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"Marine Stone™" as Material for Improvement of Marine Environments by Using Steelmaking Slag†

1. Introduction

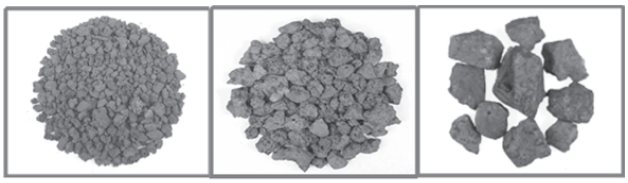
Enclosed coastal seas are affected by influents such as domestic wastewater that contain nutrient salts, and bottom sludge with a large content of nutrient salts and organic matter easily accumulates at the sea bottom. Although influents with a high nutrient salt content encourage the proliferation of plankton and other species of marine life, this also causes an oxygen-deficient condition near the bottom sediments, as the remains of the dead organisms settle to the bottom as organic matter and consume oxygen during decomposition. It is also known that sulfate-reducing bacteria, which form hydrogen sulfide, are activated under oxygen-deficient conditions. Accordingly, the bottom of sea areas where silty sediment has accumulates forms a suitable environment for the proliferation of sulfate-reducing bacteria, and thus is a source of hydrogen sulfide. In addition to the foul odor of hydrogen sulfide, this compound is also extremely toxic, which causes further deterioration of marine habitats. Sand-capping using natural sand is a representative method for improving bottom sediments that have deteriorated due to accumulation of sludge. However, as dredging of sea sand is prohibited in all areas, securing a substitute material for sea sand has become an issue.

Moreover, many shoals and seaweed beds in coastal areas of Japan have been lost due to reclamation of industrial land, construction of upright seawalls, etc., and improvement of marine environments to restore them has become an urgent need.

"Marine Stone™" (hereinafter, simply Marine Stone) was developed by JFE Steel Corporation as a material that contributes to the improvement of marine environments by using steelmaking slag as a raw material.

2. Main Features of Marine Stone

The appearance and chemical composition of Marine Stone are shown in **Photo 1** and **Table 1**, respectively. Its main features are outline below.



Marine Stone 10　Marine Stone 30　Marine Stone 85

Photo 1　Appearances of "Marine Stone"

Table 1　Example of chemical composition

T.Fe	SiO_2	CaO	Al_2O_3	MnO	MgO	TiO_2
17.5	29.3	33.0	6.0	8.7	4.9	1.2

(1) Hydrogen sulfide and phosphate ions in bottom sediments can be chemically adsorbed by capping Marine Stone on sediments where bottom sludge has accumulated. This suppresses the generation of foul odor due to hydrogen sulfide, etc. and elution of phosphorus from the sea bottom, and chemically improves the deteriorated bottom layer water and bottom sediments. In addition, prevention of oxygen depletion and blue tide by suppressing oxygen consumption by hydrogen sulfide can also be expected.

(2) As the surface and crevices of Marine Stone particles form a base for adhesion of organisms that live at the sea bottom (benthos), it is possible to create habitats for marine organisms. In particular, because it is known that bivalves, sea squirts and similar organisms filter suspended solids and thereby purify the water and bottom sediments, an increase in the self-purification capacity by these organisms can be expected.

(3) Because Marine Stone has a large particle diameter and particle density in comparison with natural sand, it is stable and is not easily washed away by waves, etc. Therefore, in shallow seas where sunlight can reach, it also functions as an adhesion base for algae and seaweeds.

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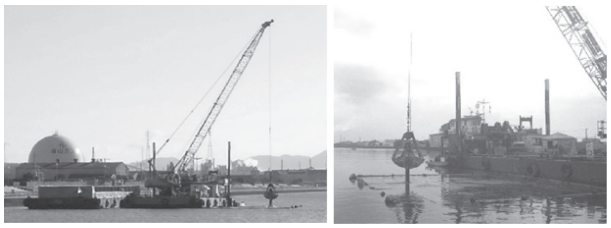

Photo 2 Scenes of construction of improvement of marine environment project using "Marine Stone" in November 2015

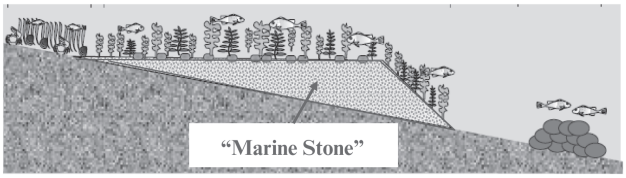

Fig. 1 Cross-sectional image of shoal created using "Marine Stone" in Iwakuni, Yamaguchi Pref. [5]

