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MAINTENANCE TECHNOLOGY OF WAVE-DISSIPATING WORKS USING 3-D DATA

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Mots-clés : Ouvrages de dissipation des vagues, blocs de dissipation des vagues, Tétrapode, données 3D, TIC, drone

1 INTRODUCTION

In Japan, many structures constructed during high economic growth period are now reaching the end of working life. In addition, typhoons, which are becoming larger and of which tracks are changing due to global warming, frequently causes external forces that exceed design conditions. For those reasons, the maintenance of public facilities is important due to the aging of structures and the increasing severity of disasters. On the other hand, productivity improvement in the construction field has also become an important issue because the working-age population is decreasing. In these regards, the utilisation of Information and Communication Technology (ICT) and 3-D data is expected to contribute to labour-saving and productivity improvement in construction work. The Ministry of Land, Infrastructure, Transport and Tourism (hereafter referred to as 'MLIT') is therefore working on an i-Construction policy to make the construction industry more attractive.

In ports, ICT and 3-D data are increasingly used for design, construction, and maintenance in many projects such as dredging, foundation work, main body work, and block installation work. For example, ICT is introduced in surveying and construction management, and 3-D data in design and maintenance of port facilities [National Institute for Land and Infrastructure Management, 2018]. However, that is not the case for wave-dissipating works because wave-dissipating blocks are installed randomly and in a complicated fashion.

Therefore, we have investigated the utilization of ICT and 3-D data in wave-dissipating works. This paper presents examples of maintenance methods for wave-dissipating works using 3-D data.

2 UAV SURVEYING ON WAVE-DISSIPATING WORKS

3-D surveying on wave-dissipating works using an Unmanned Aerial Vehicle (UAV) (hereafter referred to as 'UAV surveying') was carried out. The main purpose of the UAV surveying was to visually and quantitatively understand the condition of the wave-dissipating works. As the UAV surveying gives three-dimensional views of the wave dissipating works, it is possible to draw a cross-sectional profile at any location on it. Quantitative analysis gives the degree of deterioration by using the crown height, amount of subsidence, area of subsidence, volume of subsidence, etc.

One of the advantages of UAV surveying is it provides safer and swifter field work than in the conventional method (see Figure 2). This results in labour-saving. The UAV surveying of wave-dissipating works is conducted in the following steps: (i) planning of field works including flight setting; (ii) installation and coordinate measurement of Ground Control Points (GCPs); (iii) continuous photographing by UAV; (iv) analysis of the GCP coordinates; (v) creation of point cloud data; (vi) making of cross-sectional profiles and composite images; and (vii) conversion to Digital Surface Model (DSM). Among these steps, (ii) and (iii) are done in the field, while the rest are done on a tablet or PC.

Figure 1 shows the 3-D point cloud data of a 2.5 km-long breakwater A, surveying time of which at the site was about 4 hours. Figure 2 gives the schematic image of the conventional method for measuring the crown height of the wave-dissipating works. The measurement is made with a level staff by a pair of workers; one standing on the caisson and the another on the blocks. Usually, the measurement is conducted at places where subsidence is heavy. The time required for the measurement of the same breakwater by the conventional method would be about a week.

