A NEW PRACTICAL SOLUTION FOR EFFECTIVE USE OF DREDGED SAND - MIXTURE OF DREDGED SAND AND LIGHTWEIGHT MATERIALS

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ABSTRACT

Construction of ports and offshore airports, which is now performed on a large scale in Japan, requires a large volume of materials (mainly sand) for ground formation. However, it has become difficult to obtain large amounts of pit sand from mountains because of nature conservation rules. On the other hand, dredging operations for maintenance of seaways and berths have produced a large volume of soft waste materials (earth and sand) with associated disposal problems. To recycle the dredged materials, lightweight mixtures have been developed and are effectively reused as ground material. Lightweight mixtures are now produced as artificial ground material by treating the dredged materials with solidifiers and lightweight materials (air bubbles, expanded beads, etc.). This process allows control over the density and strength of the lightweight mixtures. This report describes the present status of construction technology using such lightweight mixtures together with a practical solution

Keywords: Lightweight mixing treatment, dredged earth and sand, recycling, air bubbles, expanded beads

INTRODUCTION

Public attention is now aware of the increasing importance of environmental preservation. In the marine construction area, studies have been carried out to recycle the large amounts of dredged materials from dredging work of seaways and berths as a construction material at ports or offshore airport sites, and some recycling methods are now in use. The dredged materials, which are soft and loose, cannot be used as dredged. Therefore, the dredged materials are mixed with functional additives for effective use in ground formation, thus meeting the demand at various construction sites. The recycling methods have reduced dredged material treatment costs and disposal volume. This is now expected to be a significant method for the environmental preservation.

In Japan, various techniques and methods are available to produce artificial ground materials using soft and loose dredged materials (earth and sand). This report describes the construction technique and method of a lightweight mixture developed by treating the dredged materials with solidifiers and lightweight materials (air bubbles, expanded beads, etc.)

RECYCLING TECHNIQUES OF DREDGED MATERIALS

Types of Recycling Techniques

At present, techniques to reuse the dredged materials as value-added ground materials are mainly classified into three types: solidification, dehydration, and classification. Of these types, the solidification method includes mixing solidification by a process plant, in-pipe mixing solidification, solidification in situ, and pre-mixing solidification. The lightweight mixing-treatment process uses mixing solidification by a process plant.

Solidification treatment techniques have principally been applied to secure the necessary strength for the dredged material with a solidifier. Studies have been conducted to make the artificial ground materials more functional, and strong lightweight material has been commercialized.

In this report, the air bubble mixing and expanded beads mixing-treatment methods are introduced as lightweight mixing-treatment processes. The former can provide artificial ground material with lightweight characteristics by mixing air bubbles, and the latter, by mixing expanded beads.

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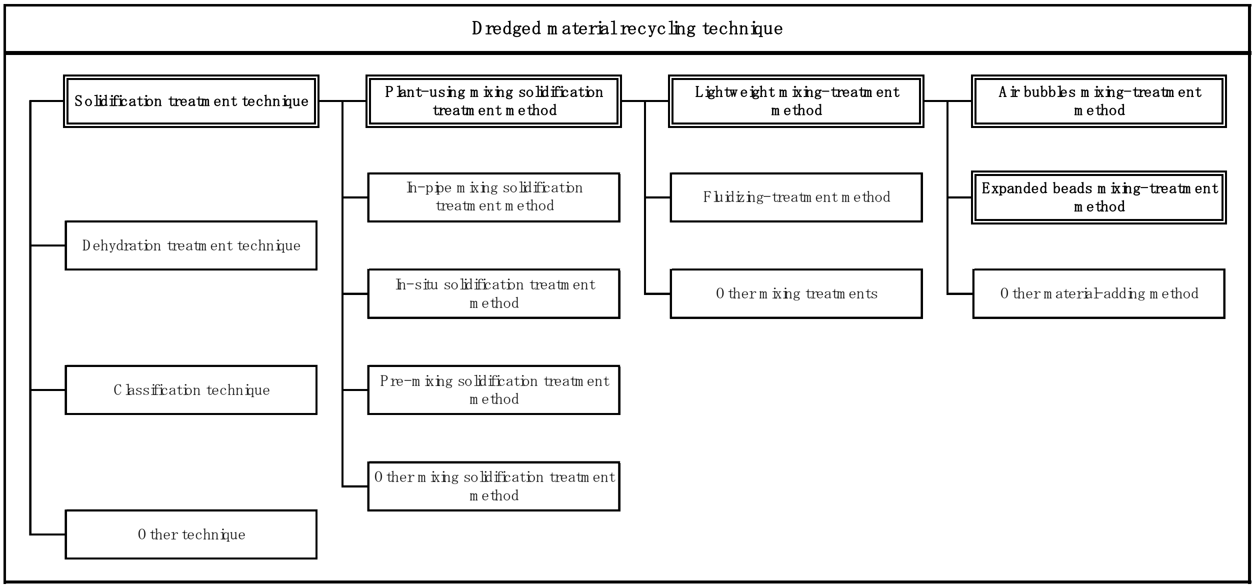


Figure 1. Dredged material recycling techniques.

