

Study on Records of Underwater Excavations Utilizing Geophysical Equipment

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ABSTRACT

This study intends to examine the records of underwater excavations utilizing sound waves at the underwater sites with bad visibilities. Marine geophysical exploration equipment was operated and method of investigation and record using it was examined. First, in the underwater excavation of waters of Dangmpo, Taean, side-scanning sonar, multi-beam echo sounder, and scanning sonar were used to record the soil investigation section in order to find out which maritime geophysical exploration equipment is suitable for underwater excavation survey. As a result, it was found that side scanning sonar showed relatively high resolution when using a frequency of 1250 kHz, but there was a problem in that distortion occurred during the investigation process. The multi-beam echo sounder did not cause significant distortion, but the resolution was poor. The scanning sonar had relatively little distortion and had good results, so it was suitable for recording soil removal survey section. In order to review the usability of scanning sonar for the underwater excavation conducted in turbid environment, images of scanning sonar of underwater excavation in the waters of Nakweoldo, Yeonggwang and Myeongryangdaecheopro, Jindo were used to make drawings for survey. By conducting this experiment, it was confirmed that it was possible to make more effective records than drawings made in existing underwater excavation survey when scanning sonar is used for turbid underwater site.

Keywords: sound wave, geophysical exploration, scanning sonar, underwater excavation

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Figure 1 Mosaic image of scanning sonar for Area A of underwater excavation of waters of Nakweoldo, Yeonggwang

Figure 2 Mosaic image using reflector (frequency 675 kHz, measurement range 25 m, ◯ reflector)

INTRODUCTION

The methods of recording artifacts and remains during underwater excavations are not that different from that of land ones. Drawings are created with actual measurements and photos and videos are taken. However, when the water is turbid, it is often difficult to record basic information. The water is turbid due to the presence of many floating objects, which block light and obscure the visibility, hindering actual measurement and recording. In underwater archeology, marine geophysical exploration equipment is mainly used to find artifacts under the surface of the water such as old shipwrecks.

The purpose of this study is to find a way to complement produced records with marine geophysical survey equipment to underwater excavation and at the same time to improve the utilization of physical survey equipment in underwater archeology. To this end, marine geophysical exploration equipment was compared and reviewed in waters of Dangampo, Taean in 2017 and the underwater excavation recording method using the exploration equipment was studied in waters of Nakweoldo, Yeonggwang and Myeongryangdaecheopro, Jindo between 2018 and 2019. This paper intends to present methods for recording underwater excavations using marine geophysical survey equipment by organizing the contents and results of these field experiments.

COMPARATIVE REVIEW ON MARINE GEOPHYSICAL EXPLOARTION EQUIPMENT APPLICABLE TO UNDERWATER EXCAVATION

Comparative study of marine geophysical exploration in waters of Dangampo, Taean

In the underwater excavation of waters of Dangampo, a side scan sonar, multi beam echo sounder, and scanning sonar were used to record the underwater survey for areas temporarily designated as historical site and soil removal section. As these exploration devices use sound waves to investigate the seabed, it was expected that they would be able to record changes in the seabed caused by excavation.

Survey using side scan sonar

Survey using side scan sonar in waters of Dangampo was carried out before removing soil. DSME's S-150 was used, and this model can use frequencies of 400kHz and 1250 kHz. Since the side scan sonar has a relatively small volume and a simple configuration, temporarily designated historical site (500 m × 200 m) was investigated using a rubber boat. A frequency of 400 kHz was used, and the swath which is a range that can survey the seabed at once, was set to 105 m. The swath was wide and the entire designated site could be surveyed by going back and forth three times in the east-west direction and overlapping the scan width by more than 100 per cent. Regarding the soil removal section, the frequency of 400 kHz and swath of 105 m and the frequency of 1250 kHz and swath of 75 m were used repeatedly several times to obtain high-quality results.