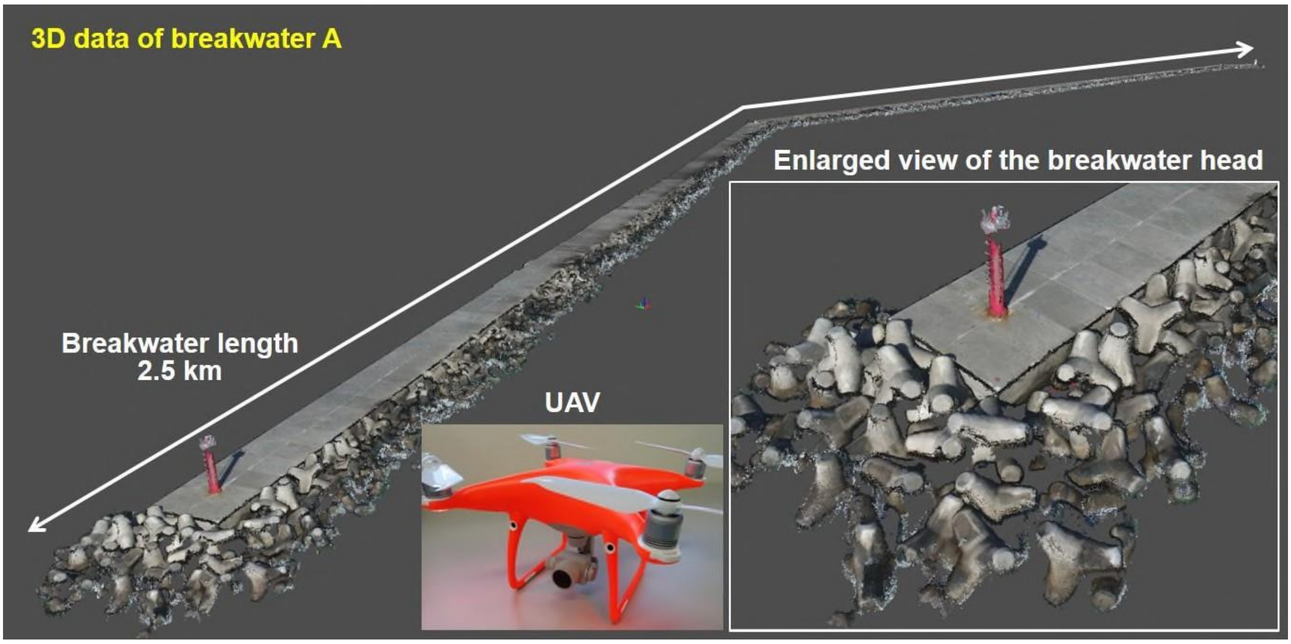


Figure 1: Example of 3-D data using UAV

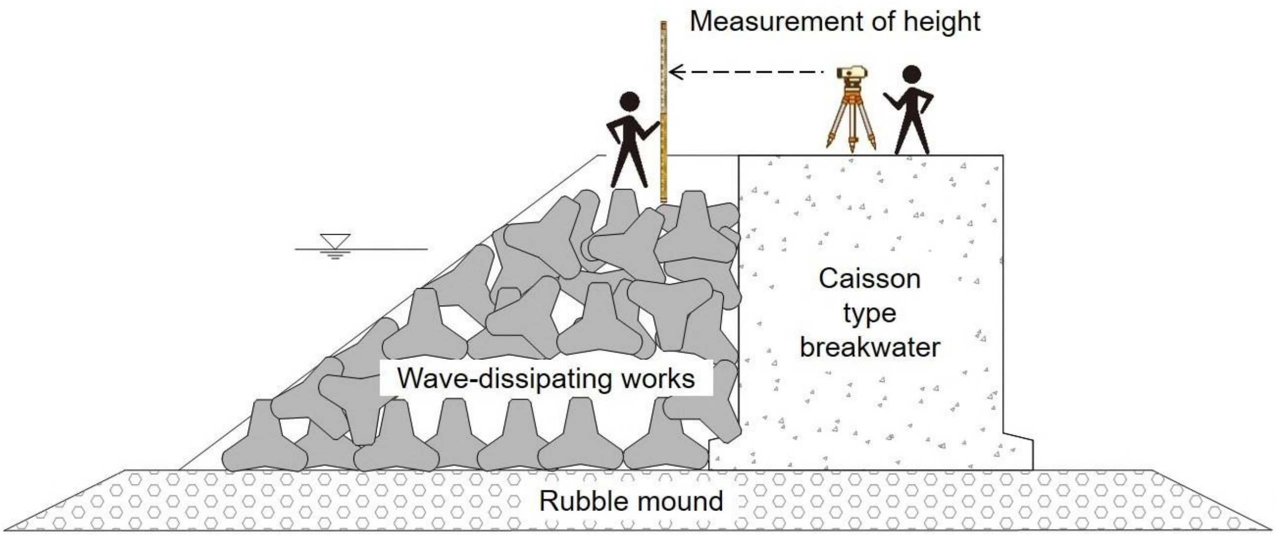


Figure 2: Conventional surveying method in wave-dissipating works

3 EVALUATION OF DETERIORATION OF WAVE-DISSIPATING WORKS

6.1 Technical Guideline for Port Facilities Maintenance

The Japanese guideline [MLIT, 2021] specifies the general rules of maintenance through periodic inspection and diagnosis for port facilities. Table 1 shows the deterioration criteria of wave- dissipating works. The items to be inspected are: ‘movement, scattering and subsidence’, and ‘damage and cracks’. All of these are visually inspected.

Target facilities	Inspection items		Inspection methods	Judgment criteria for deterioration degree	
Caisson type breakwater	Wave-dissipating works	Movement Scattering Subsidence	Visual inspection ・Deformation of crown, slope, shoulder, etc. of wave-dissipating works ・Movement and scattering of wave-dissipating blocks	a	The cross-section of the wave-dissipating works was reduced by more than one layer thickness of block.
				b	The cross-section of the wave-dissipating works was reduced by less than one layer thickness of block.
				c	Some wave-dissipating blocks had moved, scattered or subsided.
				d	No deformation.
		Damage Cracks	Visual inspection ・Damage and cracks of wave-dissipating blocks ・Number of broken blocks	a	More than 25 % of the blocks were damaged.
				b	Damages between a and c.
				c	Some wave-dissipating blocks were damaged.
				d	No damage.

Table 1: Judgment criteria for the degree of deterioration in wave-dissipating works (modified after MLIT (2021))

6.2 An Example of Deterioration Degree Judgment by 3-D Data

According to the criteria shown in Table 1, an evaluation method for the deterioration of wave- dissipating works using 3-D data was examined. In this paper, the inspection items focused on are the subsidence of wave-dissipating works and the damage to blocks.

For the subsidence of wave-dissipating works, the distance from the designed crown height to the observed height was calculated as the subsidence amount by using 3-D data. Figure 3 shows the result of the 3-D data analysis: observed (blue line) and designed (yellow line) crown heights are drawn in the longitudinal direction. The area enclosed by the two lines was calculated as the subsidence area (pink shaded area). Then, the average subsidence amount (red line) was calculated by dividing the subsidence area by the section length. This sequence of work was repeated for each section of the entire length.

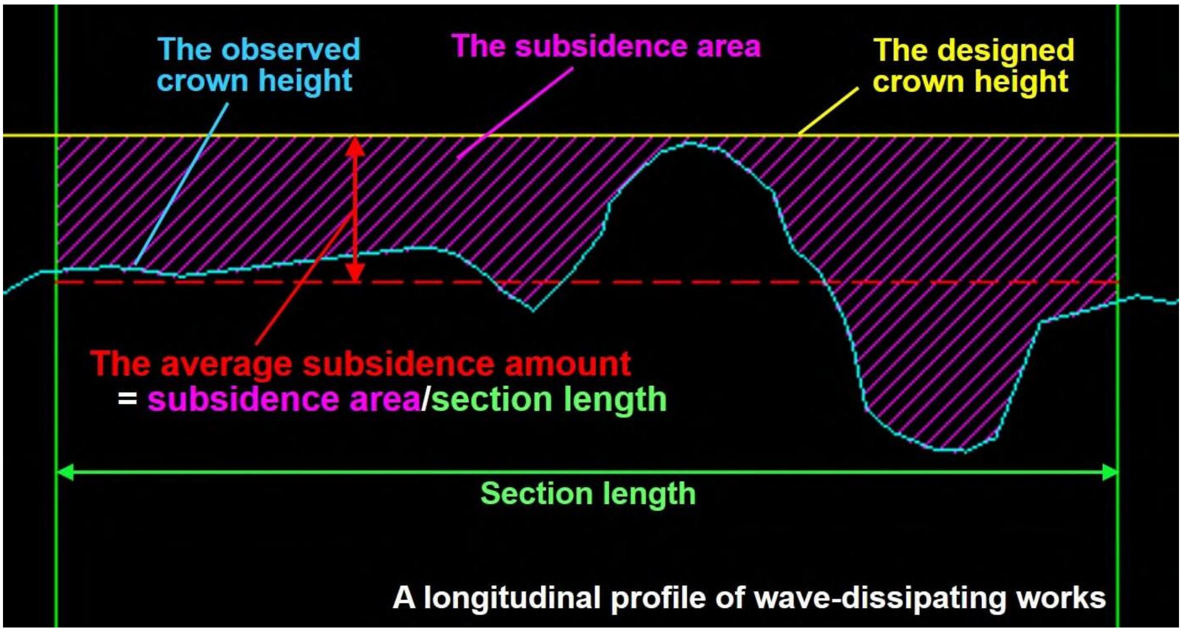


Figure 3: Subsidence amount calculation

For damage to blocks, the number of broken blocks was visually counted using a composite image (orthoimage) and the 3-D data are as shown in Figure 4.