3. Examples of Use

3.1 Use as Bottom Sediment Improvement Material

In a joint project with the National University Corporation Hiroshima University (hereinafter, Hiroshima University), JFE Steel conducted a field demonstration test with the aim of solving the problem of hydrogen sulfide generation from the silty sediment at Fukuyama Inner Harbor (Fukuyama City, Hiroshima Prefecture), which is a typical enclosed coastal water body, and confirmed the bottom sediment improvement effects of Marine Stone, which included suppression of hydrogen sulfide generation, creation of habitats for benthos, etc[1,2]. Based on these results, Marine Stone was adopted as a bottom sediment improvement material in the "Fukuyama Harbor-Port and Harbor Waters Environment Creation Project (Inner Harbor Area) " carried out by Hiroshima Prefecture. As shown in **Photo 2**, approximately 39 000 t of Marine Stone was constructed over an area of about 67 500 m^2 in the Fukuyama Inner Harbor (Fukuyama City, Hiroshima Prefecture).

3.2 Use as Shoal Creation Material

Shoals are water areas such as sand, rocky reefs, etc. that have a water depth shallower than 10–15 m and function as a nursery ground for seaweeds, shellfish and other marine life. In recent years, natural shoals have decreased as a result of dredging of sea sand, coastal development, etc.

JFE Steel carried out demonstration tests of shoal creation in FY 2001 (2001 Joint Research Project of Hiroshima Prefecture Environment-related Industry Creation Promotion Committee) and in FY 2009 in the waters of Japan's Seto Inland Sea[3,4]. In both cases, construction was performed using Marine Stone, without constructing submerged mounds, in areas where the water was deep and almost no seaweeds existed. Surveys conducted after the construction revealed that the Marine Stone functioned as an adhesion base for shellfish, seaweeds, etc. similar to natural shoals at both locations.

Based on these results, Marine Stone was adopted in an artificial shoal construction project on the coast in Iwakuni City, Yamaguchi Prefecture. **Figure 1** shows an image of the shoal which was created using Marine Stone. Satisfactory results are being obtained in a monitoring survey; for example, the survey has confirmed adhesion of large seaweeds and shellfish, including species which are high-valued commercial species of fishery products[5].

4. Evaluation as Environmental Improvement Material

4.1 Technical Demonstration and Certification by Third Parties

The results of demonstrations of Marine Stone and other slag products as a FY 2009 Environmental Technology Verification (ETV) Program of Japan's Ministry of the Environment have been published (Demonstration No. 090–0902)[6]. Marine Stone has also been registered in the New Technology Information System (NETIS)[7] of the Ministry of Land, Infrastructure, Transport and Tourism (registration No. CGK-140003-A).

4.2 Evaluation from Outside of JFE Steel

In recognition of the outstanding results of "Marine Stone: A restoration material to improve water and sediment quality of enclosed coastal seas,"JFE Steel Corporation and Hiroshima University jointly received the "12th Eco Products Award" (hosted by the Eco Products Award Promotion Council, supported by the Ministry of Finance, Ministry of Health, Labour and Welfare, Ministry of Agriculture, Forestry and Fisheries, Ministry of Economy, Trade and Industry, Ministry of Land, Infrastructure, Transport and Tourism, Ministry of the Environment) Minister's Prize (Grand Prize) from the Ministry of Agriculture, Forestry, and Fisheries[8]. In addition, JFE Steel and Hiroshima University also received the 2016 (26th) Nikkei Global Environmental Technology Award for Excellence (sponsored by Nikkei, Inc.) for Marine Environment Improvement Technology Using the Recycled Material 'Marine Stone' in 2016[9].

It is considered that both of these awards were based on a high evaluation of the development and practical application of Marine Stone, which is a material that improves the waters and bottom sediments in sea areas, and also suppresses the generation of foul odor (hydrogen sulfide) by chemically adsorbing hydrogen sulfide generated from the silty sediments in enclosed coastal seas.

5. Conclusion

JFE Steel hopes to contribute to improvement and protection of the environment in coastal waters through the expanded application and development of even more outstanding slag products for coastal waters including Marine Stone.

References

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