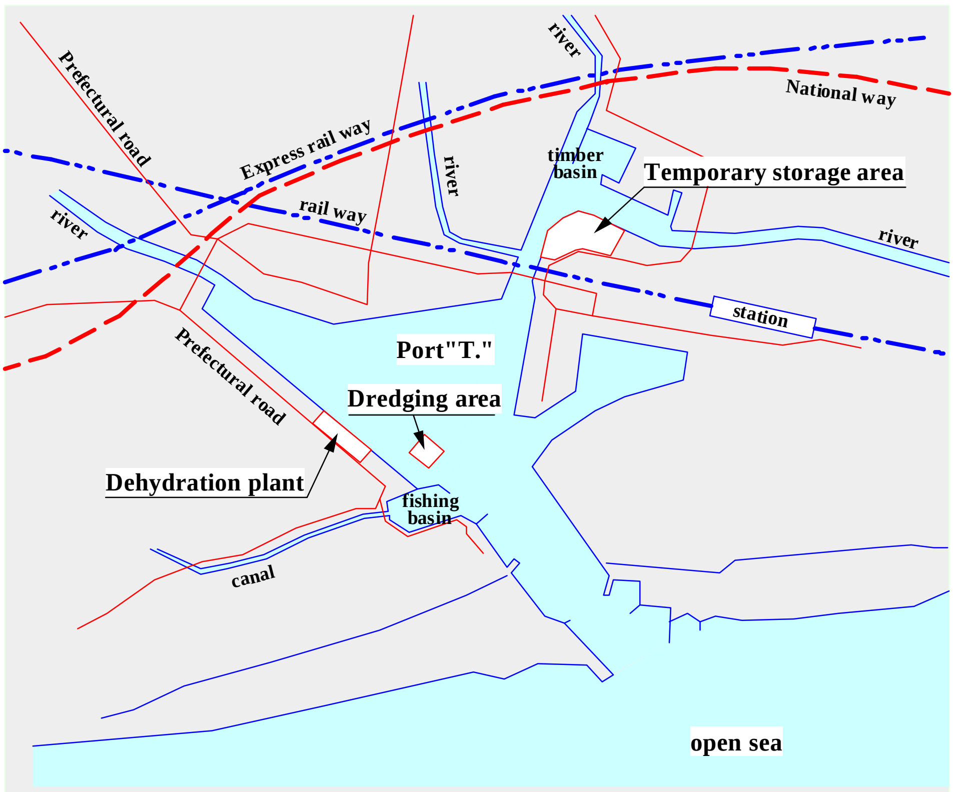

Figure 3. Construction sites.

Outline of Intermediate Processing Work

Intermediate processing is outlined below.

1) Unloading: Unloading of dredged material from the barge (total quantity of material: approximately 15,300 m^3)

2) Sieving: Separation of sand and gravel on an as-needed basis

3) Dewatering:

Compression-type dewatering using two 6.8-m^3-class high pressure filter presses (PFP)

Compression-type squeeze dewatering using a screw press of 1,350-mm diameter (Eco-Screw)

4) Effluent treatment: Discharge of effluent after turbid water treatment

5) Transport and temporary storage: Transport of dewatered sediment and separated sand and gravel to a temporary storage approximately 3 km away

Figure 4 shows a plan of the intermediate processing plant. Photograph 2 shows the dewatering system.