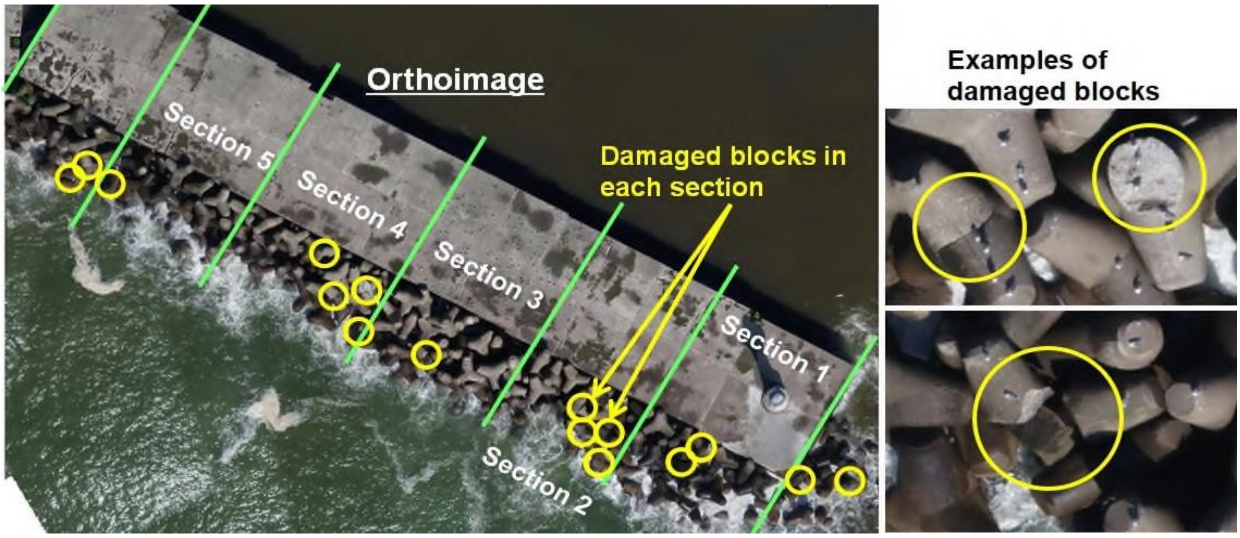


Figure 4: Counting damaged blocks

Table 2 shows an example of the evaluation on deterioration extent on a wave-dissipating works using the above mentioned method. The degree of deterioration (a, b, c and d) in wave-dissipating works is judged by applying the average subsidence amount and the number of damaged blocks to the criteria in Table 1. However, Table 1 does not provide specific values of criteria for subsidence and block damage, therefore a set of new judgment criteria is provided as shown in Table 3. While the conventional surveying method (Figure 2) can only provide the condition of certain sections, or a limited range of the wave-dissipating works, our method can continuously and precisely provide for the condition of the entire wave-dissipating works.

Inspection items		Inspection results																					
		Section No.												Totalization									
														a		b		c		d		Total	
		1	2	3	4	5	6	7	8	9	10	···	30	Count	Ratio	Count	Ratio	Count	Ratio	Count	Ratio	Count	Ratio
Wave-dissipating works	Subsidence	b	a	c	b	b	c	c	b	c	a	···	c	2	0.067	11	0.367	17	0.567	0	0.000	30	1
	Damage	c	b	a	c	c	c	b	c	c	c	···	b	1	0.033	7	0.233	19	0.633	3	0.100	30	1

Table 2: Example of the evaluation on deterioration extent on a wave-dissipating works using 3-D data

Degree of deterioration	Subsidence amount d_s (l : Half the length of two layers of blocks)	Number of damage blocks n (N : Total number above the sea level)
a	$l \leq d_s$	$N/4 \leq n$
b	$0.5\,l \leq d_s < l$	$N/8 \leq n < N/4$
c	$0.1\,l \leq d_s < 0.5\,l$	$1 \leq n < N/8$
d	$d_s < 0.1\,l$	0

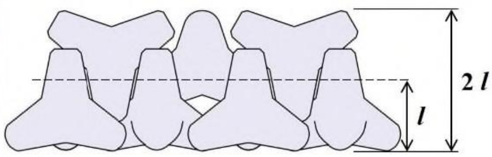


Table 3: New judgment criteria for the degree of deterioration in wave-dissipating works

4 CALCULATION OF REPLENISHMENT QUANTITY

6.3 Calculation Method of Block Replenishment Quantity

When a wave-dissipating works has subsided due to wave action, blocks may be replenished as a maintenance project. In such cases, the shortage of blocks relative to the design quantity is generally calculated using the average cross-section method (Method 1). In Method 1, the replenishment area of each cross section is calculated by subtracting the existing cross-sectional area from the design cross section. Then, the replenishment volume is calculated by multiplying the average of the replenishment areas of the two adjacent cross sections by the section extension, and this is converted to the number of blocks. This process is repeated for each section. However, the longer the length of the wave-dissipating works, the more the number of the cross-sectional profiles, which results in an increase of time and effort required for calculation.

Therefore, a method for calculating the number of wave-dissipating blocks by using 3-D data (Method 2) was examined. Figure 5 shows the calculation image for Method 2. First, the volume of the existing wave-dissipating works was directly calculated by using 3-D data (Ve). Then, the replenishment volume (volume shortage) was obtained by subtracting Ve from the volume of the designed wave-dissipating works (Vd). Finally, the number of blocks required was calculated by converting for the replenishment volume.

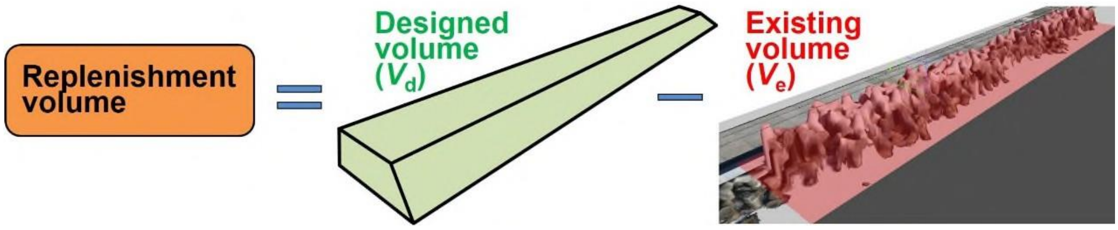


Figure 5: Calculation of the replenishment volume by Method 2.

6.4 Verification of the Method 2 for Replenishment Volume Calculation

The verification was conducted by calculating the replenishment volume at a section 30 m long using Method 1 and Method 2. The work time for each method was also measured.

In Method 1, cross-sectional profiles were created from 3-D data at intervals of 5 m (7 cross sections) and 15 m (3 cross sections) (Figure 6).

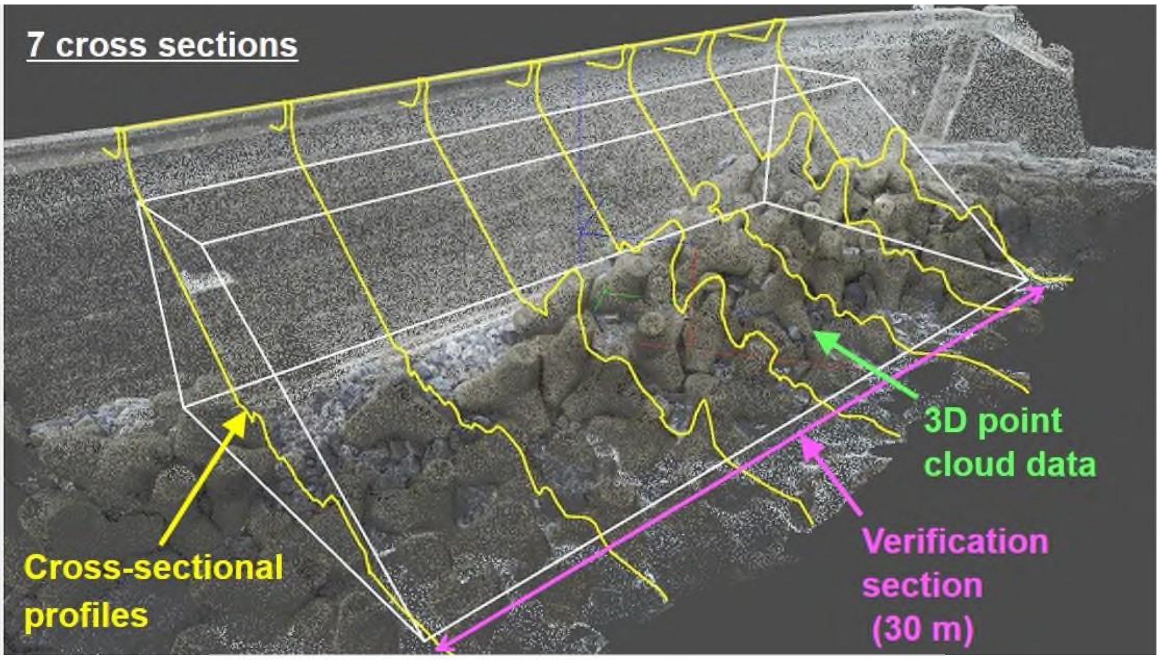


Figure 6: Cross-sectional profiles for Method 1

Then the replenishment area of each cross section was obtained as the difference between the existing and the design cross-sectional areas. The replenishment volume was calculated by multiplying the average of the replenishment areas of the two adjacent cross sections by the interval length (15 m and 5 m).

