Offshore Technologies in Japan to Exploit the Ocean

Technologie japonaise pour l'exploitation des océans

Neue Japanische Technologien zur Erschließung des Meeres

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SUMMARY

There are expectations for the ocean to be exploited for space, energy resources, biological, and mineral resources going into the 21st century, and the offshore engineering for these will be required to deal with problems concerning the increasingly diversified uses of structures and needs in siting. Recent public opinion for provision of facilities friendly to the environment, needs to be satisfied. In this paper, a number of examples of new technologies and structures being worked on based on such concepts – new types of breakwaters, marine ranches, wide-area clean-up engineering – will be described.

RESUMÉ

Il est fort probable que le milieu, les ressources énergétiques, biologiques et minières des mers puissent être exploités par l'homme dans sa marche vers le 21ème siècle. Il lui faudra donc recourir à des techniques de constructions en mer, afin de maîtriser les problèmes liés à la diversification sans cesse croissante des structures à réaliser et des besoins d'aménagement des sites en résultant. La tendance actuelle de l'opinion publique semble tendre dans le sens d'installations plus favorables qu'hostiles à la protection de la nature et de l'environnement. Ce rapport expose divers exemples du développement de nouvelles techniques et structures fondées sur cette conception plus écologique, comme de nouveaux types de jetées, des fermes marines, des méthodes de nettoyage de grandes surfaces.

ZUSAMMENFASSUNG

Es wird erwartet, daß auf dem Wege zum 21. Jahrhundert die Meere zunehmend für Raum und als Energiequellen wie auch wegen ihrer biologischen und Mineralschätze ausgebeutet werden. Dafür sind moderne Technologien erforderlich, die es erlauben, die mit der zunehmenden Vielfalt in der Anwendung von Strukturen und der Suche nach geeigneten Bauplätzen verbundenen Probleme zu lösen. Außerdem muß danach gestrebt werden, die neuerdings von der Öffentlichkeit gestellten Anforderungen und umweltfreundlichen Anlagen zu erfüllen. In diesem Bericht wird eine Anzahl von Beispielen von erarbeiteten neue Technologien und Bauten wie neuartigen Wellenbrechern, Farmen im und auf dem Meer und Verfahren zum Säubern ausgedehnter Gebiete beschrieben.

1. INTRODUCTION

Ocean space abounds in infinite possibilities, and attention is being focused on it as the last remaining unutilized space. There is a great variety of development projects planned in Japan. Projects presently under construction are, for example, a) Kansai International Airport, the first international airport in the world to be on an offshore artificial island, b) The Honshu-Shikoku Bridges, large-span bridges connecting islands of the Inland Sea of Japan, and c) Tokyo Trans-Bay Highway to cross Tokyo Bay by long bridges and underwater tunnels (Fig.1). Environmental impact assessments have been conventionally made in connection with such offshore development projects using marine space, and such assessments related to ocean space involve various difficulties such as described below.

When effects on the marine environment are to be considered, what must first be done is to predict the effect on the boundless natural system of the sea and to aim for coping with the situation beforehand. In such case, a considerable problem is determining the scope of the environmental impact assessment. Furthermore, there has recently been a rising concern in society about protection of the natural environment such as by regulation of large-scale leisure facilities development and tackling the problem of the global environment on an international level. As can be understood from the oil spills in the Persian Gulf in the Middle East, the effects of the spills will spread with time, and it is said more than one hundred years will be required for a return to the former natural condition.