Survey using multi beam echo sounder

The multi beam echo sounder survey was conducted, before the soil removal on the same day. R2Sonic's Sonic2024 was used, and this model generates 256 sound waves of 400 kHz at a time from the transducer and receives the sound waves reflected on the seabed and returned. After installing a multi-beam echo sounder in Seamuse (18 tons), the survey was conducted before and after high tide, the highest sea level during the day. The swath of a multi beam echo sounder installed on the ship varies depending on the water depth, and is usually about 4 times the depth. Since the water depth of waters of Dangampo is about 4 m to 10 m, the multi beam echo sounder's swath is about 16 m to 40 m. Therefore, the survey measurement line was set at intervals of 10 m from north to south, and the seafloor was surveyed while going back and forth 7.5 times in the east-west direction.

Survey using scanning sonar

Kongsberg's 1171 model was used by selecting a frequency between 600 kHz and 1200 kHz and the measurement range is 0.5 m to 100 m. In the temporarily designated historical sites, the survey was planned only in the range of 260 m × 180 m. The reason why the entire temporarily designated historical site was not covered was due to the limitation of the survey time. Scanning sonar should be moved and installed several times in order to acquire high-quality data for a certain area and this process is expected to take a lot of time. A method of irradiating a wide range at once by increasing the measurement distance can be considered, but it is not effective because the longer the measurement range, the lower the resolution as the reflectivity of sound waves decreases.

A frequency of 675 kHz was used and the measurement range were set at 30 m and 50 m. As a result of operating the scanning sonar for two days, data could be obtained only from 8 places out of 24 points planned for acquiring data. This is because it took more time than expected to accurately position the scanning sonar at the target point, and the high tide time available for investigation was not long. The scanning sonar survey of the soil removal section was conducted during the soil removal. Data were obtained after placing the transducer adjacent to the soil removal section. A frequency of 675 kHz and a measurement range of 25 m were used.

Results of experiments using maritime geophysical exploration equipment

Results of marine geophysical exploration in survey sea area

In the image acquired by the side scan sonar, the area where the soil removal was conducted was distinguished from the area where soil was not removed or showed clear differences in shade due to the trace of soil removal. Comparing the results obtained with frequencies of 400 kHz and 1250 kHz, only the range of the soil survey section was identified at the frequency of 400 kHz, and it was difficult to check the inside of the soil removal section. On the other hand, at a frequency of 1250 kHz, the changed seabed due to the soil removal could be clearly identified. In the image acquired by the side scan sonar, the overall shape of the soil removal section was distorted rather than straight. This distortion is because the towfish did not maintain constant speed, water depth, direction, etc. in the water. Therefore, in order to obtain high-quality results, it was repeated several times to examine the area around the soil removal section, but it was difficult to obtain an image of an accurate shape.

The multi beam echo sounder survey results showed that the soil survey section had a bumpier appearance than the surrounding seabed, and unlike the side scan sonar results, the overall appearance was straight and not distorted. This is because factors that may cause distortion were corrected through the post-correction process mentioned above. However, the appearance of the inside of soil removal survey section was not expressed as delicately as expected. It is similar to the result of 400 kHz side scan sonar using the same frequency, and the resolution is lower than that of 1250 kHz side scan sonar.

The image acquired by the scanning sonar had little error or distortion in the result even without special post-correction, so it was possible to clearly check the soil removal survey section. Although it was not possible to distinguish $5\text{ m} \times 5\text{ m}$ grid accurately, it was possible to distinguish the $10\text{ m} \times 10\text{ m}$ square initially set up when the grid was installed. In addition, in the survey line shortly after the completion of the earthwork investigation, it was confirmed that the seabed had changed like ridges and furrows due to the soil removal.

Review on results of marine geophysical exploration

In order to use marine geophysical survey equipment for underwater excavation survey, several conditions should be met. First, the changes in seabed caused by soil removal should be clearly identified as soil removal at seabed is conducted for underwater excavation. Next, the error due to distortion must be small. Marine geophysical survey equipment which may cause distortion in the results depending on the characteristics of the equipment, operation method, and surrounding environment and severe distortion makes it difficult to check soil removal survey area. Being able to check the results quickly is helpful for survey. Considering these conditions, as a result of reviewing three exploration equipment operated in waters of Dangampo, it was judged that the scanning sonar was the most suitable for the underwater excavation survey record.