As explained in Figure 5, Method 2 provides the replenishment volume of the wave-dissipating works as the difference between the 3-D design data (the blue trapezoidal shape in Figure 7) and the existing data (the red area in Figure 7) [Noboru et al., 2018].

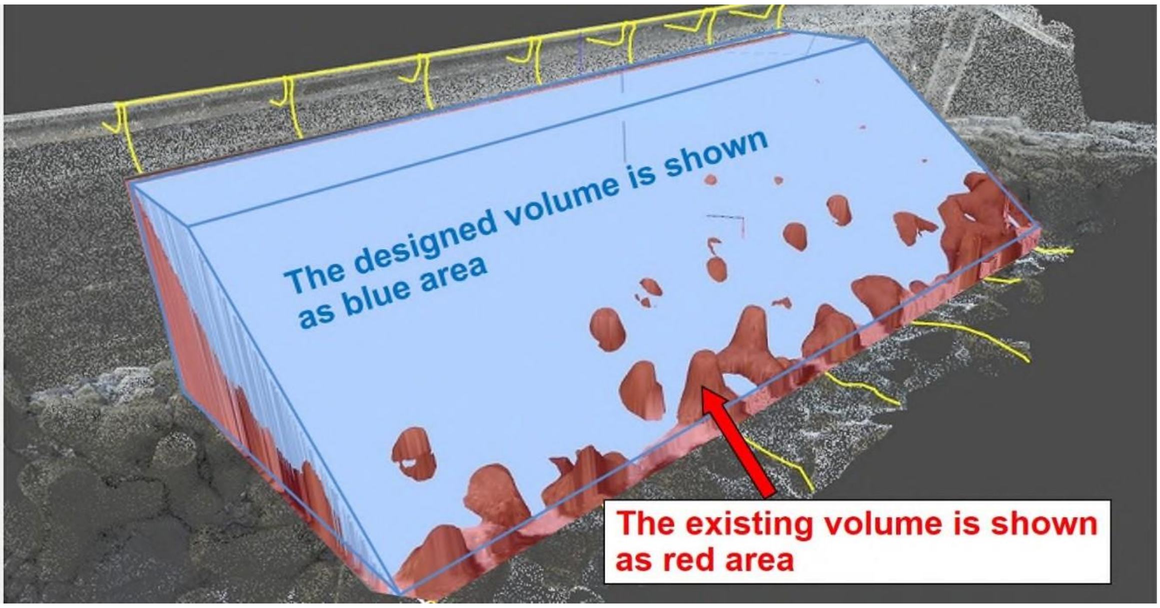


Figure 7: Example of calculation of the replenishment volume by difference (Method 2)

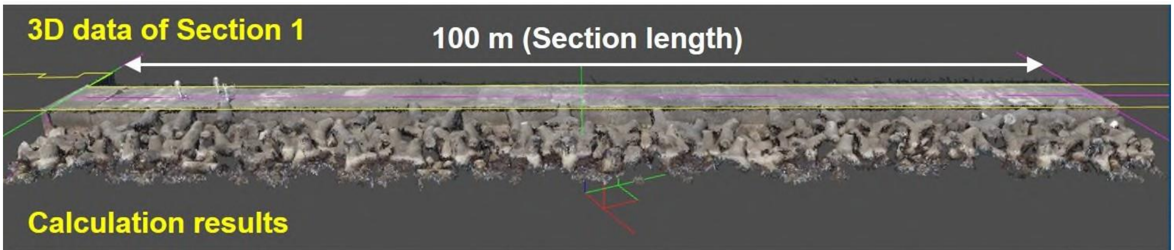
The results are shown in Table 4. The volume calculated and the time required for each case are compared as the ratio against the results of Method 1 with 3 cross sections (15 m intervals). The volumes calculated are larger in the order of Method 2, Method 1 with 7 cross sections, and Method 1 with 3 cross sections. This can be attributed to the fact that Method 2 reflects the unevenness of the blocks in detail, resulting in higher accuracy. As for the time required for Method 1, the calculation time is longer when the number of cross sections is larger. On the other hand, Method 2 enables the calculation of the existing volume in a shorter time than Method 1, and it is clear that the calculation time is significantly shorter if the design volume is obtained in advance.

Calculation methods		Ratio of calculated volumes (%)	Ratio of time (%)
Method 1	3 cross sections	100	100
	7 cross sections	101.6	200
Method 2		102.3	26.0

Table 4: Calculation results of replenishment volume

Next, Method 2 was applied to a wave-dissipating works of 1.5 km long to measure calculation time. The site was divided into 15 sections of 100 m length and the replenishment volume of each section and time required for the calculation were measured. Figure 8 shows the results. The calculation time required for the entire length (1.5 km) was about 4 hours (about 15 minutes per section).

The accuracy of the 3-D data used is high as the data obtained by UAV surveying are corrected by GCPs. Therefore, the volume of the existing wave-dissipating works in Method 2 is considered to be calculated accurately. However, as Method 2 precisely took into calculation the unevenness of the shape of the existing wave-dissipating works, the volume obtained by Method 2 may have some errors compared with the actual replenishment volume. The verification of its accuracy will be described in the next chapter.



	Section 1	Section 2	···	Section 15	Total
The designed volume (m^3)	1890.4	1890.4	···	1511.4	
The existing volume (m^3)	1109.93	982.04	···	1113.17	
The replenishment volume (m^3)	780.47	908.36	···	398.24	
Calculation time (min)	15	15	···	15	240

Figure 8: Examples of 3-D data and calculation results

5 ACCURACY VERIFICATION OF METHOD 2 FOR REPLENISHMENT VOLUME CALCULATION

The factors which affect the accuracy of the calculation of replenishment volume are considered to be surface irregularity, structure type and block size. In this chapter, the calculation accuracy of Method 2 is examined by focusing on the surface irregularity of a wave-dissipating works.

6.5 Verification Method

The verification was carried out using 1/70 model (numbers used in Figure 9 and Figure 10 are converted to actual size), in the following steps: (i) the volume of a prism with two trapezoidal bases which represents a wave-dissipating works (hereinafter referred to as the trapezoidal volume V_t) and the required number of blocks to fill in V_t were obtained as shown in Figure 9; (ii) a trapezoidal-type wave-dissipating works was reproduced by piling up 156 mortar block models as shown in Figure 10; (iii) the point cloud data were obtained by 3-D hand scanner as shown in Figure 11 and converted to the actual size; (iv) Digital Surface Model (DSM) data were created from the point cloud data using analysis software; (v) the volume considering the unevenness of the wave-dissipating works was directly calculated using the DSM data (hereinafter referred to as the calculated volume V_c) as shown in Figure 12; (vi) the trapezoidal volume V_t and the calculated volume V_c were compared.