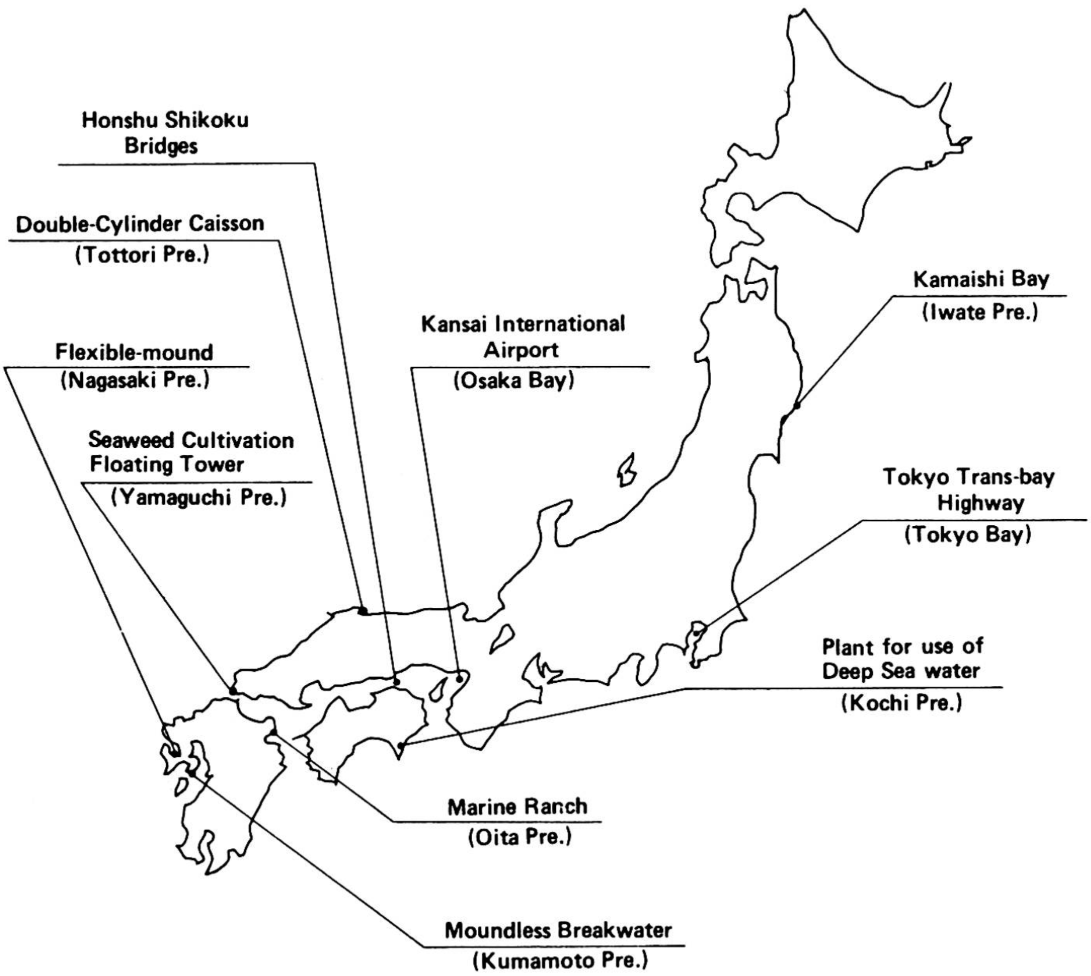


Fig.1 Offshore project map in Japan

Next, it is necessary for the effect on fisheries to be predicted and to provide measures to deal with the situation. Still further, considerations must include the influences on the fishing industry and the people's diet. The regional economy in marine development and the compatibility of pursuing convenience in daily life and the posture to protect the natural environment are becoming increasingly important in recent ocean space development. In the offshore engineering from now on, research and development for dealing with even more severe marine conditions will be necessary. Furthermore, it is needed "not for only unambitious assessment of the impact of construction to be made, but planning of marine development done from the aspect of more positively, in other word, 'creating an environment readily compatible with everyday life of people and natural ecology in addition to the original purpose'."

This paper, therefore, will present a number of cases of R&D and engineering being promoted in Japan, although not yet to an adequate degree, aiming for attainment of new technologies and structures in step with such thinking.

2. NEW TYPES OF SEA AREA CONTROL STRUCTURES

Structures for controlling waves and currents include breakwaters, and training jetties. With the waterfront development of recent years, particularly, with the increased popularization of marine leisure activities, R&D is going on concerning breakwaters for great water depths and for extra soft ground from the consideration of more efficient use of the coastal sea area, and concerning structures capable of managing the sea area while protecting the natural environment and scenic views from the desire to create a more favorable marine environment. A number of examples will be described below.

2.1 Challenging the Deep

A breakwater presently under construction at the port of Kamaishi, Iwate Prefecture, is at a location of water depth as much as 63m, and is drawing attention as the breakwater having the greatest depth in the world. This breakwater, as shown in Fig.2, consists of a foundation mound of rubble-stones from the sea bottom to a water depth of 20 to 30m, with 31 large caissons each 30m in length, width, and height, weighing 16,000t installed on the mound for a composite breakwater.
In manufacture of the caissons, since these are of extra-large size, they cannot be made at one place in a single operation, and therefore, build-up is done in sequence starting from a 6,000-t floating dock and moving from first to fifth offshore concrete placement stations. Construction was begun in 1988, and the third caisson have been installed so far. Completion of the whole project is scheduled for 1998. Upon completion, people living near the shore will be relieved from the fear of tsunamis, the waters inside the bay will be calmed, and navigation of watercraft made safe. Multipurpose ocean utilization will be promoted and a great contribution made to coastal development.