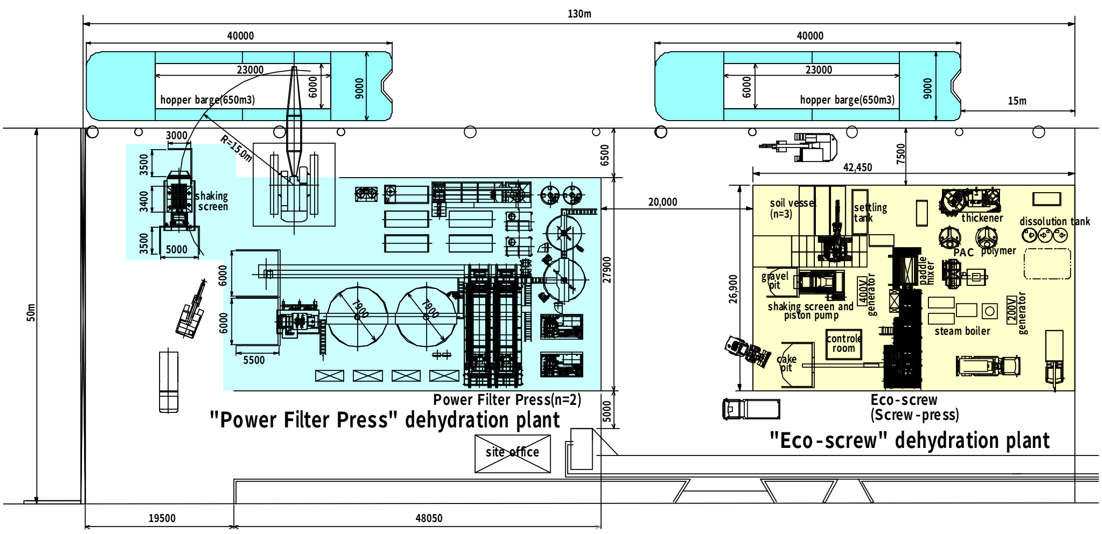

Figure 4. Plan of intermediate processing plant.

Photograph 2. Dewatering system (one screw press of 1,350-mm diameter).

Part of Eco-Screw System We Constructed

1) Unloading: Unloading of dredged material from the barge (quantity of material: approximately 5,100 m^3)

2) Sieving: Separation of particles of 30-mm or larger diameter (in the initial stage), and those of 10-mm or larger diameter (after the change of the screen)

3) Dewatering: Compression-type squeeze dewatering using an Eco-Screw of 1,350-mm diameter

4) Effluent treatment: Discharge of effluent after turbid water treatment

5) Temporary work: Transport, assembly and dismantling of Eco-Screw system dewatering plant facilities

Construction was carried out only during the daytime (from sunrise to sunset). It was required to treat approximately 150 m^3 of sediment per day (upon acceptance in the barge) and to provide the dewatered sediment with a strength represented by a cone index qc of more than 300 kN/m^2.

3.3 Construction of Eco-Screw system

(1) Outline of facilities

1) Layout

The screw press was installed after peripherals, so work space for a large crane was secured.