In the case of the side scan sonar, as it is found in the survey, it can survey a wide range in a short time, and when using a frequency of 1250 kHz, it showed high resolution for the soil removal section. However, repetitive surveys were required to obtain high-quality results, distortions frequently occurred during the survey process and correction was not easy.

Since the multi beam echo sounder provides 3D images, it is effective in checking the seabed topography over a wide range, and has the advantage that distortion is hardly visible in the soil removal section. However, it was not suitable for recording the soil removal section due to its low resolution compared to other exploration equipment, and it took a relatively long time to obtain the result because it had to go through post-correction.

The scanning sonar showed good resolution for the soil removal section and was effective in recording the soil removal section with little distortion without special post-correction. This is because, unlike the previous two exploration equipment, it is fixed on the seabed to acquire data, and there are few factors that can adversely affect the results except for tide. However, the scanning sonar had the disadvantage of requiring a lot of time to investigate a wide range.

Usage of scanning sonar for underwater excavation in turbid and wide range

The experiment conducted in waters of Dangampo, Taean concluded that the scanning sonar is suitable for recording the soil removal section. However, since the waters of Dangampo had a relatively good underwater visibility, it was necessary to check whether it was possible to make a record using a scanning sonar in turbid water. To this end, the scanning sonar was operated in the underwater excavation of Nakweoldo, Yeonggwang and Myeongryangdaechepro, Jindo.

Survey using scanning sonar in waters of Nakweoldo , Yeonggwang

In an experiment conducted in waters of Dangampo, it was difficult for the scanning sonar to investigate a wide range due to limited time. In the second underwater excavation survey in Dangampo, it was possible to create a single image by connecting three scanning stations or data. This means that with enough time, one large scanning station or image can be produced over a wide area. If the change of the seabed is recorded after the completion of the excavation, it is very likely the seabed changed from the time of investigation, such as reburial of the soil removal section investigated in the early stage of the excavation. Therefore, it is more effective to record seabed changes from time to time during the survey process and connect them.

The frequency used was 675 kHz, and the measurement distance was 50 m. In addition, 11 data acquired from each point were connected to create a single image of the seabed in Area A. Finally, a grid was drawn on this image to create an excavation survey plan (Figure 1).

Waters of Myeongnyangdaechepro, Jindo survey using scanning sonar

In waters of Myeongnyangdaechepro, a reflector was installed on the seabed to accurately connect multiple sonar images. The reflector was made in a hemispherical shape with a diameter of 20 cm by referring to the shape of a radar reflector used in ships, and was attached to the handle of a probe rod to

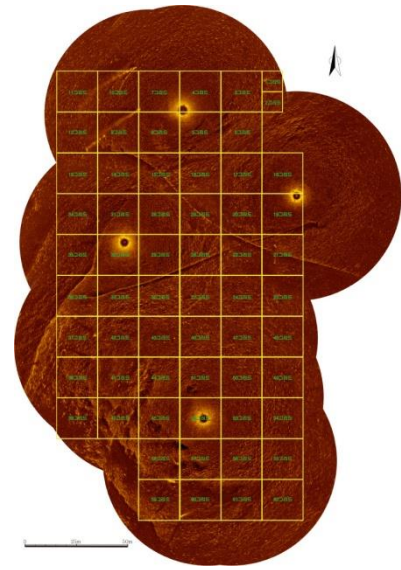


Figure 1. Mosaic image of scanning sonar for Area A of underwater excavation of waters of Nakweoldo, Yeonggwang