Air Bubble Mixing-treatment Material

This air bubble mixing-treatment material uses air bubbles for the lightweight requirement. Air bubbles are generated using compressed air and a diluted foaming agent with fresh water or seawater. Air bubbles in the air bubble mixing-treatment material will deflate due to external pressure, or if the material contains too many organic components, the air bubbles will disappear (defoaming). Therefore, the type of air bubbles and mixed quantity are determined by tests.

In addition, the typical foaming agents can be divided into the protein type and surfactant type. The type depends upon the stability and durability of the air bubbles, or adaptability to the material used.

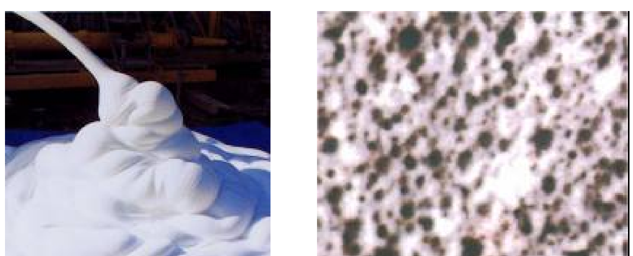


Photo 2. Air bubbles and air bubble mixing-treatment material.

Expanded Beads Mixing-treatment Material

This expanded beads mixing-treatment material uses expanded beads for the lightweight requirement. The expanded bead is the general name given to the light and solid resin beads produced by inflating granular resin with heat such as high-temperature steam. Expanded polystyrene beads are a typical example. The bead size is about 2mm in diameter and specific gravity is 0.032g/cm^2.

Compared with the air bubbles, the volume reduction of the expanded beads is smaller. However, the expanded beads mixing-treatment material shows a low separation resistance when placed in water, and the expanded beads will separate from the material. Consequently, the measures must be taken for outflow prevention from the construction area and recovery of beads.

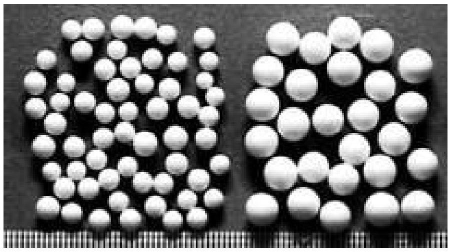
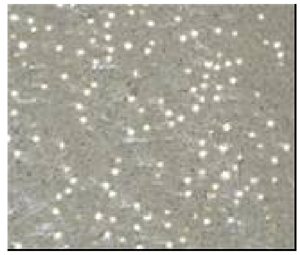
 

Photo 2. Expanded beads and expanded beads mixing-treatment material.

CHARACTERISTICS OF LIGHTWEIGHT MIXING-TREATMENT MATERIALS

The lightweight mixing-treatment material is produced as the ground material with a density of 8 to 12kN/m^3 from the density-controlled material by mixing with the solidifier and lightweight material. The density-controlled material is prepared from dredged materials by adding water. The material just after being processed has sufficient fluidity for pumping out via a concrete pump. With time, the solidifying reaction proceeds, and the material finally becomes the solid ground material with a strength of 100 to 500kN. The density and strength of the lightweight mixing-treatment material can arbitrarily be determined by controlling the adding quantity of solidifier and lightweight material within the range of the above values. Table 1 explains the characteristics of the lightweight mixing-treatment material.

Table 1. Characteristics of lightweight mixing-treatment material.

Items	Characteristics
Density	-Possible to provide the material with adequate density by regulating the quantity of the lightweight material (8 to 12kN/m3) - Density of the lightweight mixing-treatment material when manufactured will vary due to defoaming before the material solidifies. The increase in density can be compensated with additional air bubbles. - Density of the lightweight mixing-treatment material will increase due to shrinkage of the lightweight materials under the water pressure when placement is carried out in water. By considering the water pressure, adequate mixture with the lightweight material can be provided. - After the strength is fully displayed, changes in the density will not occur.
Strength	- Strength management can be achieved by controlling the quantity of the solidifier. (100 to 500kN/m2) - Density as well as strength will slightly increase due to the effect of the water pressure during curing.
Fluidity	- When the water content is higher, the fluidity becomes larger due to the effect of the water content in the density-controlled material. - Fluidity in water is smaller due to the effect of the water pressure and buoyancy than that in the air.
Separation resistance in water	- Separation resistance is influenced by the properties of the dredged material as well as quantities of the solidifier and lightweight material.
Applicability	- Constant construction management is essential to cope with changes in properties of the dredged material.