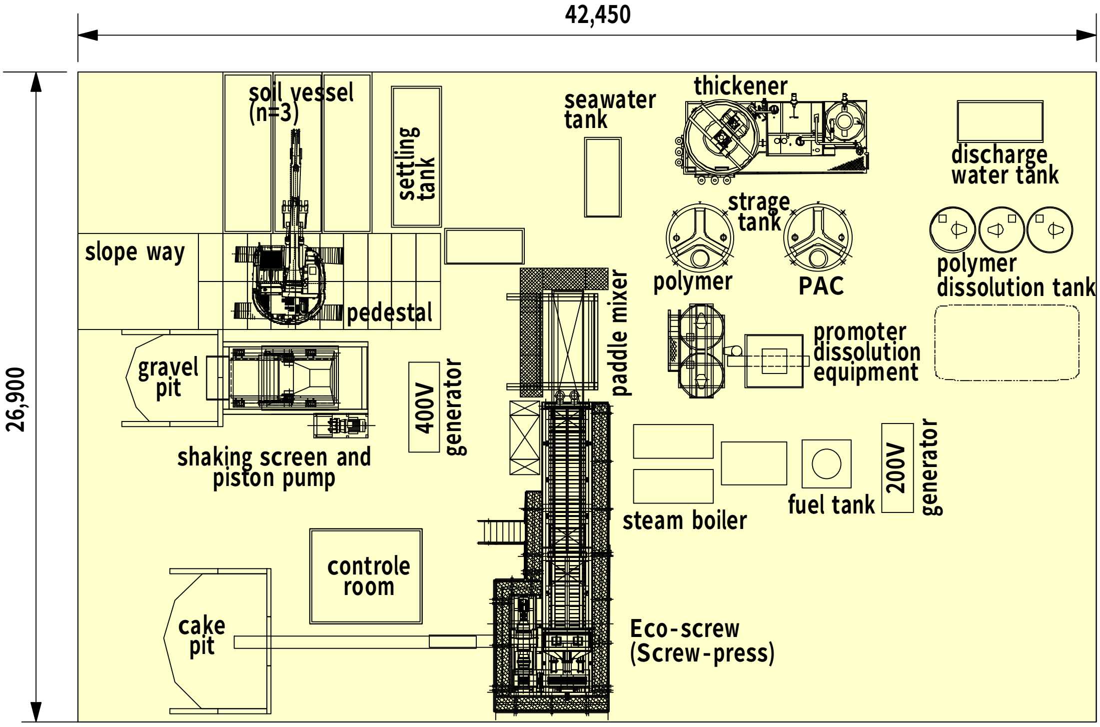

Figure 5. Locations of equipment.

.2) Flow of operation steps

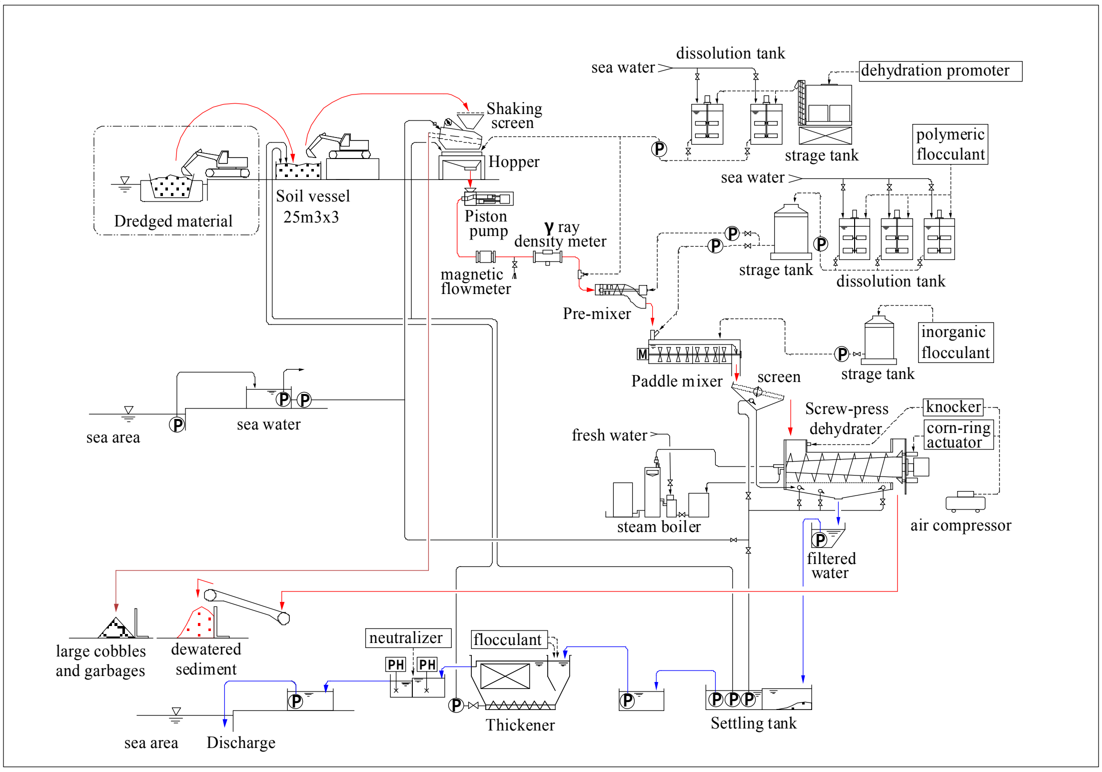

Figure 6. Flow of operation steps.