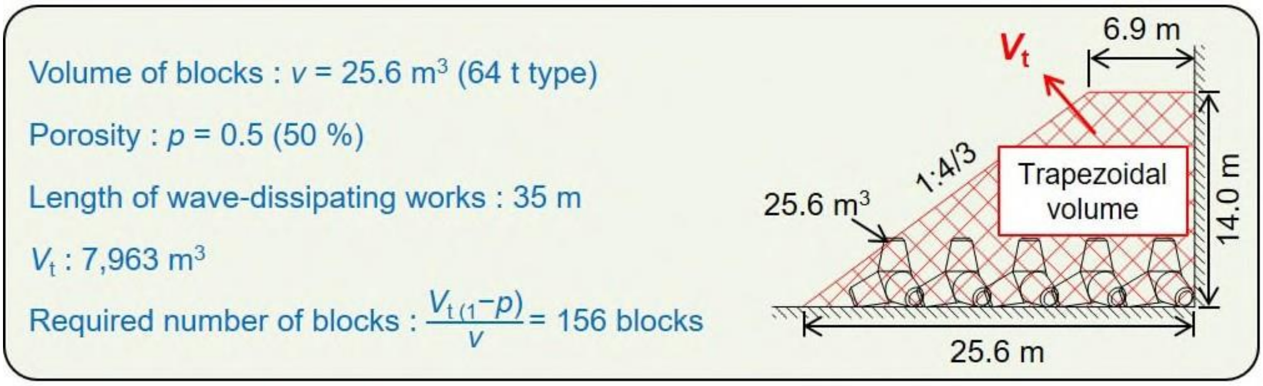


Figure 9: Specifications of wave-dissipating works

Figure 10: Reproduction of a trapezoidal-type wave-dissipating works

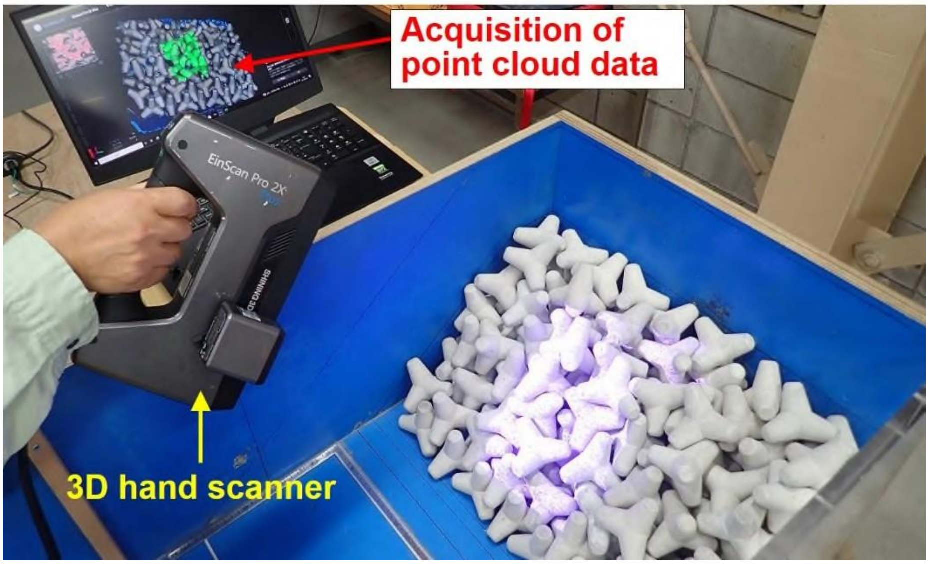


Figure 11: Acquisition of point cloud data using a 3-D hand scanner

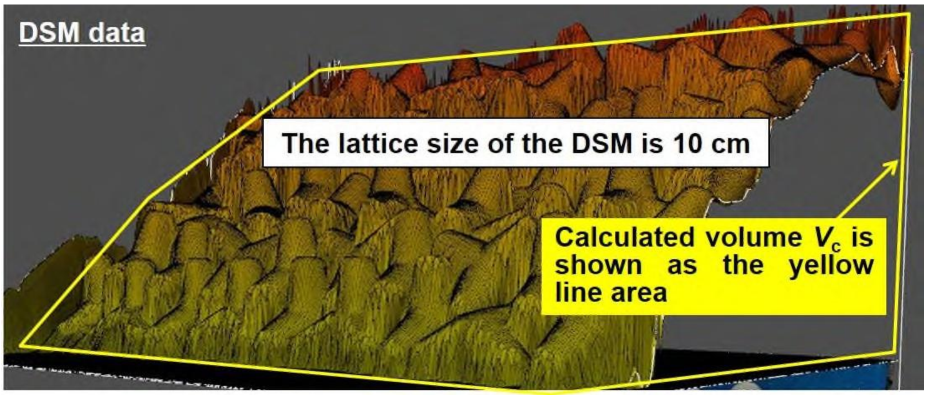


Figure 12: Calculation of the volume of wave-dissipating works using DSM data

In order to examine the effect of the difference in the reproducibility of unevenness on the calculated volume, 6 sets of lattice size of the DSM were set as shown in the upper row of Table 5

Lattice size of the DSM (cm)	5	10	14	20	30	50
Point density D_p (number of point/m^2)	400	100	51	25	11	4
Reproducibility of unevenness of wave-dissipating works	high ⇔ low					

Table 5: Lattice size and point density of DSM

for analytical purposes. The point density D_p in the lower row is described later. Figure 13 shows some examples of DSM data for each lattice size. The calculation was made 10 times for each set.

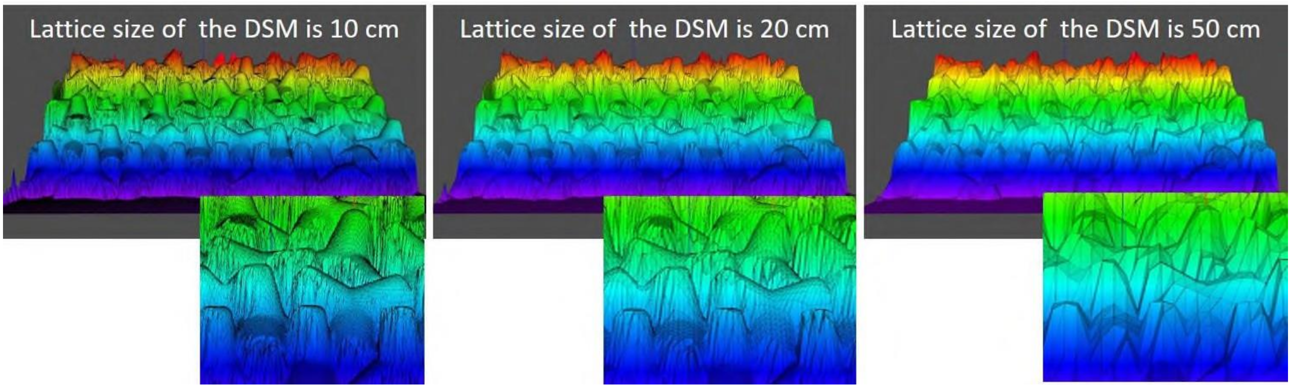


Figure 13: Examples of DSM data for each lattice size

6.6 The Effect of Lattice Size on the Calculated Volume in Wave-Dissipating Works

Figure 14 shows the results of the examination: lattice size of the DSM on the horizontal axis and the ratio of Vc to Vt on the vertical axis (hereafter referred to as the volume ratio). The volume ratios, tending to decrease as the lattice size increase, are less than 1 for all cases. This may be attributed to the effect of the unevenness of the surface as shown in Figure 15.