OUTLINE OF LIGHTWEIGHT MIXING-TREATMENT MATERIAL METHOD

Features of the Method

Under this method, the lightweight mixing-treatment material is produced by mixing the dredged materials with solidifier of 80 to 200kg/m^3 and lightweight material of 0.4 to 0.8l/m^3. The features are as follows:

(1) The lightweight mixing-treatment material, as a matter of course, differs from those obtained intact from nature. The material shows a very effective feature to reduce ground subsidence by load compaction since the density and strength of the material are controllable and uniform to meet the requirements.

(2) Design of mix proportion provided with underwater separation resistance is possible. Accordingly, the influence on the peripheral environment of the construction site can be reduced.

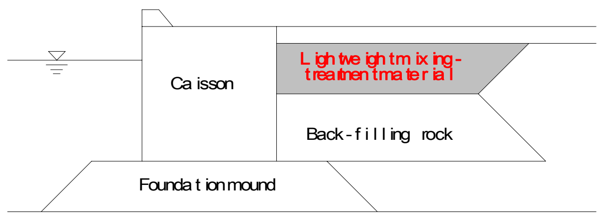
(3) Adequate fluidity of the material can be sent out by a pump to a remote site. The material placement can be achieved for free forming without compaction.

(4) The dredged material of high water content can effectively be used as a base material.

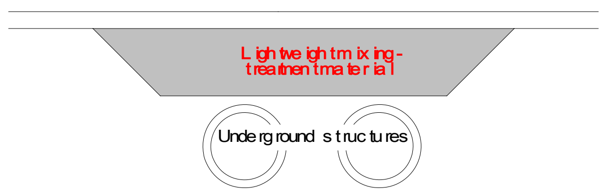
Use of Lightweight Mixing-treatment Material Method

The method can be applied to reduction of subsidence, suppression of lateral displacement, liquefaction prevention, and reduction of ground improvement work. The principal use is described below.

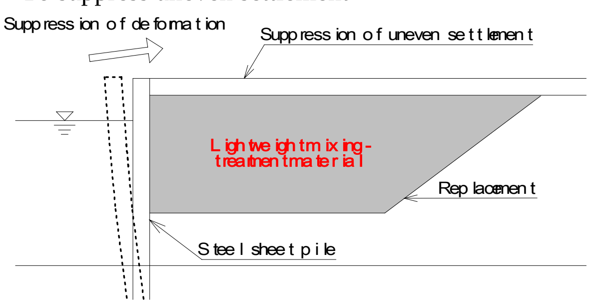
(1) Backfilling use for seawall
Purposes of lightweight mixing-treatment material
- To reduce ground pressure
- To decrease subsidence
- To prevent liquefaction



(2) Backfilling over underground structures
Purpose of lightweight mixing-treatment material
- To protect structures
- For protective filling



(3) Wharf (seawall)
Purpose of lightweight mixing-treatment material
- To suppress lateral displacement
- To suppress uneven settlement



(4) Filling over soft ground
Purpose of lightweight mixing-treatment material
- To suppress subsidence
- For ground improvement and volume reduction of counterweight filling
- To prevent slip failure

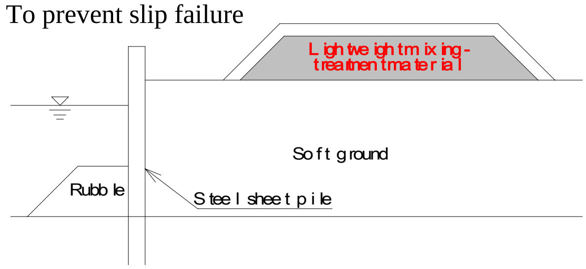


Figure 2. Principal use of lightweight mixing-treatment material method.

SITE CONSTRUCTION BY LIGHTWEIGHT MIXING-TREATMENT MATERIAL METHOD

Placement Procedures

The construction method with the lightweight mixing-treatment material is indicated in Figure 3. The method consists of (1) Dissolution Process of the dredged material, (2) Preparation Process for mixing, (3) Mixing Process with solidifier and lightweight material, and (4) Placement Process of the material. A brief explanation is given below.