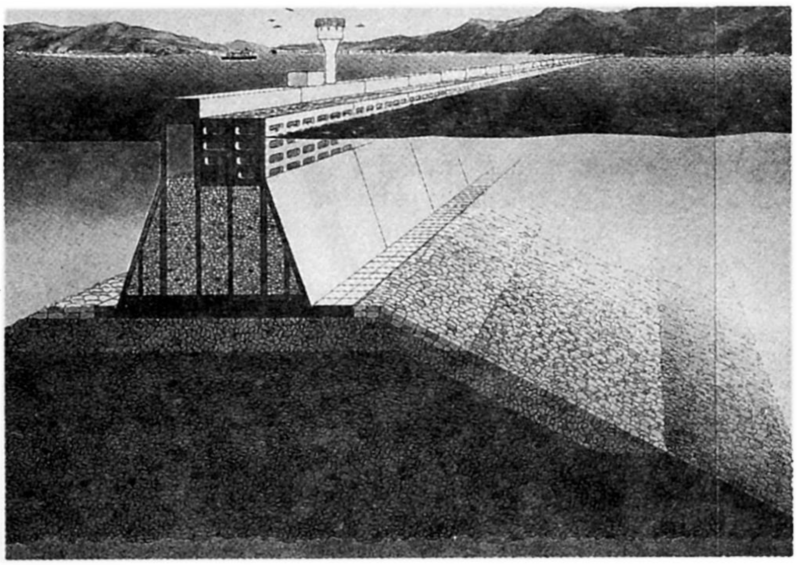


Fig. 2 Breakwater installed at great water depth (Courtesy of Ministry of Transport)

2.2 Overcoming of Soft Seabed

This new type of breakwater with wide footing requires no ground improvement (Fig.3). The adhesive force between the structures bottom and the ground surface underneath, and the horizontal resistance of piles are working against sliding enabling the breakwater's weight to be reduced. On-site proving tests were completed in 1986, and such a break -water has been in practical use at Kumamoto Port since 1988. The construction period required for this type of breakwater is expected to one-forth of that for a conventional gravity type and the cost one-seventh. Studies are being continued with the aim of achieving further improvements.

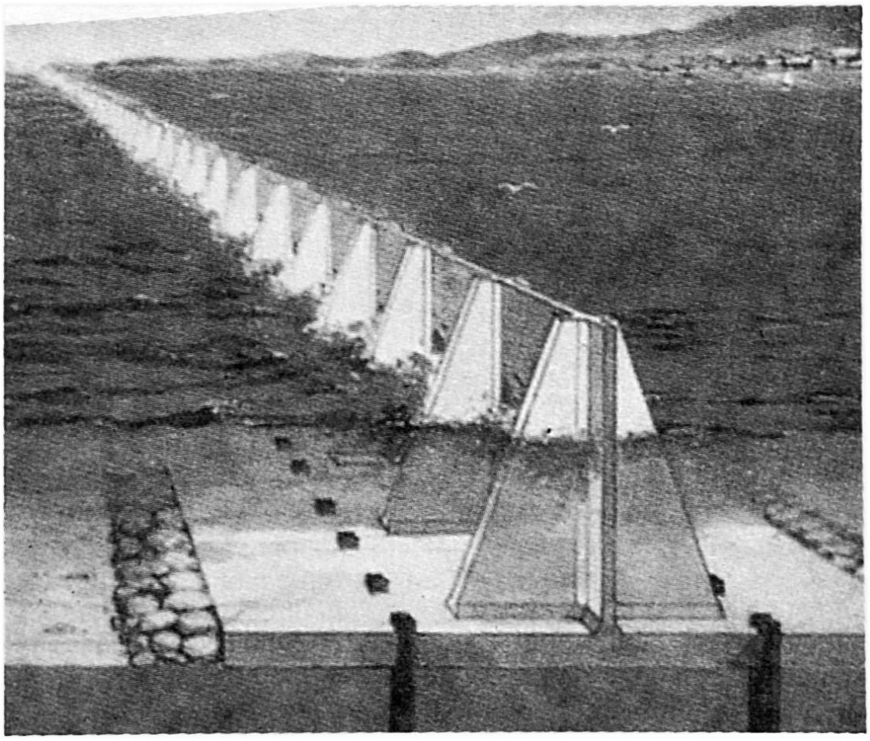


Fig.3 Breakwater installed directly on soft seabed. (Courtesy of Ministry of Transport)