3) List of equipment

Table 1. List of major equipment.

Type	Quantity	Specifications	Weight (kg)
Backhoe	One unit	$0.7m^3$	
Low-head screen	One unit	1,500×4,200×2D	5,170
Pump	One unit	$47m^3/h×82kgf/cm^2$	2,520
Electromagnetic flow meter	One unit	4B	
Gamma ray density gauge	One unit	4B	
Premixer	One unit	15kW	450
Paddle mixer	One unit	Biaxial type, 34 kW, equipped with a start-up panel	6,000
Eco-Screw	One unit	φ1350mm,45kW	35,000
Boiler	Two units	2,000kg/h ,11kW	2,320
Flocculant dissolution tank	Three units	$5\ m^3$, round propellers, 2.2 kW	
Dehydration promoter dissolution and storage tank	Two units	$3m^3$,1.5kW	
PAC storage tank	One unit	$10\text{-}m^3$ Dailite tank	
Belt conveyor	Two units	BW=450mm ,L=10m	
Power generator	One unit	300 kVA, for 100-200 V	5,030
Power generator	One unit	220 kVA, for 400 V	4,080

(i) Paddle mixer

In the paddle mixer, the sediment is supplied with polymeric flocculant, inorganic flocculant and dehydration promoter and agitated. Right quantities of flocculant should be added to the sediment at a right position according to the properties of the sediment that is transported continuously. It is necessary to finely adjust the position of flocculant application and the period in which flocculant should stay in the mixer.

Photograph 3. Paddle mixer.

(ii) Screw press

A screw press of 1,350-mm diameter, largest in Japan, was used.

Photograph 4. Screw press.

(iii) Boilers

The sediment was also heated with boilers because cohesive soil was dewatered. Two units of 2,000 kg/h boilers were adopted based on the results of preliminary studies.

Photograph 5. Boilers.

4) Photographs showing the field conditions

Photograph 6. Inputting the sediment.

Photograph 7. Separating gravel.

Photograph 8. Flocculation.

Photograph 9. Discharging filtered water.

Photograph 10. Discharging dewatered sediment through outlet.

Photograph 11. Discharging dewatered sediment to a pit.

Photograph 12. Loading dewatered sediment.

Photograph 13. Temporary storage.

Soil Properties of Dredged Sediment

Soil properties of dredged sediment samples collected during construction were examined. The results are described below.

The grain size distribution in the sediment varied greatly according to the location or depth of dredging. Then, water content and consistency also varied substantially.

Table 2. Soil properties of sediment.

Item		Unit	Sediment
Soil particle density		g/cm^3	2.581～2.660
Water content		%	44～214
Grain size distribution	Gravel	%	5.3～26.0
	Sand	%	27.6～47.2
	Silt	%	20.0～45.3
	Clay	%	6.9～21.8
Consistency	Liquid limit	%	51.8～118.8
	Plastic limit	%	43.9～64.3
	Plastic index	—	7.9～54.5
Ignition loss		%	5.4～12.4
pH		—	7.2～7.9

Quantity of Sediment Handled

The quantity of sediment handled was obtained based on the construction data collected during the construction period.

As described above, the grain size distribution varied greatly in the sediment, so the quantity of sediment handled also varied according to the sand content.

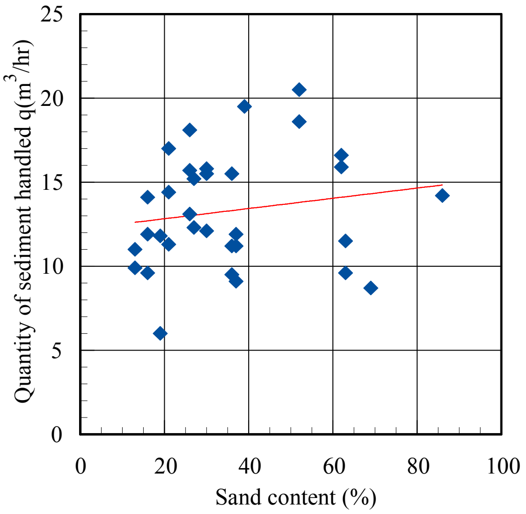

Figure 7. Sand content and quantity of sediment handled.

