Appendix-1：Underwater Structure Shape Measurement System Using an Underwater 3D Scanner

1. Introduction

In port facilities, understanding the condition of underwater portions is by no means easy because they are affected by waves and other environmental factors. When investigating seabed topography and the condition of underwater structures, surveys are generally conducted by divers using manual methods. However, diver-based surveys are strongly influenced by limitations such as diving time and depth, tidal currents, and water turbidity, and therefore cannot always be considered efficient. For this reason, in recent years, methods that improve survey efficiency through the use of various measuring instruments have increasingly been adopted. This section introduces a method for investigating the presence or absence of damage to underwater structures using an underwater three-dimensional scanner.[1),2)]

2. Overview of the Technology

2.1 General

An underwater 3D scanner (hereinafter referred to as the 3DSC) is an acoustic device that measures underwater structures and seabed topography as high-accuracy, high-density point cloud data, and is originally intended to be operated in a stationary position on the seabed. In addition, a technology has been developed that combines the 3DSC with a motion sensor and installs it on a survey vessel, enabling measurements to be taken while the vessel is navigating.

This technology enables the accurate capture of underwater infrastructure geometry while sailing, thereby significantly enhancing safety, efficiency, and cost-effectiveness. Because the 3DSC is compact and lightweight, it can be operated with only a small number of personnel and minimal equipment (a work vessel), eliminating the need for heavy machinery. It can also be used in turbid water and in currents of up to 2 m/s, where diver-based surveys are not feasible.

The survey targets are deformations with a size of 10 cm or larger. Accordingly, the system can efficiently measure phenomena such as peeling of revetment coverings, scattering of blocks, opening of joints, wear and loss of cathodic protection systems, and holes in sheet piles and piles. However, it is not intended for detecting concrete cracks or corrosion on steel surfaces.

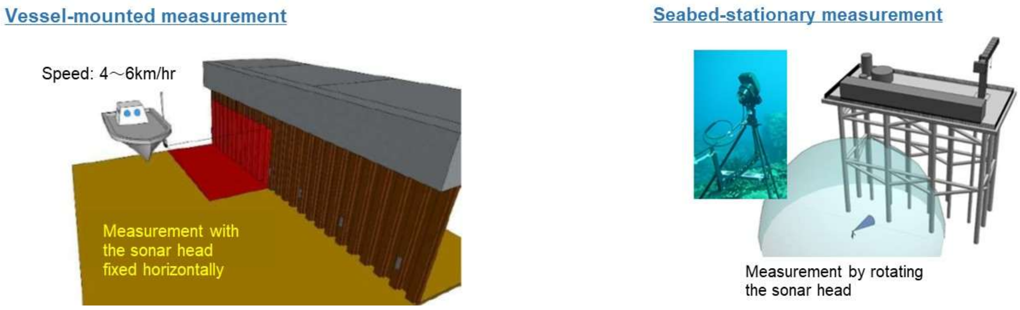


Figure 1 Image of underwater measurement using an underwater 3D scanner

2.2 Measurement Method

The contents of this technology are explained below in accordance with the measurement procedure.

(1) Highly directional 1,350 Hz acoustic waves are emitted in a fan shape toward the measurement target (256 beams, vertical angle 42°, horizontal angle 1°), and the reflected waves are received to measure the time difference.

(2) The distance to the target object is calculated from the time difference.

(3) When installed on a vessel, the vertical angle of the acoustic transmitter is fixed, and acoustic waves are emitted horizontally to the side of the work vessel. By navigating parallel to structures such as breakwaters

and quay walls and indicating the distances to underwater structures and the seabed at numerous points, the geometry of the structures is visualized as 3D point cloud data.

(4) After completion of the initial measurement, the vertical angle is changed, and additional navigation and measurement are carried out. By integrating the point cloud data, 3D point cloud data of the structures from just below the water surface down to a water depth of 15 m are obtained.

2.3 Applicable Locations

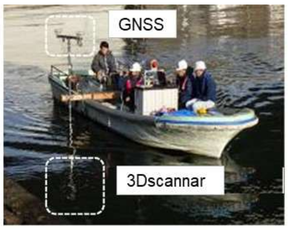
The facilities to which this system can be applied are shown in Table 1. The measurement targets of this system include sediment deposition, scour, and deformations with a size of 10 cm or larger. Measurable deformations include openings of caissons, displacement of revetment works and toe protection works, holes in sheet piles and piles, consumption and loss of cathodic protection systems (anodes), and settlement and damage of wave-dissipating works.
Due to the characteristics of the measuring equipment, areas where ultrasonic waves cannot be directly applied, such as the rear sides of pier piles and wave-dissipating blocks, should preferably be supplemented by survey methods such as visual inspection by divers or imaging using underwater drones.

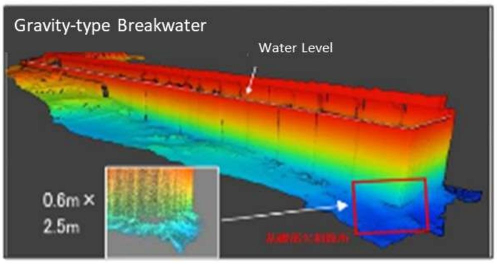
Table 1 Applicable Facilities for This System

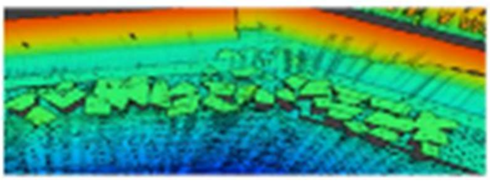
Target facilities	Remarks (structural type, etc.)
Protective facilities for harbors	Gravity-type, Sheet pile-type
Mooring facilities	Gravity-type, Sheet pile-type、Pier-type
Waterways and basins	
Others	Nature-friendly facilities、Submarine cables、Seaweed beds, coral, etc.

2. Examples of Measurement

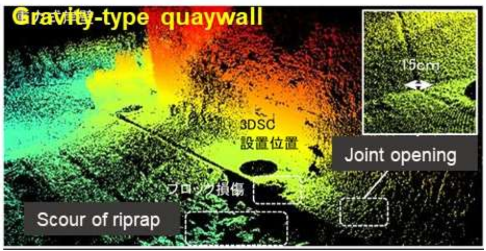
Vessel-mounted measurement

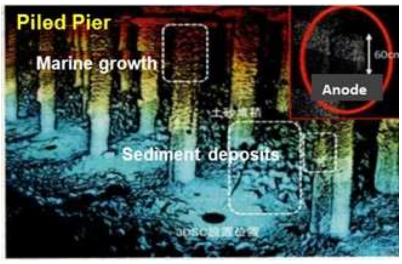






Seabed-stationary measurement





References

1) https://ideacon.jp/technology/inet/vol48/vol48_alls.pdf
2) https://www.mlit.go.jp/kowan/kowan_tk5_000040.html