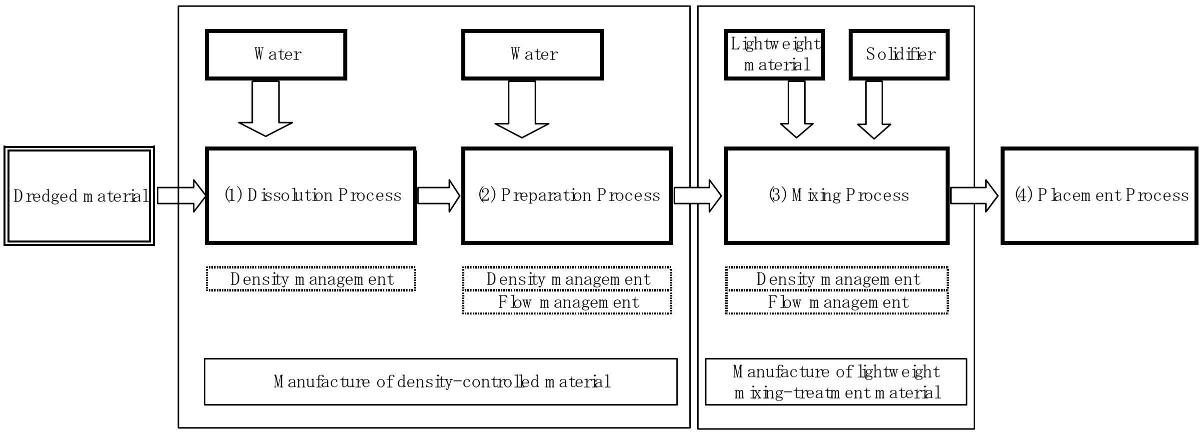


Figure 3. Construction procedure by lightweight mixing-treatment material method

(1) Dissolution process
The dredged material is transported by sand carriers, and gravel with a diameter of 10mm and over, and other obstacles in the material are first separated in the dissolution equipment. Subsequently, water is added to dissolve clay lumps and increase fluidity for pumping.

(2) Preparation process
The material with high fluidity is sent to the preparation equipment where water is added and mixed for density control. Density-controlled material is thus obtained. The density and fluidity are closely connected with the performance of the material. Therefore, careful management of the density and fluidity is required for the process.

(3) Mixing Process
The density-controlled material is sent to the mixing equipment where the material is mixed with the solidifier and lightweight material. The lightweight mixing-treatment material is thus produced as the ground material. The required quality assurance of the product is achieved by repeated sampling tests of the material for the production management. In addition, mixing of materials with a large different density requires a high performance mixer.

(4) Placement process
The product, lightweight mixing-treatment material, is pumped out to a construction site and placed using a special placement unit. Placement can be achieved underwater or in air.

When the air bubble mixing-treatment material is placed underwater, air bubbles in the material deflate (defoam) under water pressure, and the density increases. Therefore, the quantity of the air bubbles must be determined by considering the water pressure.

When the expanded beads mixing-treatment material is used, the pump pressure causes the deflation of the expanded beads in the material during transfer in a pipeline. The shrunk beads will not restore completely after placement. Consequently, the quantity of the expanded beads must be decided by taking the pump pressure and shrinking ratio into account.

The air bubbles and expanded beads mixing-treatment materials have characteristic differences, so different construction methods are required for the respective materials as described below.

Construction Method for Air Bubbles Mixing-treatment Mmaterial

When the air bubbles is used as lightweight material, the air bubbles are provided at the construction site. Preparation of air bubbles is carried out using seawater or water to dilute the foaming agent to the required degree. Then, foaming is conducted with compressed air up to the necessary degree. This method has been applied in general.

Furthermore, the external pressure easily influences the air bubbles contained in the material. Past experience has shown that the air bubble mixing-treatment material increases in density after being sent by pumping to the site. The followings also cause increases in the density:

(1) Presence of oil and organic substances in the dredged material

(2) Mixing process in the mixing equipment

(3) Pressure in the transfer pipeline

(4) Water pressure at the time of underwater placement

The density increase occurs when air bubbles contained in the material disappear or deflate. In (1) through (3) above, the lightweight material disappears, and (4) represents deflation of air bubbles.

By estimating the density increase at placement, adequate addition of lightweight material can be determined, to meet the quality requirement for the product.

The density increase value of (4) can be obtained from calculations since the water pressure causes defoaming. Those of (1), (2), and (3) vary with the content of the organic substances, time required for mixing, and the transfer distance. Therefore, the density increase values must be checked at the beginning of construction work.

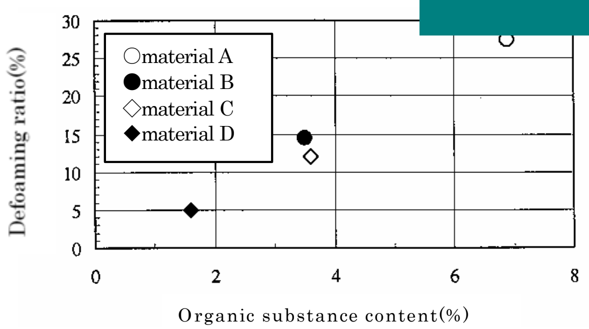


Figure 4. Relationship between organic content and defoaming ratio.

