Disaster Prevention Facilities and Marine Environment Improvement Effect

by

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ABSTRACT

Concrete structures are indispensable for disaster prevention. Nevertheless, its inorganic structure was sometimes pointed out as a symbol of environmental destruction. In Japan, concepts of ecological consideration were incorporated into Environment Basic Act, present River Act and Seacoast Act in the 1990s, and shapes of concrete structures have been modified. However, many of these were mitigations against development activities and consideration for the environment during development. Under these circumstances, the authors have developed SUBPLEO-FRAME (SPF) combining stone material with concrete and Environmentally Active Concrete (EAC) using amino acids, aiming at compatibility between “disaster prevention” and “environmental conservation". In this paper, examples of realizing conservation and improvement of surrounding marine environment while realizing disaster prevention function are introduced.

1. INTRODUCTION

Concrete structures such as breakwaters, revetment and wave-dissipating blocks are indispensable to protect the functions of ports and harbours as well as in terms of disaster prevention. Nevertheless, its inorganic structure was sometimes pointed out as a symbol of environmental destruction. Installing a structure has been often regarded as a confrontation between development and environment since it has a great influence on the animals and plants that exist there conventionally.

In Japan, since in the 1990s, the concepts of ecological consideration were incorporated into Environment Basic Act, present River Act and Seacoast Act, shapes of concrete structures have been improved. In addition, artificial tideland and seaweed bed creation are also being tried. However, most of these activities are not primarily aimed at regeneration or creation of the environment. These were mitigation of environmental influences due to development activities such as effective use of dredged soil and reclamation, and consideration for the environment during development activities. In recent

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years, efforts to further advance these concepts and consider and implement the disaster prevention and the environmental consideration with the same weight have begun. In the Basic Program for the Conservation of the Environment of the Seto Inland Sea 2015 and the Technical Standards for Port and Harbour Facilities in Japan 2018, it is clearly specified that when developing disaster prevention facilities, the environment conservation must be provided.

These trends became clear even from a global standpoint, and ‘17 Sustainable Development Goals (SDGs)’ were established in “The 2030 Agenda for Sustainable Development” adopted at the United Nations Sustainable Development Summit in September 2015. These 17 goals include “Goal 13. Take urgent action to combat climate change and its impacts” and “Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development”. The harmonization between these two goals, that is, development of the construction to achieve both “disaster prevention” and “environmental conservation” is an important key for the realization of a sustainable society.

From this kind of circumstance, our research and development group has developed SUBPLEO-FRAME (Hiraishi et al., 2011 ; Matsushita et al., 2013) combining stone materials with concrete and Environmentally Active Concrete (Sato et al., 2011) using amino acids, aiming at compatibility between disaster prevention and environmental conservation. In this paper, examples of realizing conservation and improvement of surrounding marine environment while realizing disaster prevention function are introduced.

2. EXAMPLES OF SUBPLEO-FRAME COMBINING STONE MATERIALS WITH CONCRETE

2.1 SUBPLEO-FRAME

SUBPLEO-FRAME (hereinafter referred to as SPF) was proposed by Hiraishi et al. (2011) as a new reinforcing method for harbour side of caisson breakwaters against accidental tsunamis and waves (see Fig1). Fig.2 show the image of installation of SPF. It is a simple structure in which concrete frame blocks are installed in the harbour side of breakwater and filling stones are filled into the hole (see Fig.3). The sliding resistance of the caisson breakwater increased by interlocking between filling stones restrained by the frame block and mound stones, which makes it possible to build the resilient structure. Thus far, Matsushita et al. (2013) and Matsushita et al. (2014) have verified the effects on tsunamis and waves by conducting hydraulic model experiments (see Fig.4). The size of SPF is 3.0m long x 3.0m wide x 1.5m high, and the size of the inner frame is 1.8m long x 1.8m wide x 1.5m high. The mass of the single filling stone is around 30kg. Normally, when using stones of around 30kg in the sea, though they will be scattered by overtopping-waves and flows, they can stay there by the restraining effect of the block because the filling stones of SPF are inside the frame block. Also, since there are many voids and roughness on the surface by using stone materials, it is possible to generate the turbulent flow on the surface even if there is only a slight flow in the sea. Therefore, it is difficult for suspended solids such as silt floating in the sea to accumulate, and habitats for various benthos can be created.

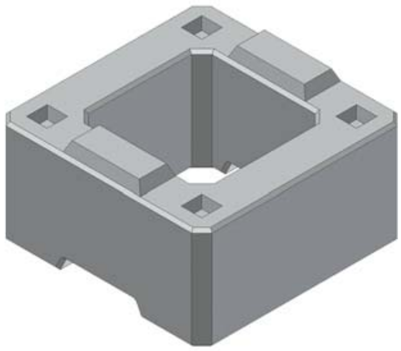


Figure 1 : SUBPLEO-FRAME(SPF)