2.3 Flexible-mound

Flexible-mound is a wave control structure of a completely new concept. It consists of a flexible membrane bag of approximately semi-cylindrical shape made of fiber-reinforced hard rubber. Conventional submerged breakwaters break up waves passing across to dissipate their energy, whereas Flexible-mound itself deforms due to incident waves, and through the two effects of the secondly waves (radiation waves) formed by the deformation interfering with waves incident and passing across, and the energy damping by movement of the membrane, the waves at the back side of Flexible-mound will be smaller. It will suffice for the cross-sectional area to be about one-fourth compared with a conventional submerged breakwater so that exchange of sea water occurs more easily, while moreover, there is no obstruction to navigation of watercraft.

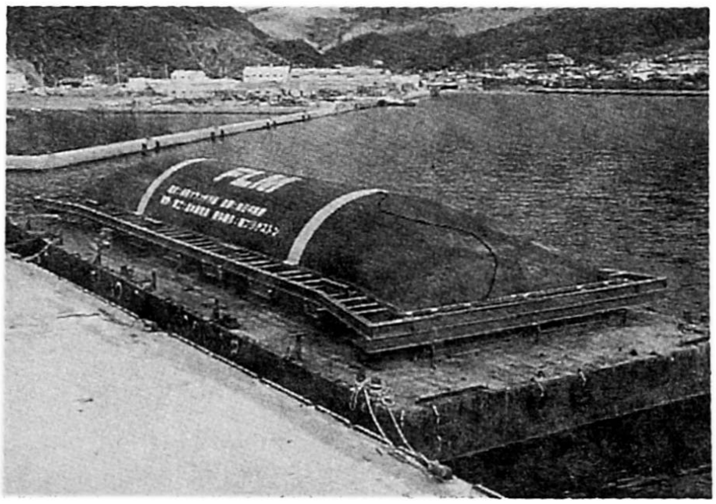


Fig.4 Flexible-mound during airtightness test on a barge (40m(L) x 9m(W) x 3m(H))

Figures 4 and 5 show the airtightness test of it being conducted on a barge and the image of Flexible-mound installed at Omura Bay in Nagasaki Prefecture in 1991. This Flexible-mound is filled with sea water during a storm as shown in Fig.6 for dispating of waves incident from the mouth of the harbor, while during normal times, the sea water is discharged from the bag and the crest is lowered to the level of the sea bottom for a system allowing regular liners and sight-seeing boats to freely navigate the harbor entrance.