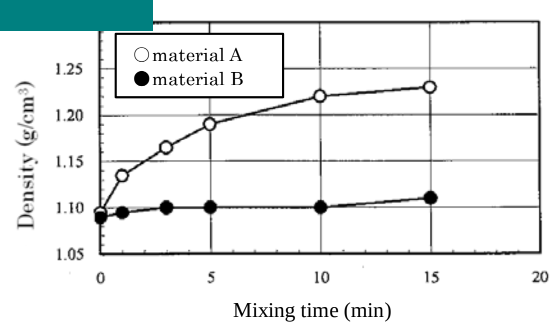


Figure 5. Relationship between mixing period and density.

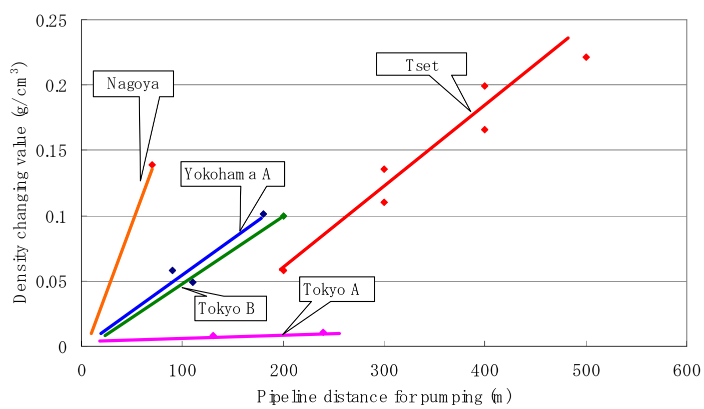


Figure 6. Relationship between transfer distance and density difference.

Construction Method for Eexpanded Beads Mixing-treatment Material

When the expanded beads are used as the lightweight material, the expanded beads produced at a factory are generally transported to the construction site, where the expanded beads are fed to the mixer at a fixed quantity via a volume feeder.

Since expanded beads are used as the lightweight material, the material will not be influenced so much as the air bubble mixing-treatment material. However, the expanded beads will shrink under pressure above a certain degree during the transfer through the pipeline. Naturally, the density of the expanded beads mixing-treatment material increases. The volume of the beads is larger than that of air bubbles, and when the viscosity of the dredged material is smaller, the separation resistance tends to become lower.

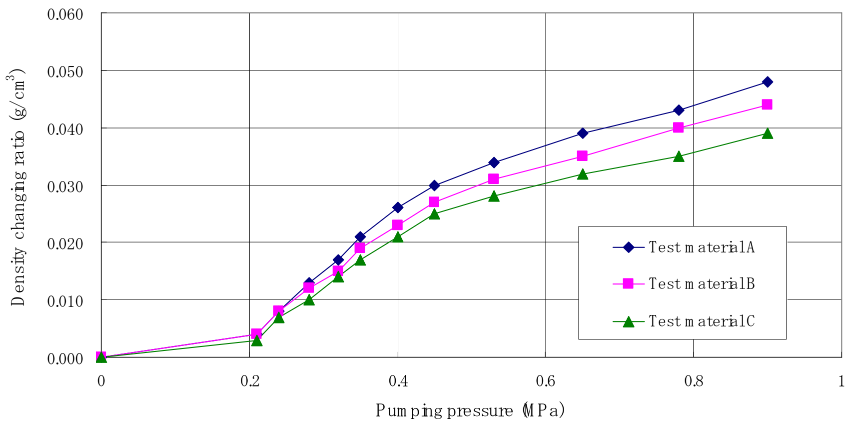


Figure 7. Relationship between pump pressure and density.

Placement Machinery (use on land)

The construction method using the lightweight mixing-treatment material is one of the latest developments, and standard placement machinery is not available. In many cases, the existing machines are adapted for the specific projects. For the adaptation, tests on the machinery are carried out before actual placement work. This promotes the quality assurance of the material produced as well as stable construction performance and quality.

Facilities on land must have a capacity suitable for construction scale and conditions. At present, three types of facilities are available, having a handling capacity of $50m^3$/hr, $100m^3$/hr, and $200m^3$/hr. Past construction achievements have been carried out with those facilities. Typical machinery is exemplified in Figure. 8 and Photo 3.