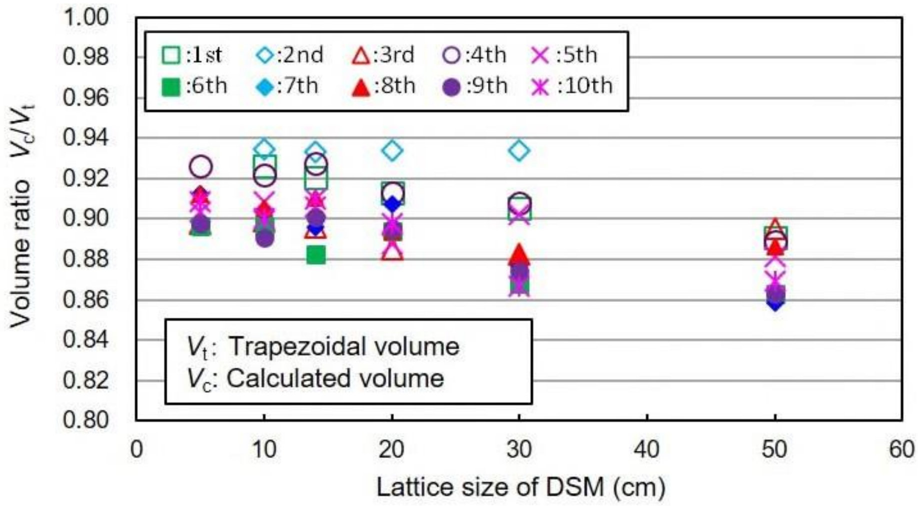


Figure 14: Relationship of volume ratio to lattice size of DSM

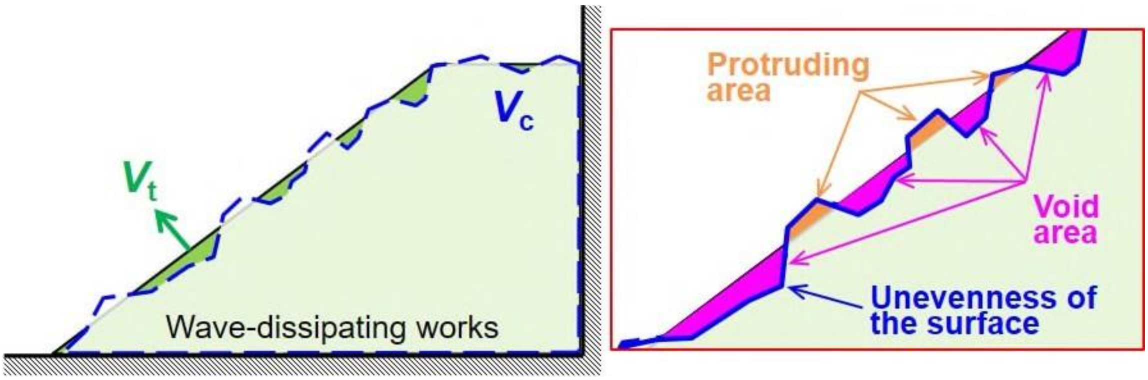


Figure 15: Schematic image of the surface of wave-dissipating works

6.7 A Formula for Replenishment Volume Calculation Considering Surface Irregularity

The coefficient that makes the calculated volume Vc equal to the trapezoidal volume Vt is α1(=Vt/Vc), and the relationship of α1 to the point density Dp (number of point/m^2) is shown in Figure 16. Here, the point density Dp is converted from the lattice size of DSM to the number of points per square meter (Figure 17), and the relationship between the lattice size and the point density Dp is shown in Table 5. In Figure 16, the black cross marks indicate α1, and the red circles are the average value of α1 at each point density Dp. The coefficient α1 has a decreasing trend in the range of 4 ≤ Dp < 50 and is almost constant for Dp ≥ 50. Therefore, the average value of α1 can be formulated as Equation (1).

$$\alpha_1 = \begin{cases} 1.16 D_p^{-0.013} & (4 \le D_p < 50) \\ 1.10 & (D_p \ge 50) \end{cases} \tag{1}$$

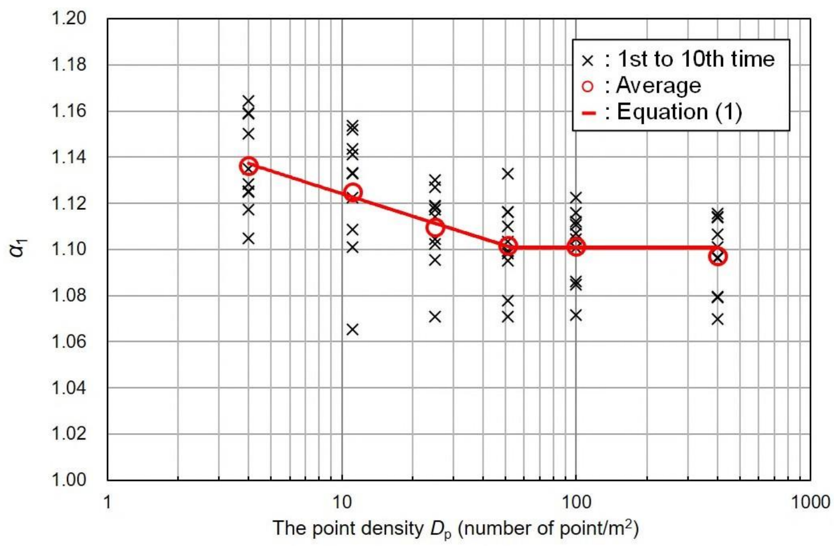


Figure 16: Relationship of α1 to the point density

Figure 18 shows the schematic image of volume calculation of the wave-dissipating works after replenishment. The replenishment volume V_r in a wave-dissipating works is calculated by the difference between the design volume V_d and the existing volume V_e obtained by Method 2 (=V_c). However, it was found that V_c is affected by the surface irregularity of the wave-dissipating works. Therefore, the corrected volume V', taking into account the effect by surface irregularity, can be formulated as Equation (2). This Equation (2) can calculate the number of blocks from 3-D data accurately and efficiently.