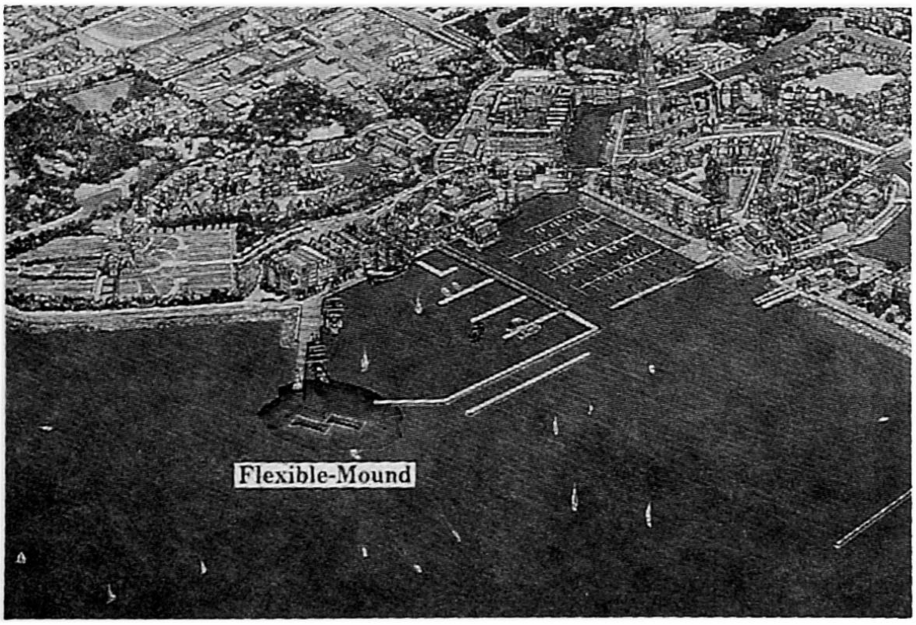


Fig.5 Image of Flexible-mound installation in Huis ten bosch

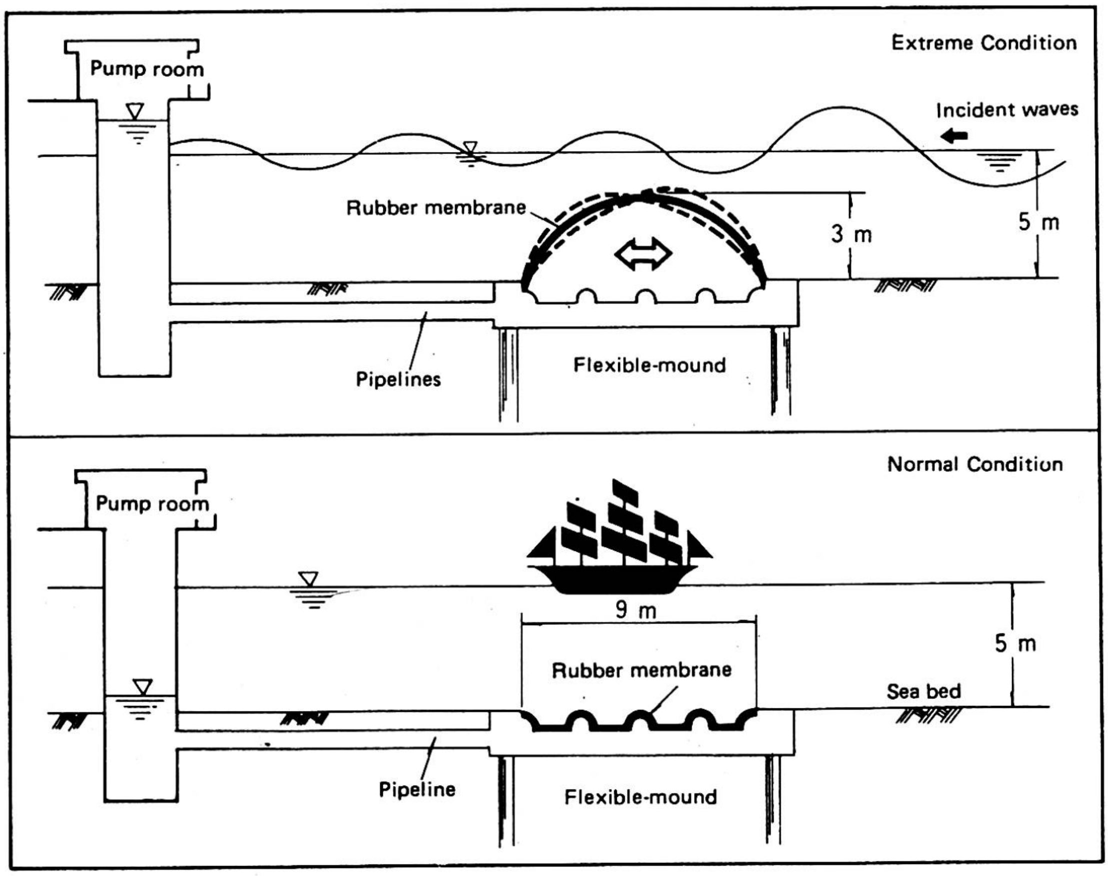


Fig.6 Conceptual drawing of Flexible-mound system

2.4 Double-cylinder Caisson-type Breakwater

The double-cylinder caisson is a new type of caisson which has been under development as a structure for controlling waves at great water depths (Fig.7). The principle feature of this breakwater is perforated double-cylinder structure. The outer cylinder is pervious with a doughnut-shaped retarding pool in the space between the outer and inner cylinders. Waves arriving at the breakwater enter the retarding pool through windows in the outer cylinder, go around either side of the pool, and collide with each other at the back. The section underneath of the retarding pool and the inner cylinder are filled with material such as sand to provide weight. Features of this caisson are the following:

-Being of cylindrical structure, savings can be made in members so that wave forces acting can be alleviated, an economical breakwater for wave control in waters of great depth results.
-The ratios of openings of the outer cylinder wall can be selected as suited for any variation between impervious strucure and pervious structure, while since reflected waves can be made small, this is a breakwater effective for preserving the water quality environment in the harbor and improving navigability of small watercraft in the front sea area of the breakwater.
-Being of cylindrical shape, the normal line of the breakwater can be curved with consideration given from the point of view of appearance.