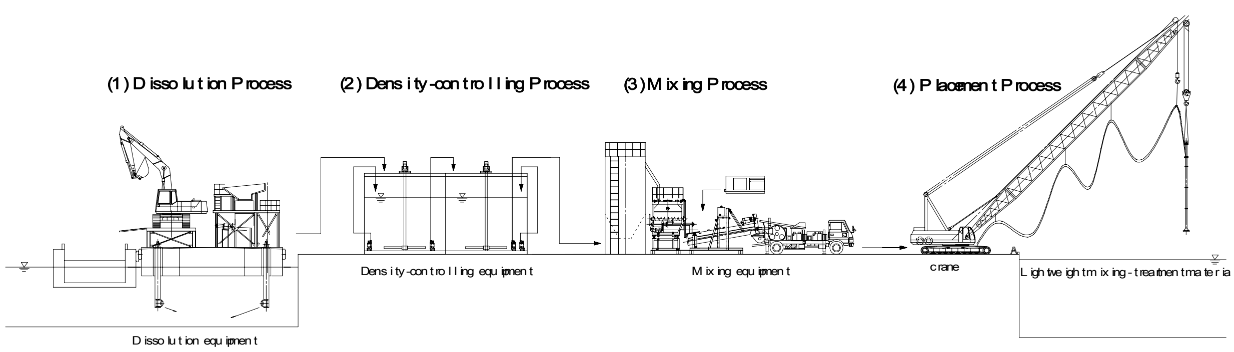


Figure 8. Typical machinery examples.

(1) Dissolution Process

(3) Mixing Process

(2) Preparation Process

(4) Placement Process

Photo 3. Machinery required for placement.

Placement Machinery (use in water)

Through many construction achievements, new demand for massive-rapid construction has arisen due to requirements for increasing construction scale and shorter construction period. To satisfy the requirements, R&D has been conducted for such facilities. Ryu Jin is one of the new developments, which has been developed to be applicable to massive-rapid construction.

The vessel has a capacity about two times larger than that of the land facility, and is expected to demonstrate full capacity for large construction projects in the future. The Ryu Jin had no achievement when this report was prepared. However, the vessel will have entered first service for a project using the lightweight mixing-treatment method in the Osaka district of Japan at the end of 2006.

Photo 4. Ryu Jin, lightweight mixing-treatment vessel.

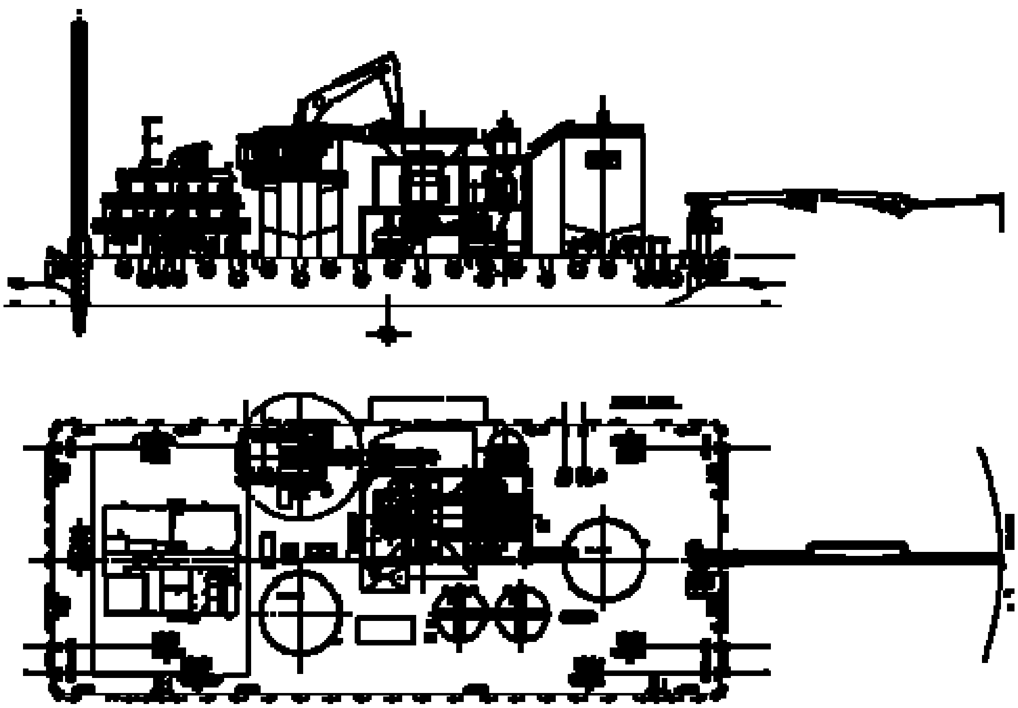


Figure 11. Ryu Jin, lightweight mixing-treatment vessel.

CONSTRUCTION ACHIEVEMENTS BY LIGHTWEIGHT MIXING-TREATMENT METHOD

This method was applied to more than 30 projects amounting to about 300,000m^3 in terms of construction volume since it was commercialized ten years ago, several typical projects of which are described below.