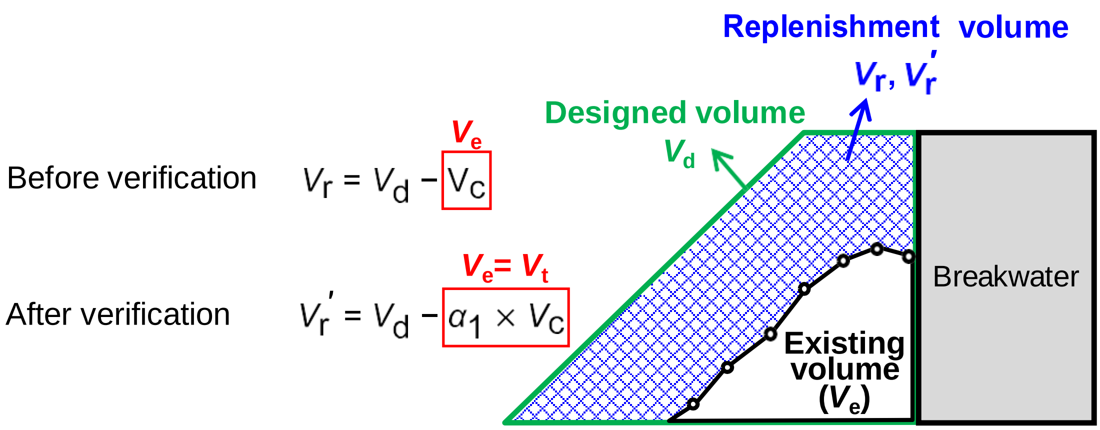


Figure 18: Volume calculation of the wave-dissipating works after replenishment

$$V_{r'} = V_d - a_1 \times V_C \quad (2)$$

The remaining factors, which may affect the accuracy, such as the shape and size of the blocks and cross-sectional shape of the wave-dissipating works will be examined in the future.

6 MODELING OF WAVE-DISSIPATING WORKS

In recent years, Building/ Construction Information Modelling, Management (BIM/CIM) has been introduced in Japan in order to improve the efficiency and the productivity of projects by sharing 3-D model information of structures at each phase of surveying, design, construction, and maintenance [Japan Federation of Construction Contractors, 2019]. A 3-D model of a target structure in BIM/CIM has the design and construction information (attribute information) assigned to each member of the structure. So far, this is not the case for wave-dissipating works. Individual blocks are not distinguished nor handled independently.

Therefore, a set of software that automatically arranges and installs the 3-D data of individual blocks on the data of an entire wave-dissipating works has been developed, aiming to sophisticate the design, construction, and maintenance of wave-dissipating works. The following is a brief explanation.

6.8 Creation Method of 3-D Model of Wave-Dissipating Works

A 3-D model of wave-dissipating works can be created automatically using Software A and Software B. Importantly, the model is produced as a solid model and provides attributable information on each block.

Software A automatically arranges a 3-D model of a block to match the responding point cloud data of the current condition. By using this, the existing condition of wave dissipating works can be faithfully reproduced, as is the case for completed conditions after replenishment. For example, a model block can be placed to match the exact place and posture by selecting and specifying a specific part in the point cloud data as a reference (Figure 19). Figure 20 shows an example of 3-D modelling of a wave-dissipating works with Software A. The minimum time for automatic placement is about one minute per block. The accuracy of the placement is generally within the gap of 3 % of the block height between the point cloud data and the surface of the model.

Software B can create a model of randomly installed wave-dissipating works by free-falling 3-D models of individual blocks, as shown in Figure 21. Modelling time is usually within one hour (generally for 100 blocks). It is also possible to place new block models on the imported 3-D current data. Therefore, Software B can be expected to be used for construction planning in new and replenishment projects for wave-dissipating works.

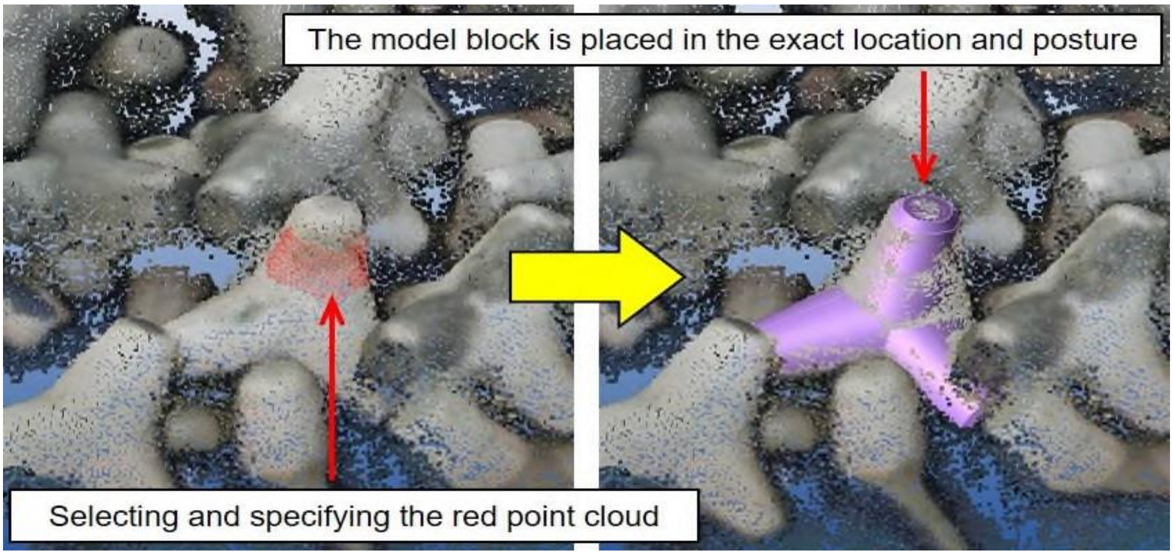


Figure 19: Placement of the model block in point cloud data

Figure 20: Modeling of wave-dissipating works (Software A)

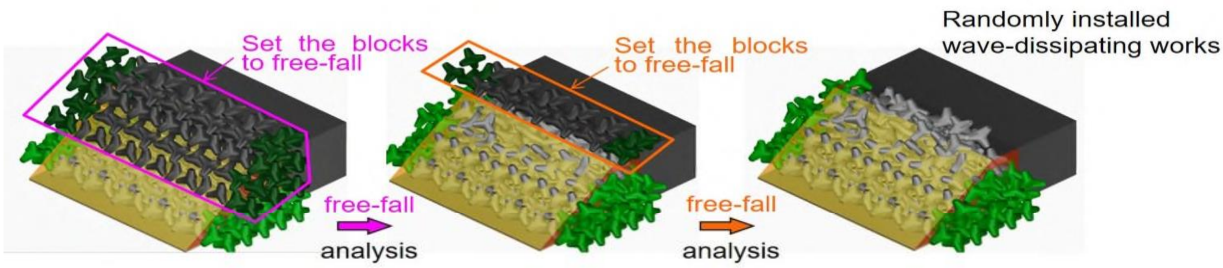


Figure 21: Random installation of model blocks by Software B

6.9 Application of Modelling Data to Installation and Maintenance of Wave-Dissipating Works

In the modelling of wave-dissipating works by Software A and Software B, models are reproduced posture can be obtained. Using these data, it will be possible to sophisticate the construction and maintenance of wave-dissipating works.