Demonstration tests were completed at Sakai Port in Tottori Prefecture in 1989, and it is scheduled for caissons 30m in height to be constructed at Shibayama port in Hyogo Prefecture in 1992.

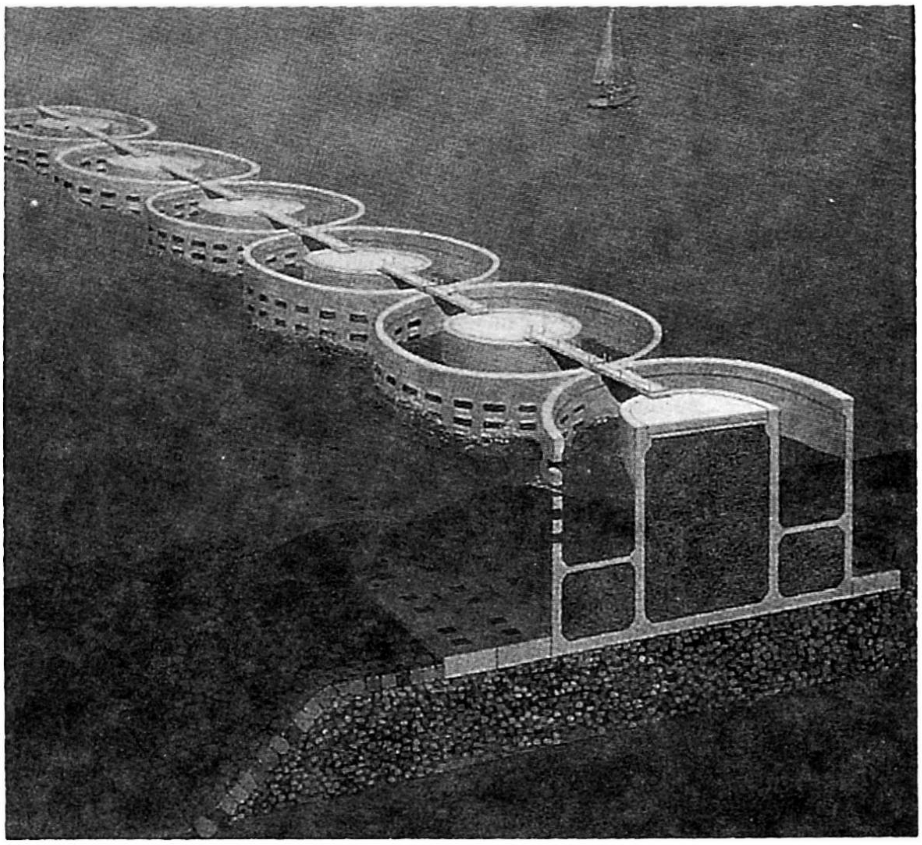


Fig.7 Double-cylinder caisson-type breakwater
(Courtesy of Ministry of Transport)

3. MARINE RANCH SYSTEMS

A marine ranch is a system where the method of putting cattle and horses to pasturage is applied to fishery production, where fish are released into the natural sea and instead of providing fences the range of movement of the released fish is controlled by sound and availability of feed. Since areas available for ocean fishing have shrunk as countries of the world have declared 200-sea-mile exclusive fishery zones, marine ranches which are a form of fisheries made in coastal areas where resources are nurtured, controlled and harvested, have gained attention.

The systematization of marine ranches where synergistic effects are produced through compositing of marine photovoltaic power generating system, plant for effective use of deep sea water, and seaweed cultivation floating tower with marine ranches, is described below.

3.1 Marine Ranch (Acoustic Conditioning Feeding Process Type)

The smallest unit of marine ranch consists of an artificial fish reef and a feeding buoy which supplies feed while emitting sounds several times daily. Figure 8 is a conceptual drawing of the world first marine ranch system introduced in Oita Prefecture. Here, a set of artificial fish reefs and two acoustic feeding buoys are installed, and the movement and quantity of red sea bream are measured by sensors attached to the buoys, with this information, along with sea area environment data, being transmitted by radio waves to an onshore monitoring station.