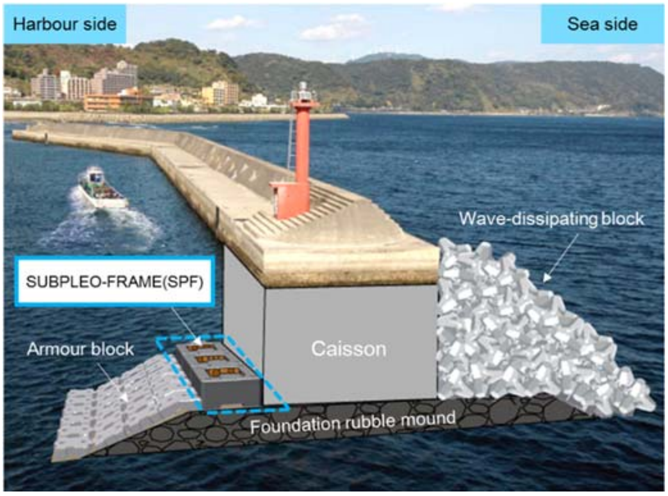


Figure 2 : Installation Image of SPF

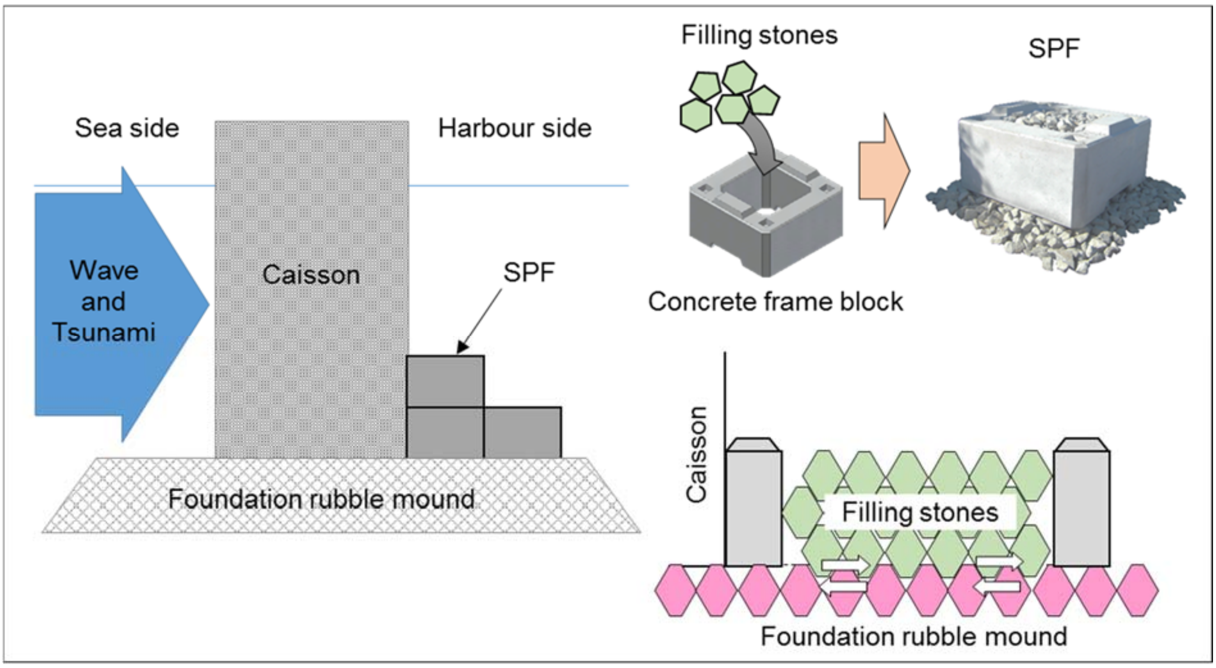


Figure 3 : Structure of SPF

(a) Test against waves in wave basin

(b) Test against Tsunami in wave flume

Figure 4 : Hydlaulic experiment of SPF

2.2 Condition of SPF after the installation in Port of Hachinohe

Port of Hachinohe is a large port located on the Pacific Ocean side of Aomori Prefecture (see Fig.5). The north breakwater was seriously damaged by the Great East Japan Earthquake Tsunami occurred on March 11th, 2011. The breakwater is presumed to have collapsed due to the scouring of the inside the harbour mound caused by the tsunami overtopping discharge along with a lack of sliding resistance of the caisson generated by the force of a huge tsunami. Therefore, SPF was adopted as resilient structure reinforcing the sliding resistant of breakwaters. Fig.6 shows the breakwater immediately after the disaster and after restoration. The SPF is installed in the section of approximately 700 meters inside the harbour of the breakwater. Fig.7 shows an example of a cross-section view. The restoration was completed in June 2013, about five years have passed. In this site, the SPF and foot protection block with flat surface are installed adjacent to each other. The submerged depth of crown of the SPF and the foot protection block is about -7.5 meters, which is a relatively severe condition for the adherence and growth of algae.