In construction, block installation is conducted by the crane operator following instructions given by divers, and this is unsafe and time consuming. With the 3-D modelling, the crane operation becomes safer and more efficient as the operator can check on the management screen for the target position (centre of gravity) and direction of each block, as shown in Figure 22.2

Figure 22: Installation at the target position guided by the management screen

In maintenance, the modelling data on the completion conditions of a wave-dissipating works include information on the initial condition of each block. Comparison before and after a disaster as well as age deterioration can be quantified. In the case of modelling the existing conditions, it is possible to faithfully reproduce the wave-dissipating works at the site. This allows a detailed installation plan for the blocks to be replenished. Furthermore, the modelling data on the blocks can provide use for BIM/CIM in a replenishment project of the wave-dissipating works.

7 CONCLUSIONS

In this study, labour-saving and efficiency improvement by application of 3-D data was studied, mainly on maintenance of wave-dissipating works.

The results are as follows:

- UAV surveying enables safer and swifter field work than the conventional method, resulting in more efficient and labour-saving evaluation of the current condition of wave-dissipating works;
- A method to accurately evaluate the subsidence of wave-dissipating works and the damage conditions of blocks by determining the deterioration degree using 3-D data is presented;
- A method for calculating the replenishment volume of blocks using 3-D data is presented. This was found to be faster and more efficient than the conventional method. Coefficients and equations for more accurate calculations were also proposed based on the results of the verification;
- A method for modelling individual blocks in wave-dissipating works was presented. With the model, it is possible to faithfully reproduce the current conditions and simulate the installation of new blocks to enable more efficient and sophisticated maintenance of the wave-dissipating works.

The authors believe that the results obtained in this paper are an important step forward for the sophistication of maintenance technology in wave-dissipating works. While this paper mainly focused on the wave dissipating works of caisson type breakwaters, the technology is easily applicable to other types of breakwaters such as sloping breakwaters which are widely used in many countries. Some issues remain, however, such as the effects of the structure type, and the shape and size of the block on the number of blocks to be replenished. Also the modelling of individual blocks and its applicability need to be further studied. The authors will continue their technical studies to improve the reliability of the methods presented in this paper.

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SUMMARY

This paper presents some examples of 3-D data application obtained by aerial surveying to the maintenance of wave-dissipating works, aimed at labor saving and productivity improvement. The results are as follows: (i) 3-D surveying of wave dissipating works using UAV enables safer and swifter field work, as well as labour-saving compared to the conventional method; (ii) determining the degree of deterioration using 3-D data gives more accurate and efficient evaluations of wave dissipating works; (iii) a newly proposed calculation method of the replenishment number of wave-dissipating blocks (concrete armour units) by using 3-D data is found to be quicker and more efficient than the conventional method. In addition, since Building/Construction Information Modelling, Management (in Japan, called BIM/CIM) will be introduced to the construction of wave-dissipating works in the near future, a modelling method for individual wave-dissipating blocks (Tetrapods) is studied. By converting point cloud data to a solid model, it is possible to faithfully reproduce individual Tetrapods, and to simulate the place and direction of any new blocks to be installed. This enables more efficient and sophisticated maintenance in wave-dissipating works.

RESUME

Cet article présente quelques exemples d'application de données 3D obtenues par levé aérien à la maintenance des ouvrages de dissipation des vagues, dans le but d'économiser de la main-d'œuvre et d'améliorer la productivité. Les résultats sont les suivants : (i) l'arpentage 3D des ouvrages de dissipation des vagues à l'aide d'un drone permet un travail sur le terrain plus sûr et plus rapide, ainsi qu'une économie de main-d'œuvre par rapport à la méthode conventionnelle ; (ii) la détermination du degré de détérioration à l'aide de données 3D donne des évaluations plus précises et plus efficaces des ouvrages de dissipation des vagues ; (iii) une méthode de calcul nouvellement proposée du nombre de réapprovisionnement des blocs de dissipation des vagues (unités de blindage en béton) en utilisant des données 3D s'avère plus rapide et plus efficace que la méthode conventionnelle. En outre, étant donné que la modélisation et la gestion de l'information du bâtiment et de la construction (appelée BIM/CIM au Japon) seront introduites dans la construction des ouvrages de dissipation des vagues dans un avenir proche, une méthode de modélisation des blocs individuels de dissipation des vagues (tétrapodes) est étudiée. En convertissant les données des nuages de points en un modèle solide, il est possible de reproduire fidèlement les tétrapodes individuels et de simuler l'emplacement et la direction de tout nouveau bloc à installer. Cela permet une maintenance plus efficace et plus sophistiquée des ouvrages de dissipation des vagues.

ZUSAMMENFASSUNG

In diesem Beitrag werden einige Beispiele für die Anwendung von 3D-Daten vorgestellt, die durch Luftvermessung bei der Instandhaltung von Wellenbrechern gewonnen wurden, um Arbeit einzusparen und die Produktivität zu steigern. Die Ergebnisse sind wie folgt: (i) Die 3-D-Vermessung von wellenabführenden Bauwerken mit Hilfe von UAV ermöglicht eine sicherere und schnellere Arbeit vor Ort sowie eine Arbeitsersparnis im Vergleich zur konventionellen Methode; (ii) die Bestimmung des Verschlechterungsgrades mit Hilfe von 3-D-Daten führt zu einer genaueren und effizienteren Bewertung von wellenabführenden Bauwerken; (iii) eine neu vorgeschlagene Berechnungsmethode für die Anzahl der Nachfüllungen von wellenabführenden Blöcken (Betonpanzereinheiten) mit Hilfe von 3-D-Daten erweist sich als schneller und effizienter als die konventionelle Methode. Da in naher Zukunft das Building/Construction Information Modelling, Management (in Japan BIM/CIM genannt) für den Bau von wellenverteilenden Bauwerken eingeführt werden soll, wird außerdem eine Modellierungsmethode für einzelne wellenverteilende Blöcke (Tetrapoden) untersucht. Durch die Umwandlung von Punktwolkendaten in ein Festkörpermodell ist es möglich, einzelne Tetrapoden originalgetreu zu reproduzieren und die Position und Richtung neu zu installierender Blöcke zu simulieren. Dies ermöglicht eine effizientere und ausgefeiltere Wartung von Wellenbrechern.

RESUMEN

Este artículo presenta algunos ejemplos de aplicación de datos tridimensionales obtenidos mediante topografía aérea al mantenimiento de obras de disipación de oleaje, con el fin de ahorrar mano de obra y mejorar la productividad. Los resultados son los siguientes: (i) la medición tridimensional de las obras de disipación de oleaje mediante UAV permite un trabajo de campo más seguro y rápido, así como un ahorro de mano de obra en comparación con el método convencional; (ii) la determinación del grado de deterioro mediante datos tridimensionales da lugar a evaluaciones más precisas y eficientes de las obras de disipación de oleaje; (iii) un método de cálculo recientemente propuesto del número de reposición de los bloques de disipación de oleaje (unidades de blindaje de hormigón) mediante el uso de datos tridimensionales resulta más rápido y eficiente que el método convencional. Además, dado que en un futuro próximo se introducirá en la construcción de obras de disipación de olas la gestión de la información sobre edificios/construcción (en Japón, denominada BIM/CIM), se estudia un método de modelado para bloques individuales de disipación de olas (tetrápodos). Al convertir los datos de la nube de puntos en un modelo sólido, es posible reproducir fielmente los Tetrápodos individuales, y simular el lugar y la dirección de los nuevos bloques que se instalen. Esto permite un mantenimiento más eficaz y sofisticado en las obras de disipación de oleaje.