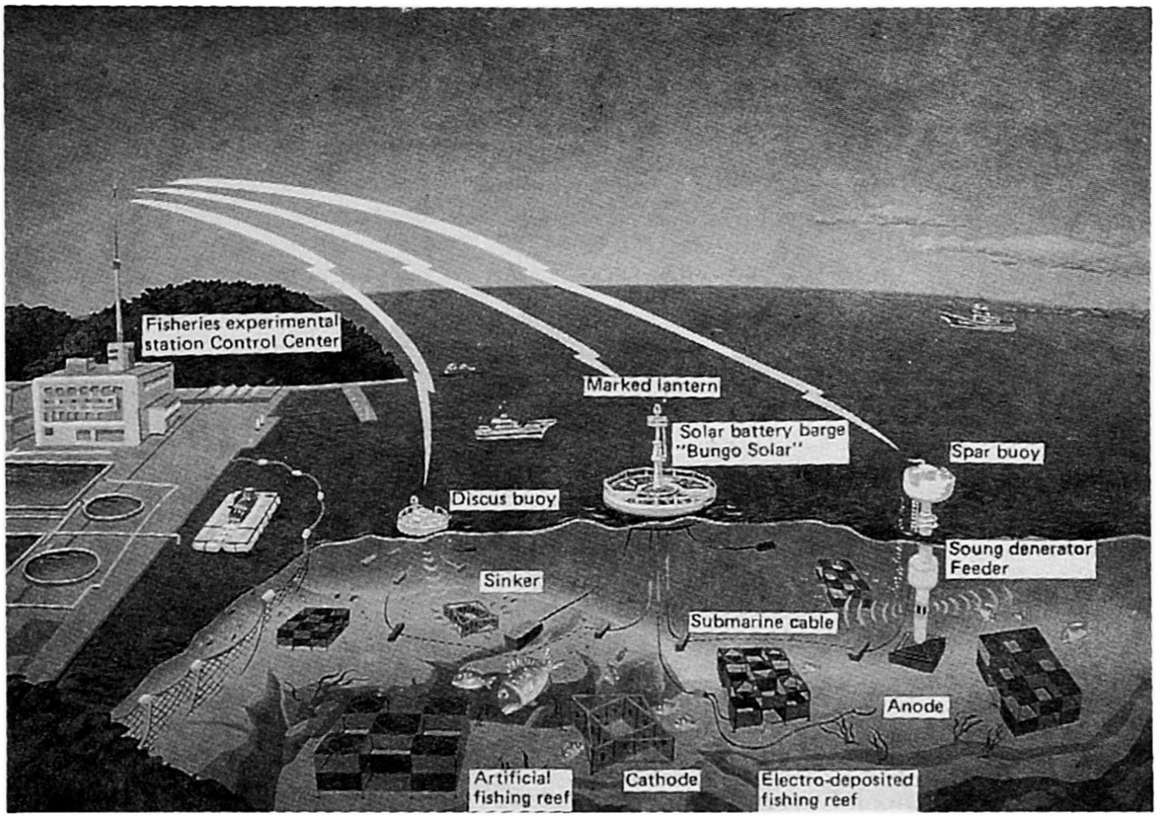


Fig.8 General view of marine ranch

The marine photovoltaic power generating system shown in Fig.9 was developed as the power supply source for this marine ranch. This system consists of 264 photovoltaic cell modules mounted on a barge of diameter 16m and height 3.8m, with this barge moored by three chains at a place of water depth 25m to generate electric power. This barge is a floating structure of concrete with thin walls (25cm) to secure draft while still being sufficiently watertight. For construction of this barge, the knowhow gained with the Arctic Ocean drilling platform, "Super CIDS", was applied adopting a structure with prestress induced in a high-strength, lightweight concrete (σ_{ck} = 3920 N/cm^2, γ_c = 1.85 kgf/cm^3).

Since this marine ranch utilizes the productive capabilities of nature, the amount of feed supply suffices to be one-half of the requirement, and there is the merit that water pollution due to excessive feed considered to be a problem in conventional fish breeding is reduced. There is much expectation of the increased provision of marine ranches as a means of overcoming the trend of decline in catches in coastal fishing seen in recent years