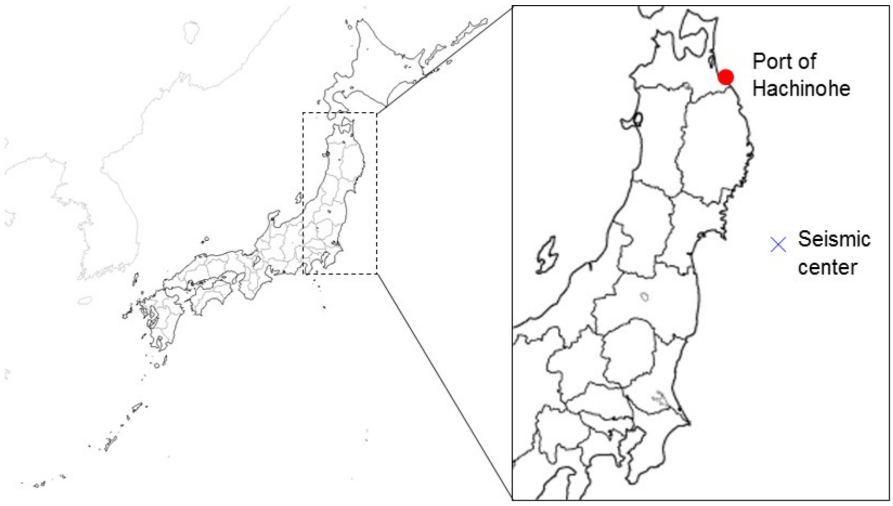
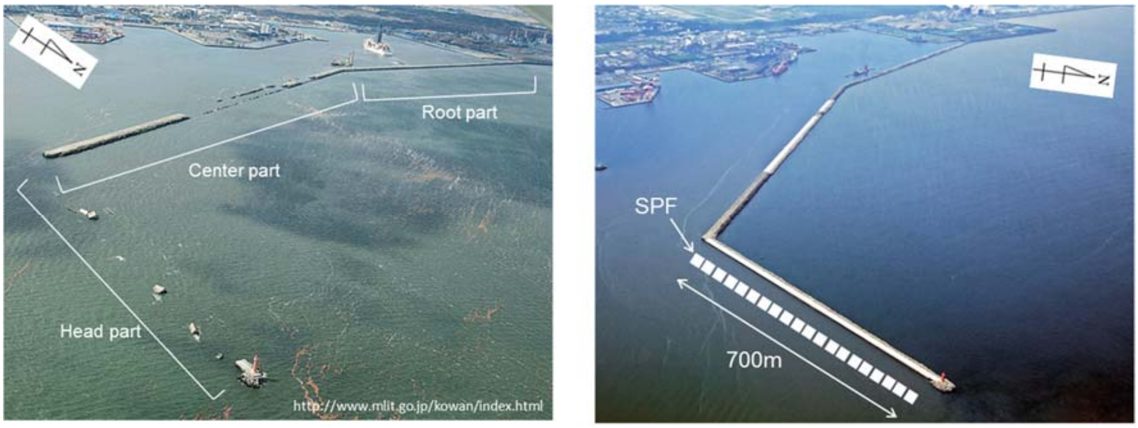


Figure 5 : Location of Port of Hachinohe



(a) Immediately after the disaster (b) After restoration

Figure 6 : Port of Hachinohe breakwater

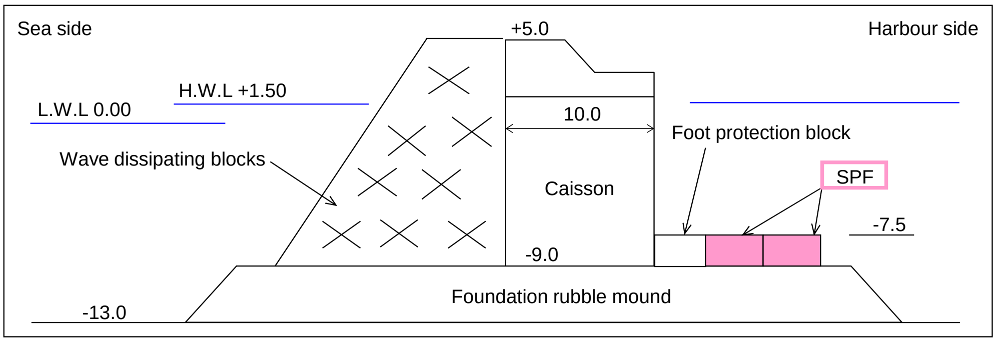


Figure 7 : An example of Cross-section

The monitoring surveys of the condition after the installation of the SPF and the foot protection block were conducted in July 2015, the first survey approximately 2 years after the installation, and in March 2016, the second survey 2 years and 9 months after the installation. Fig.8 shows the conditions of the SPF and the foot protection block. As seen from the photograph of the first survey, suspended solid is accumulated in the foot protection block on the left side, and no animals or plants were observed. For the SPF on the right side, large algae such as Wakame seaweed flourished on the concrete frame, and sea cucumber also inhabited. Large algae also flourished in the filling stones. It is shown that SPF is favorable environment for animals and plants. Subsequently, looking at the photograph of the second survey, large algae could be confirmed slightly on the foot protection block of the left side. On the contrary, inhabiting of large number of large algae and sea animals such as sea pineapple which is a special product of Sanriku District where the port of Hachinohe is located was confirmed on the SPF of the right side, and it was very appreciated by local fishermen. Fig.9 is the pattern diagram of foot protection block and SPF. The characteristics of each are shown as follows;

Foot protection block

I. Suspended solids are easy to accumulate because of the flat surface.
II. Seaweed spores are difficult to survive by the accumulation of suspended solids.
III. Sea animals are hard to inhabit by the accumulation of suspended solids.

SPF

I. Suspended solids are hard to accumulate because of the voids and roughness on the surface.
II. Seaweed spores adhere and grow.
III. Adhering animals (e.g. sea pineapples) inhabit and feed, and filter the suspended solids (water purification effect).
IV. Benthic animals (e.g. sea cucumber) live, and feed and digest sediments (sediment improvement effect).

After the installation of SPF, there was no scattering of the filling stones as confirmed by the hydraulic model experiment, even though it was attacked by several huge typhoons. In addition, SPF has a height of 1.5m, and can be piled with 2 steps, 3 steps and used even in the deep water. This survey showed that SPF is a construction method combining functions of disaster prevention (physical resiliency) and environmental improvement (creation of growth and habitats for living organisms). At the same time, improvement of fishing ground productivity is also expected.