(1) Tokyo district

Construction period: September to December 1998
Work volume: 32,000m^3
Quality requirement: Lightweight mixing-treatment material, density of 11kN/m^3
Strength: 200kN/m^3 (uniaxial compressive strength)
Characteristics: To take measures for liquefaction of the ground and reduce the load on the shield tunnel constructed under the airport taxiway
Material-placing work carried out over the shield tunnel that was in service

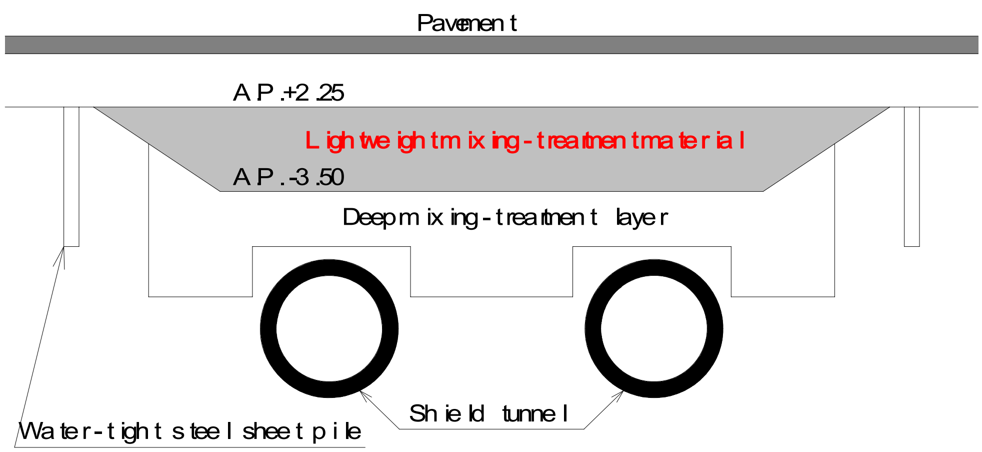


Figure 9. Cross section of construction.

Photo 5. Construction status.

(2) Nagoya district

Construction period: July 2001 to November 2002 (For 2nd phase project)
Work volume: 28,000m^3 (Total)
Quality requirement: Lightweight mixing-treatment material, density of 11kN/m^3 (water depth, -11.0m to -0.8m), Density of 12kN/m^3 (water depth, -8.0m to -2.5m)
Strength: 200kN/m^3 (uniaxial compressive strength)
Characteristics: To reduce the load on the undersea tunnel (by submerged tunnel method)
Material-placing work carried out in deep water (Max. depth, -12m)

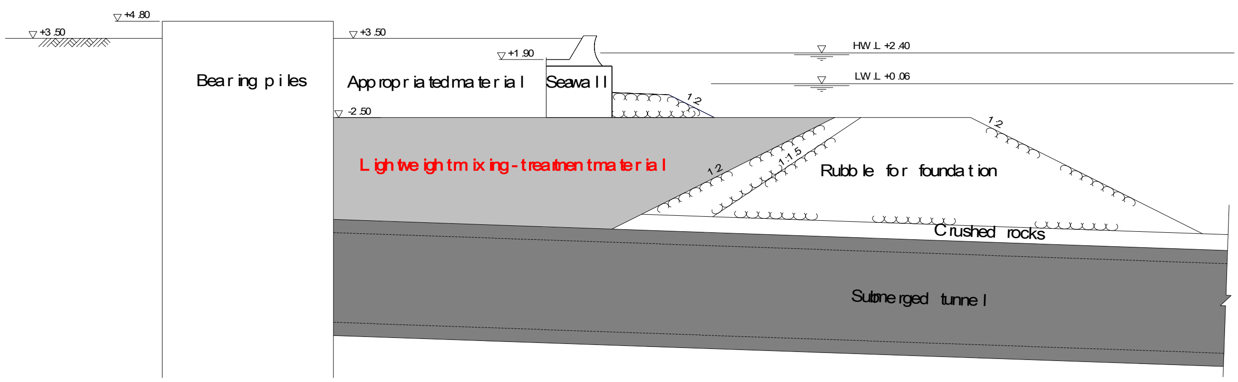


Figure 10. Cross section of construction.

Photo 6. Construction status.

(3) Hokkaido, eastern district

Construction period:	January 2001 to December 2005 (For 5th phase project)
Work volume:	15,000m^3 (Total)
Quality requirement:	Lightweight mixing-treatment material, density of 12kN/m^3
Strength:	200kN/m^3 (uniaxial compressive strength)
Characteristics:	To recycle the dredged material and reduce the ground pressure against wharf Material-placing work carried out under the mean seawater temperature 0^oC in the coldest season of the district