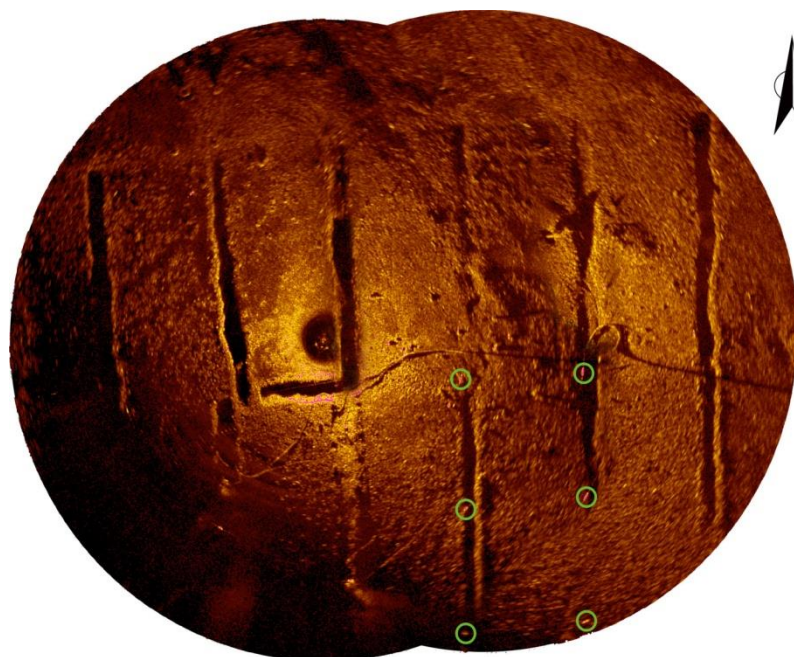


Figure 2. Mosaic image using reflector (frequency 675 kHz, measurement range 25 m, ○ reflector)

be fixed to the seabed. Reflectors (small circles in image) were placed at 10 m intervals along the prospecting trench (figure 2), and the height from the seabed to the reflectors was about 50 cm. The scanning sonar was operated down from the barge to the seabed, and the seabed was repeatedly surveyed. The frequency was 675 kHz and the measurement range was between 25 m and 40 m. The sonar images obtained from Myeongnyangdaechoepo show that the point where the reflector is installed reflected sound waves more strongly than the surroundings. Reflectors are identified in the scanning sonar images so multiple sonar images could be easily attached using the reflector as a reference point.

In this way, sonar images were prepared for the entire survey area of the sixth underwater excavation survey in the waters of Myeongnyangdaechoepo, Jindo. It is shown that going further south, the trenches are installed slightly tilted to the west. This is different from at the time of diving investigation when it was understood the trench was installed due south. In other words, understanding of the survey site can be improved by using a scanning sonar in an environment where it is difficult to check the survey status due to turbid underwater vision. In addition, as the data obtained along with the installation of the trench was attached, rather than operating the scanning sonar after the completion of the prospective excavation, the north side of the trench cleared at the beginning of the excavation was also recorded as it was at the time of the investigation.

CONCLUSIONS

In the archaeological excavation, the most important thing is the record. However, it is hard to make record due to environmental constraints in the underwater excavation.

This paper examines the method of recording underwater excavations by using marine geophysical exploration equipment that uses sound waves to overcome such limitations. Generally, higher resolution is expected in case of using high frequency sound wave compared to low frequency, but it makes measurable distance shorter. The way of operating exploration equipment could lead to different results. In underwater excavation survey in 2017 at waters of Dangampo, Taean, side scan sonar, multi-beam echo sounder, and scanning sonar results were compared. Upon using frequency of 1250 kHz, side scan sonar showed relatively high resolution but distortion in results due to variables that occur in the operation process. In addition, multi beam echo sounder was not easy to record soil removal due to poor resolution. Lastly, scanning sonar showed soil removal section relatively clearly without significant distortion. This is because factors that could impact the result except for tide were little thanks to operation type fixed to the seabed. However, the results were distorted due to variables that occurred during the operation process. In addition, the multi-beam echo sounder had a low resolution and was not easy to record soil surveys. Lastly, the scanning sonar relatively clearly showed the survey section without major distortion. This is because there are few factors that affect the outcome other than tides due to the operation method fixed to the seabed.

This study began with the idea that using sound waves to record information in turbid water could be effective. However, the experiment conducted in this paper has a limitation in that all of them were aimed at places where underwater heritage is scattered over a wide area. While the distribution area of artifacts is wide, the area where ancient/historical shipwreck is located is relatively narrow, so a study is needed to prepare for the case where such shipwrecks are discovered in an environment where measurement or taking photo are difficult like the case of Sinan shipwreck. For example, the way of utilizing ultrasound cameras or 3D scanning equipment can be considered. I hope that continuous research on underwater archaeological recording methods will be conducted to develop various survey methods that can overcome adverse conditions in the future.

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