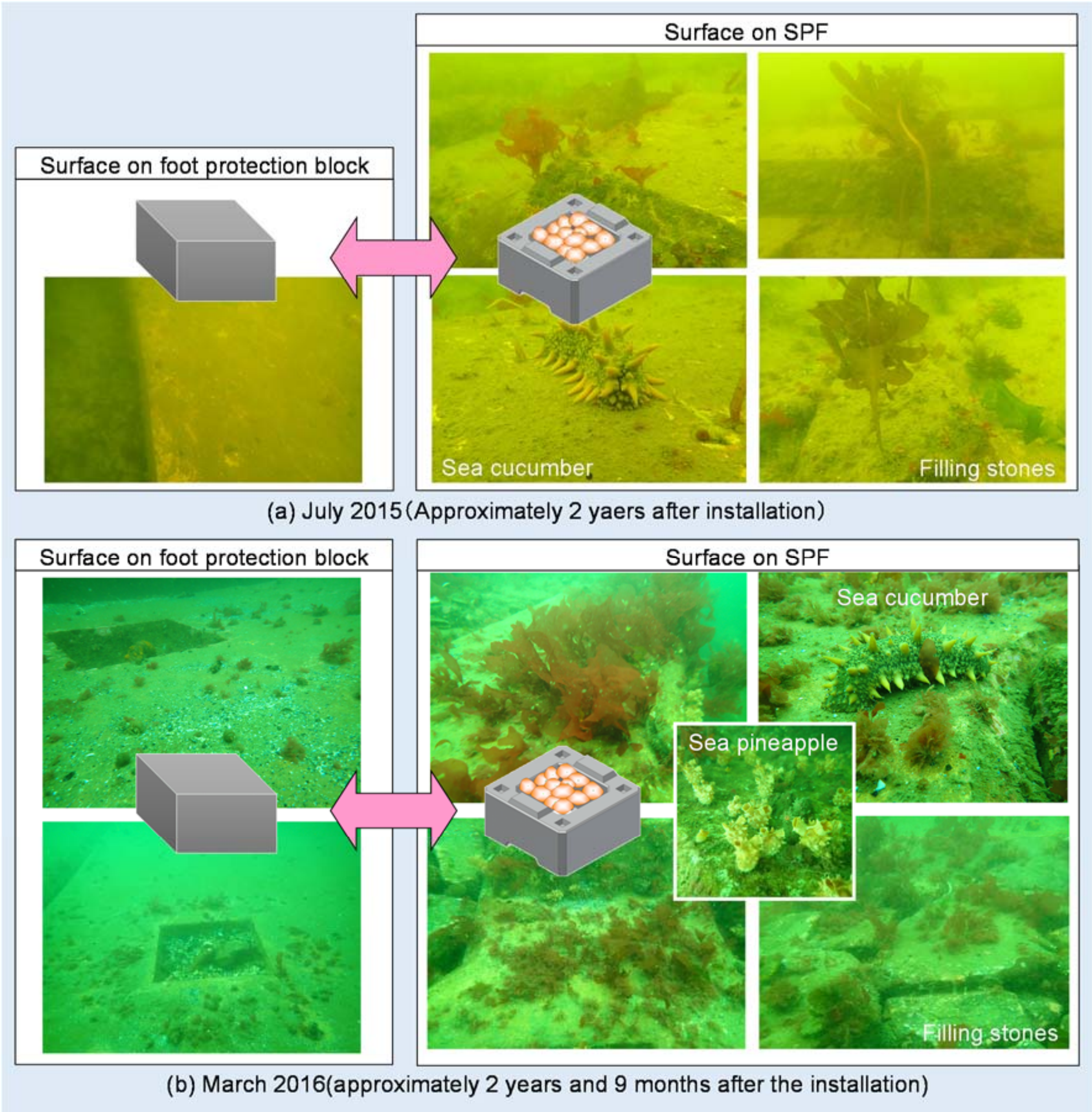


Figure 8 : Results of monitoring survey

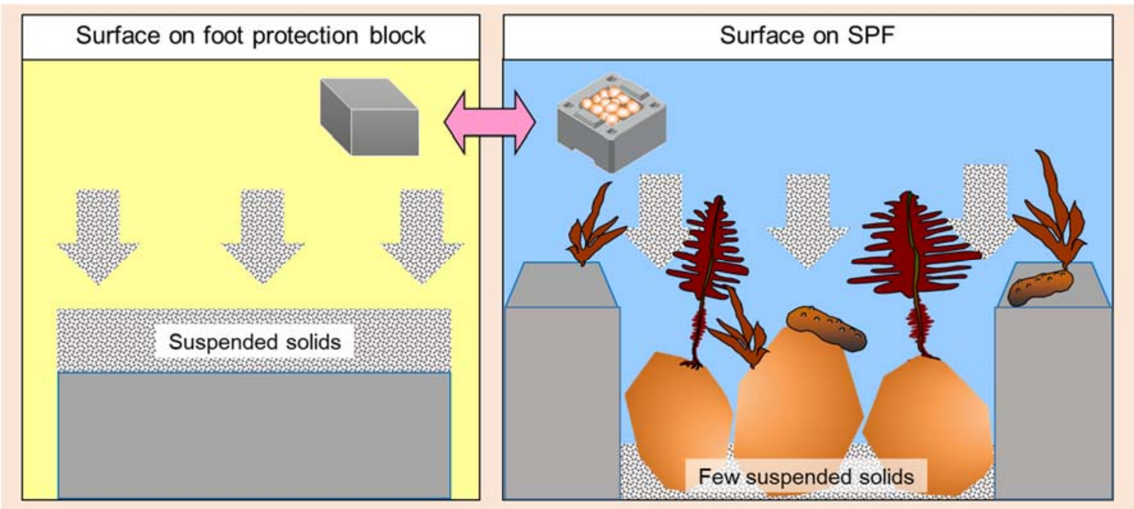


Figure 9 : Diference between foot protection block and SPF

3. EXAMPLES OF ENVIRONMENTALLY ACTIVE CONCRETE USING AMINO ACID

3.1 Environmentally Active Concrete

Environmentally Active Concrete (hereinafter referred to as EAC) is new concrete containing amino acid, developed by Sato et al.(2011) and Nishimura et al.(2014). As a result of conducting concrete strength tests with various kinds of amino acids, Arginine which has less effect on concrete strength was selected. Fig.10 shows the transition of compressive strength of arginine-mixed EAC. The weight of Arginine containing in EAC is recommended 3% of the cement weight ratio. Neither reduction of abrasion resistance by mixing Arginine nor neutralization of concrete were observed.