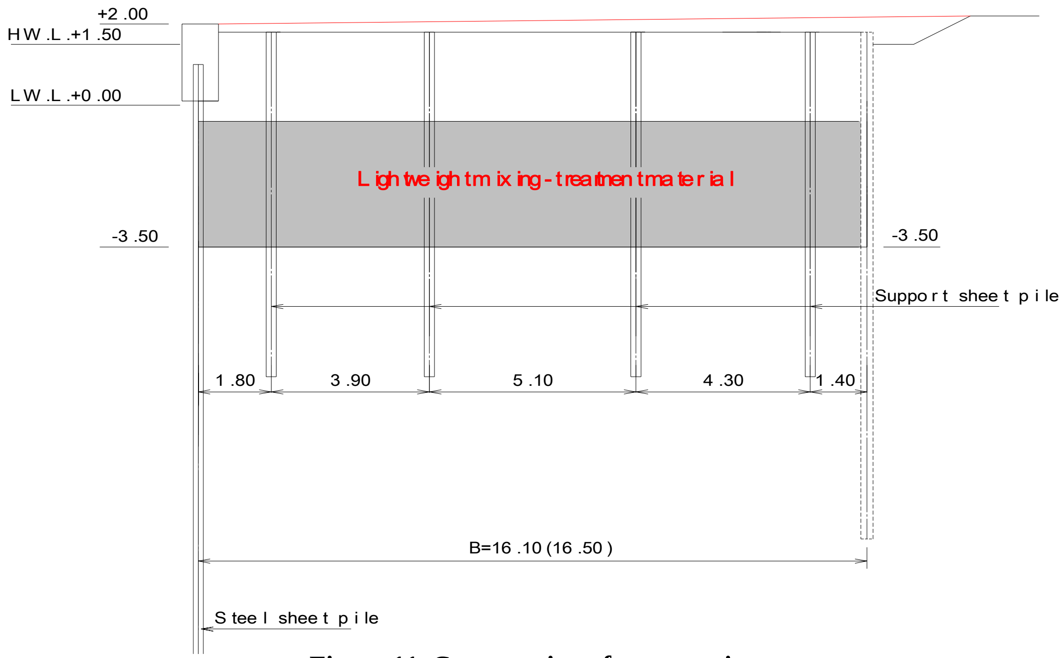


Figure 11. Cross section of construction.

Photo 7. Construction status.

(4) Osaka district

Construction period:	November 2006 to March 2007
Work volume:	68,000m^3
Quality requirement:	Lightweight mixing-treatment material, density of 12kN/m^3
Strength:	200kN/m^3 (uniaxial compressive strength)
Characteristics:	To reduce the load on the undersea tunnel (by submerged tunnel method) First material-placing work to be carried out using the lightweight mixing-treatment vessel to cope with massive-rapid construction

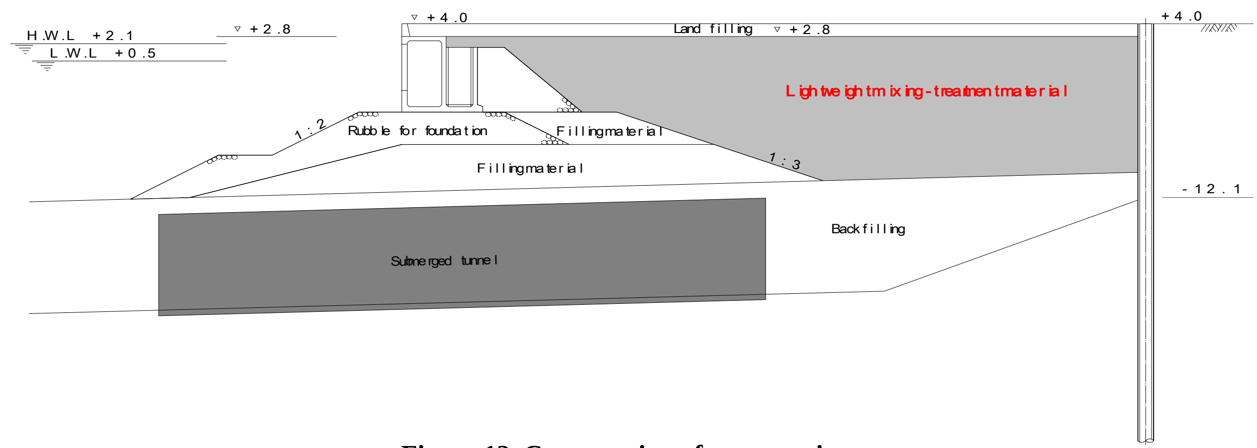


Figure 12. Cross section of construction.

Photo 8. Construction status.

CONCLUSION

Lightweight mixing-treatment materials have been employed for various construction purposes since development for recycling dredged materials as ground material. The features of the materials are summarized below:

(1) Effective recycling of dredged materials
(2) Material with adequate density by regulating the quantity of lightweight material
(3) Control of material strength by managing the quantity of the solidifier
(4) Appropriate fluidity designed for placement via the pump pipeline
(5) Placement in water possible

The lightweight mixing-treatment method that has the above features is a means to efficiently recycle dredged materials at present. In the future, it is expected that new technologies will be developed for providing the dredged materials with high value, high quality, and low cost to allow wider application and increased recycling. On the other hand, to meet the requirement for massive-rapid construction, innovation is in progress for the material placing technology as exemplified by the Ryu Jin.

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