Mechanical Properties of Dewatered Sediment

The strength of samples of dewatered sediment collected during construction was examined. The results are described below.

The cone index was higher than 300 kN/m^2 as designated in the specifications. The maximum strength was approximately 1,000 kN/m^2 as soil properties varied.

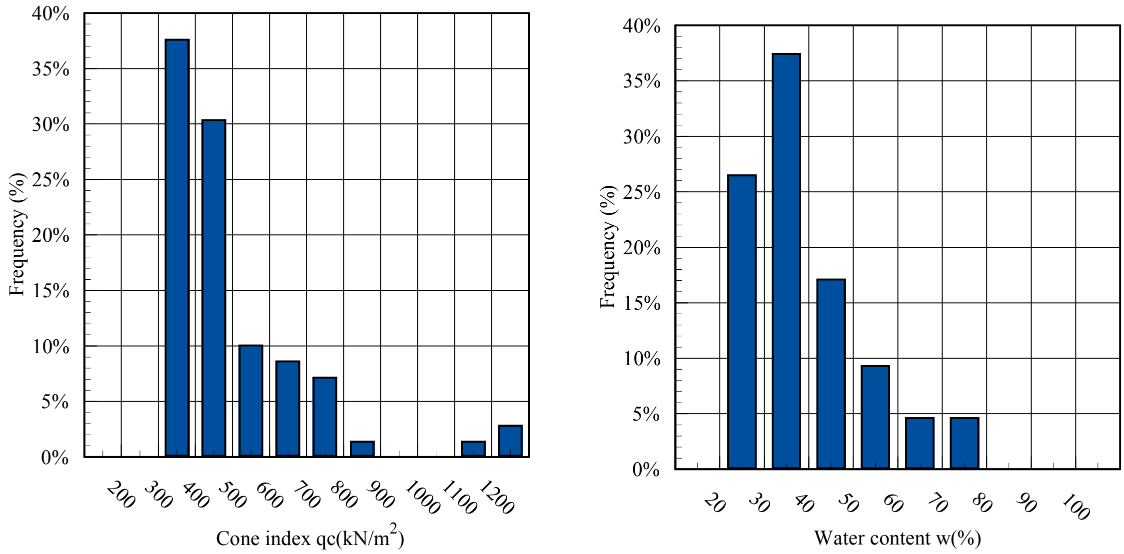

Figure 8. Mechanical properties of dewatered sediment.

Conclusions

As a result of dewatering in the project, the following points were confirmed.

(i) Designated amount of dredged sediment could be dewatered with the Eco-Screw system in the designated period.

Ten to twenty cubic meters of sediment were handled per hour according to the sand content.

(ii) A cone index of more than 300 kN/m^2 could be obtained for the dewatered sediment. Thus, the dewatered sediment was of satisfactory quality.

CLOSING REMARK

This paper has outlined the Eco-Screw system that continuously dewaters dredged sediment and presented a case study. Technologies related to dredged material are expected to be required for taking environmental measures in ports and play a greater role. As a recent topic, the Law Concerning Marine Pollution and Prevention of Marine Accidents will be implemented on April 1, 2007 that was revised based on the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972. Making effective use of dredged sediment will become even more important as stricter restrictions will be imposed on ocean dumping of sediment.

For using recycled materials including dredged sediment, developing technologies and studying their applicability for wider use will become important. Technologies should be developed for identifying the characteristics of recycled materials or establishing design methods for using recycled materials.

It is hoped that recycled dredged sediment will be used in an increasing number of cases in such projects as waterfront nature restoration and ocean environment development. Penta-Ocean Construction Co., Ltd. will be in the vanguard of dredged sediment recycling and take the initiative in controlling the production of, reducing the volume of and recycling wastes through recycling technology development for building a resources recycling social system.