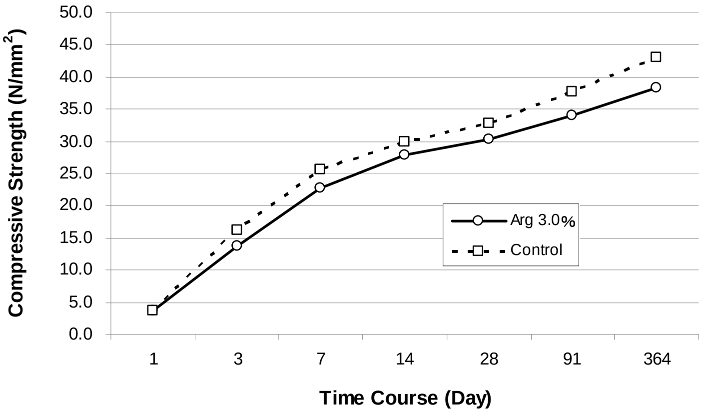


Figure 10 : Temporal Change of Compressive Strength

Fig.11 shows the adhesion state of algae on the specimens made by ordinary concrete (hereinafter referred to as Ord-con) and EAC 8 months after installation in the experiment at actual sea area conducted at the Kojima fishing port in Osaka Prefecture. The amount of arginine added to EAC specimen is 1%, 3% and 5% respectively by cement weight ratio. Many adherent algae flourish on the blocks with high content of Arginine. Fig.12 shows the transition of amounts of chlorophyll-a showing the amount of adherent algae per unit area of the surface of EAC block in which arginine is added 5% by cement weight ratio, and Ord-con block. The amount of chlorophyll-a per unit area of the EAC block was 2-5 times higher than that of the Ord-con block. However, the consumption of algae by sea animals often affects on the data obtained in the experiment at actual sea area. As a result of a laboratory experiments which are not affected by sea animals, the amount of algae on the EAC block is 5 to 10 times more than that of on the Ord-con block (see Fig.13).

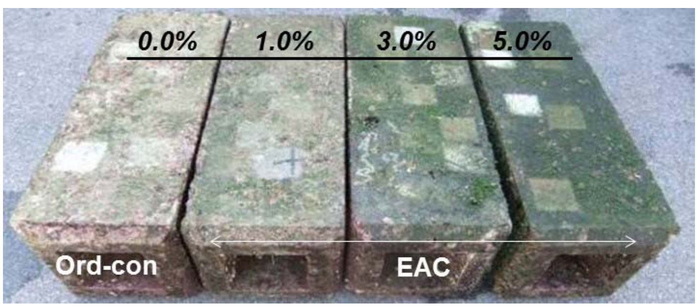


Figure 11 : Monitoring condition of blocks taken from underwater after 8 months

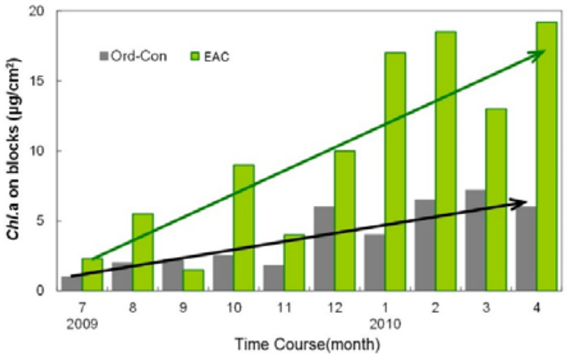


Figure 12 : Time variation of Attached *Chl*.a on blocks in the experiment at actual sea area

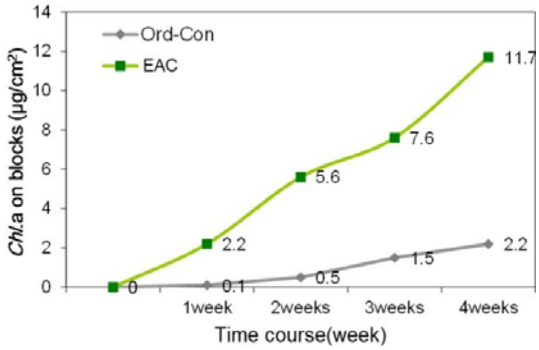


Figure 13 : Time variation of Attached *Chl*.a on blocks in Marine Lab facility

3.2 Example using EAC in Port of Wajima

In the port of Wajima located in the northern part of Noto Peninsula in Ishikawa Prefecture, the breakwater using wave-dissipating blocks, RAKUNA-IV, are installed (see Fig.14). The size of the wave-dissipating block is 20 ton.

As shown in Fig.15, EAC panels of 30cm x 30cm were strongly attached to the legs of the wave-dissipating blocks with adhesive agent and anchor. The amount of Arginine added to the EAC panels is 3% by cement weight ratio. Since the water depth of the breakwater installation location exceeds -10 meters, 5 blocks attached with EAC panels are installed at the position up to -3 meters where the sunlight certainly reaches. A total of 18 EAC panels were attached to each wave-dissipating block.

The blocks attached with EAC panels were installed in July 2013. The monitoring surveys for the effect on ecosystems were conducted 7 times in total.; 1st survey: 1 month after, 2nd survey: 3 months after, 3rd survey: 10 months after, 4th survey: 15 months after, 5th survey: 23 months after, 6th survey: 28 months after, 7th survey : 35 months after. Fig.16 are the photographs of the algae growing on the EAC panels. (a) is the EAC panel in the first survey one month later, it clearly shows that microalgae are flourishing on the EAC panel, compared with surrounding Ord-cons. (b) and (c) are 10 months and 15 months later, and algae are flourishing steadily over time. (d) and (e) are sea urchins and turban shells

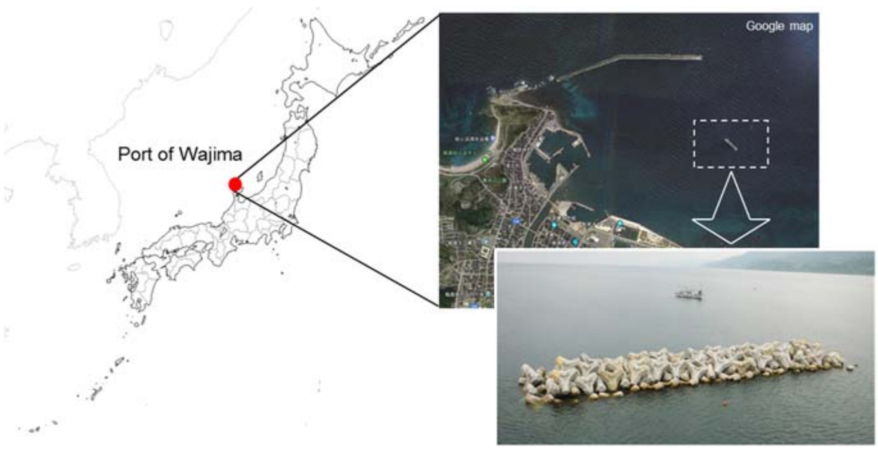


Figure 14 : Location of port of Wajima

gathering on the EAC panel, and (f) is fish migrating around the block. As just described, the stationary fish and shellfish and their fry around the EAC panel, and migratory fish around the block were confirmed. This indicates that the breakwater functions as a habitat for diverse fish and benthos. Fig.17 shows the time variation of the EAC panel. Microalgae flourish for about half a year after installation, and as time passes, it can be seen that the seaweed beds are formed by large algae. Thus by using the EAC panel, since the entire breakwater becomes an artificial fishing grounds and favorable seaweed beds, it is revealed that it is possible to realize both disaster prevention and the environment.

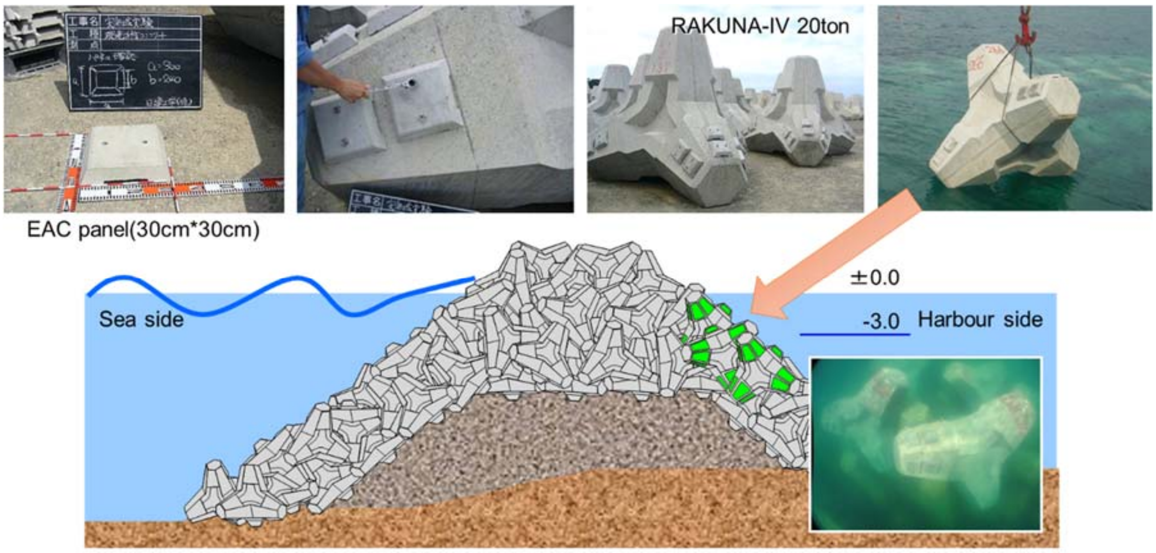
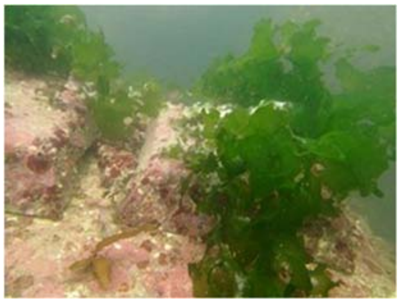


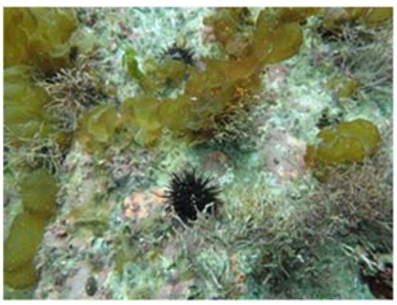
Figure 15 : Wave-dissipating block attached with EAC panel and Cross-section

(a) Microalgae on EAC panel
(1 month after installation)

(b) Seaweed on EAC panel
(10 months after installation)



(c) Seaweed on EAC panel
(15 months after installation)



(d) Sea urchin
(23 months after installation)

(e) Turban shell
(35 months after installation)

(f) Fish
(35 months after installation)

Figure 16 : Results of monitoring survey

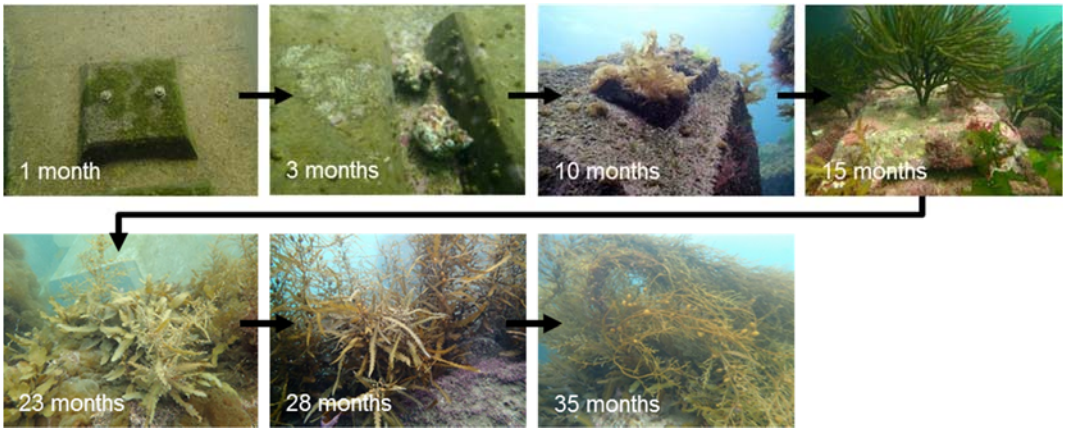


Figure 17 : Time variation of EAC panel

3.3 Example using EAC in Port of Shimonoseki

In the port of Shimonoseki located in the western end of the main island of Japan, the foundation rubble mound of revetment is armoured by armour blocks, STONE-BLOCK (see Fig.18).

In this site, the EAC panels are attached to the armour blocks installed in the end of slope of the revetment. The Ord-con panels were also used for comparison. Fig.19 are the photographs of the blocks attached with the EAC panels and cross-section view on site. The EAC panels are located at a water depth of -1.0m. The first monitoring survey for effect on ecosystem was conducted in June 2017, 9 months after the installation, and the second survey was conducted in October 2017, 13 months after the installation. The upper row of Fig.20 shows the result of the first survey and the lower row shows the result of the second survey. In the both surveys, it can be seen the growth effect by Arginine

Figure 18 : Location of port of Shimonoseki

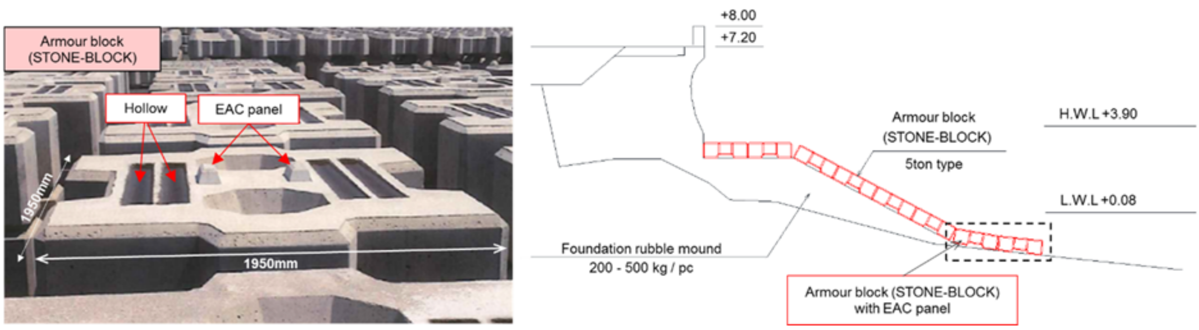


Figure 19 : Armour blocks attached with EAC panels and Cross-section

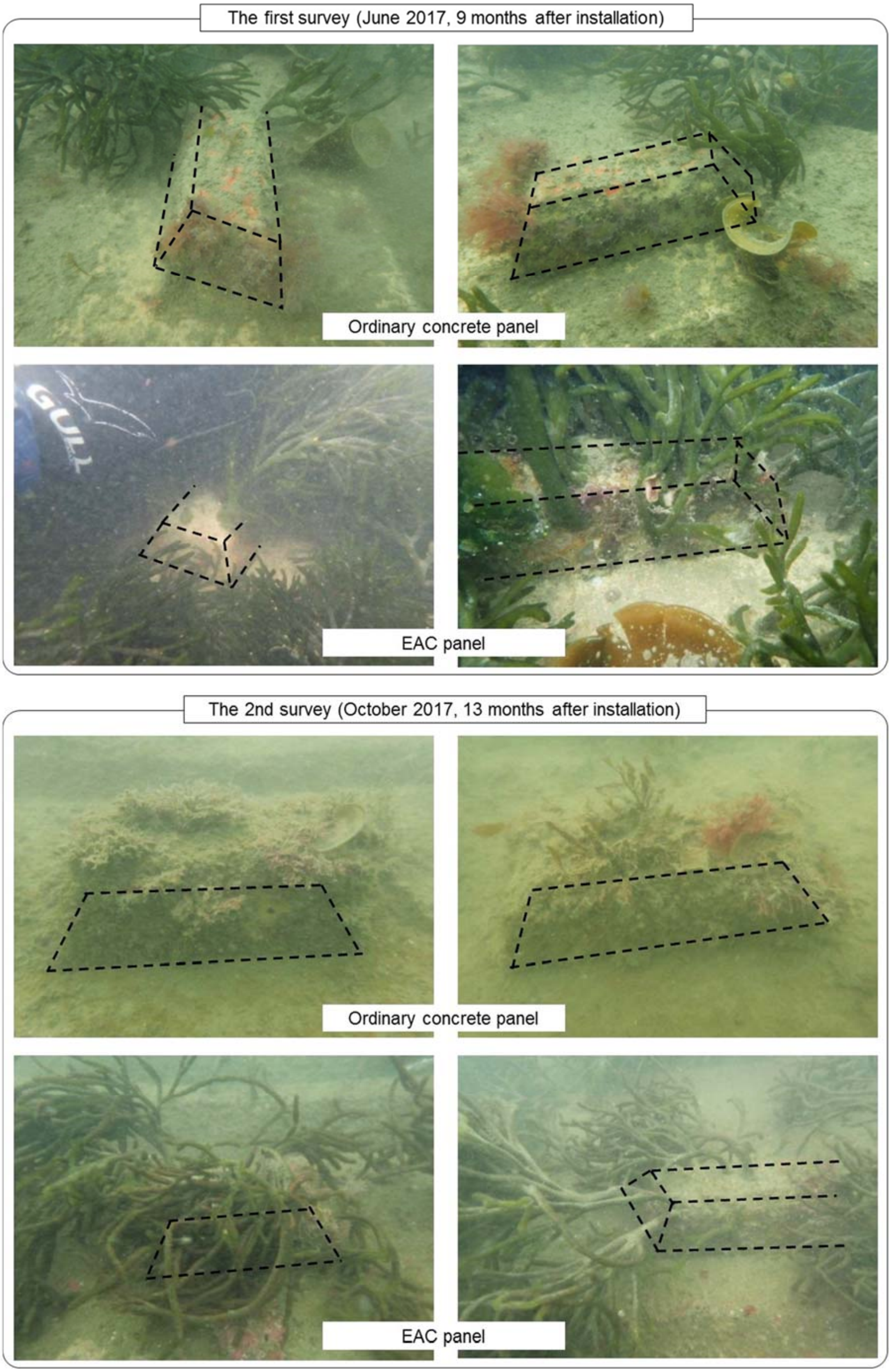


Figure 20 : Monitoring results

has appeared because there are more seaweeds growing on the EAC panels than the Ord-con panels. Mainly growing seaweed is a perennial Codium fragile, which grows most in japan from June to October. Due to its seasonal rise and fall, Codium fragile growing on the Ord-con panels had almost disappeared in the second survey in October. On the contrary, it can be confirmed that many Codium fragile remain on the EAC panels even in such conditions. Therefore, it became clear that the EAC panels are being favorable habitats for living organisms also in the port of Shimonoseki. In the future, as growth of algae spreads throughout the submerged part of revetment, it is expected that favorable habitats will be created for fish as well.

As in the examples of the port of Wajima and the port of Shimonoseki, by using EAC in which consideration for the environment is incorporated in the material itself, together with the wave-dissipating blocks and armour blocks, it is possible to achieve both disaster prevention and the environment as well as further improvement of fishing ground productivity.

4. Summary

In this paper, the examples which realized environmental improvement in the surrounding sea area while demonstrating the disaster prevention function are introduced.

In the example of the port of Hachinohe where using SPF combining stone materials with concrete, though a large number of algae and sea animals inhabited on the surface of the SPF, only few existed on the foot protection block. Therefore, it is revealed that SPF which has a physically resilient characteristic against storm surge accompanying climate change such as sea level rise and abnormal weather and tsunami caused by earthquake, and creates growth and habitat of organisms is a construction method combining both functions of disaster prevention and environmental improvement.

In both surveys at the port of Wajima and the port of Shimonoseki where EAC is actually used, it was confirmed that EAC becomes favorable foundation for living organisms, compared to the Ord-con. By using EAC for the submerged part of all concrete structures which are indispensable for disaster prevention such as breakwaters and revetment, EAC can achieve both "disaster prevention" and "environment conservation", further improvement of fishing ground productivity is expected.

Based on these success examples, SPF greatly contributes to Goal 13 of "Sustainable Development Goals (SDGs)" set by the United Nation in terms of disaster prevention by strengthen the resiliency against disasters such as storm surge accompanying climate change and tsunamis caused by earthquakes. At the same time, SPF also contributes to Goal 14 in terms of environmental conservation by creating the growth and habitats for living organisms to improve the fishing ground productivity. Likewise, EAC has already been certified by Japan Science and Technology Agency (JST) as an example for achieving SDGs in Japan and contributed to SDGs in terms of environmental conservation. Hereafter, it is hoped that these technologies will be used around the world beyond Japan and help to an achievement of both “disaster prevention” and “environmental conservation”, and realization of the sustainable society.

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