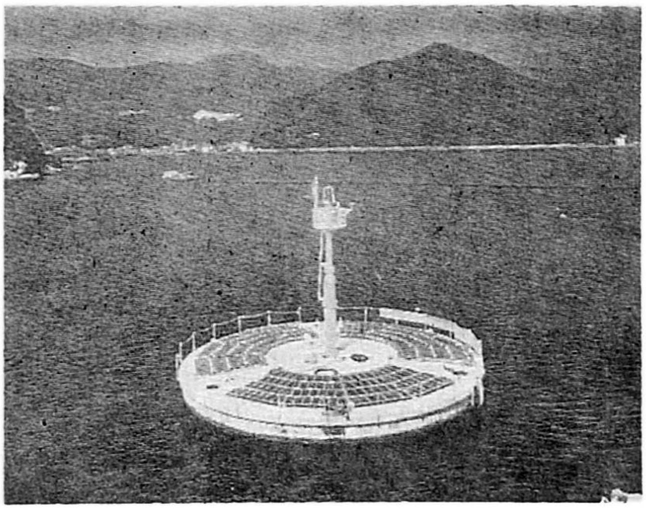
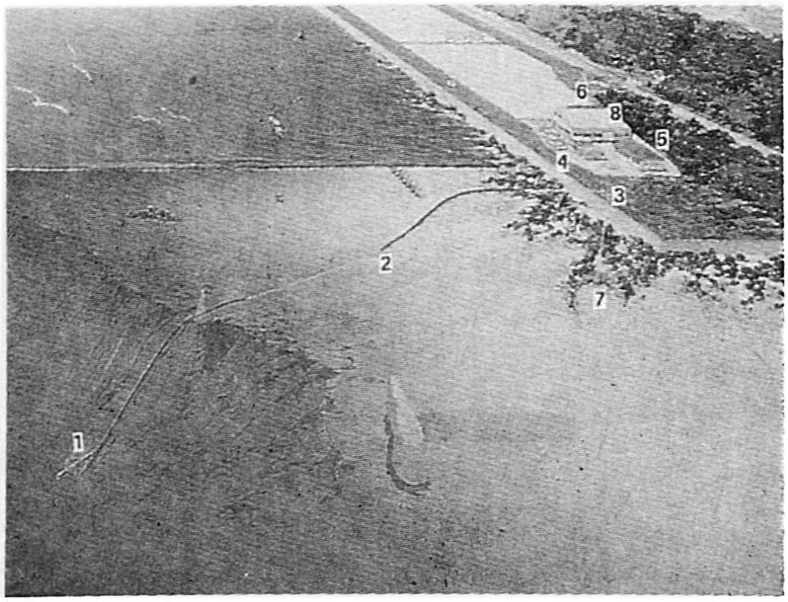


Fig. 9 Marine photovoltaic power generating system

3.2 Plant for Effective Use of Deep Sea Water

Deep sea water is sea water at depth exceeding 200m and has three features of being highly nutrient, very pure, and constant low temperature throughout the year. An experimentation plant for effective use of deep sea water taking advantage of these features was built in Kochi Prefecture in 1989. This plant, as shown in Fig.10 is composed of a deep sea water intake pipe (the high-density polyethlene pipe reinforced by steel wire), surface water intake pipe, pumping facilities, and onshore facilities, and is capable of supplying deep sea water from a depth of 320m and surface layer water from the sea surface in quantities of 460m^3/day and 500m^3/day, respectively, to the onshore experimentation facilities. Especially, the intake facilities of the deep sea water intake pipe (length 2650m, water depth 320m) takes advantage of the knowhow gained with an ocean thermal energy conversion plant constructed in the Republic of Nauru. It is possible for deep sea water and the surface water taken in to be freely mixed together at this research facility to create a breeding environment optimum for the object organisms.

Studies are being made for these characteristics of deep sea water to be taken advantage of for breeding of fishes and shellfishes and as a heat source focusing on the low-temperature properties of the water, cultivation of microscopic algae and refining of anticancer drugs using the algae for a broad scope of applications. Studies are also being made for use in storing of carbon dioxide, cleaning of sea areas, and sea water therapy. In Hawaii, where there are similar facilities, favorable results are already being attained in breeding of fishes and shellfishes, with the stage of commercial application drawing near.



1 Inlet of deep sea water
2 Suction pipe of deep sea water
3 Pump pit
4 Filter tank
5 Research laboratory
6 Experiment building
7 Inlet of surface sea water
8 Machine building

Fig.10 Experimentation plant for effective use of deep sea water

3.3 Seaweed Cultivation Floating Tower

Seaweed cultivation floating tower shown in Fig. 11, is a system for promoting breeding of fishes and shellfishes by stimulating growth of seaweed and phytoplanktons by casting sunlight on the sea bed where light does not easily reach. A demonstration test was conducted in Yamaguchi Prefecture in 1987 with brown algae as the object, while in 1992, proving tests for large water depths are being planned to be carried out in Oita Prefecture. The feature of this system is that the reflecting mirror of the light collector automatically rotates to follow the sun by means of a light sensor, with sunlight passing down through the cylinder of the buoy and being dispersed at the bottom by a concave lens to be cast on seaweed. This is a highly efficient system with little attenuation of sunlight.

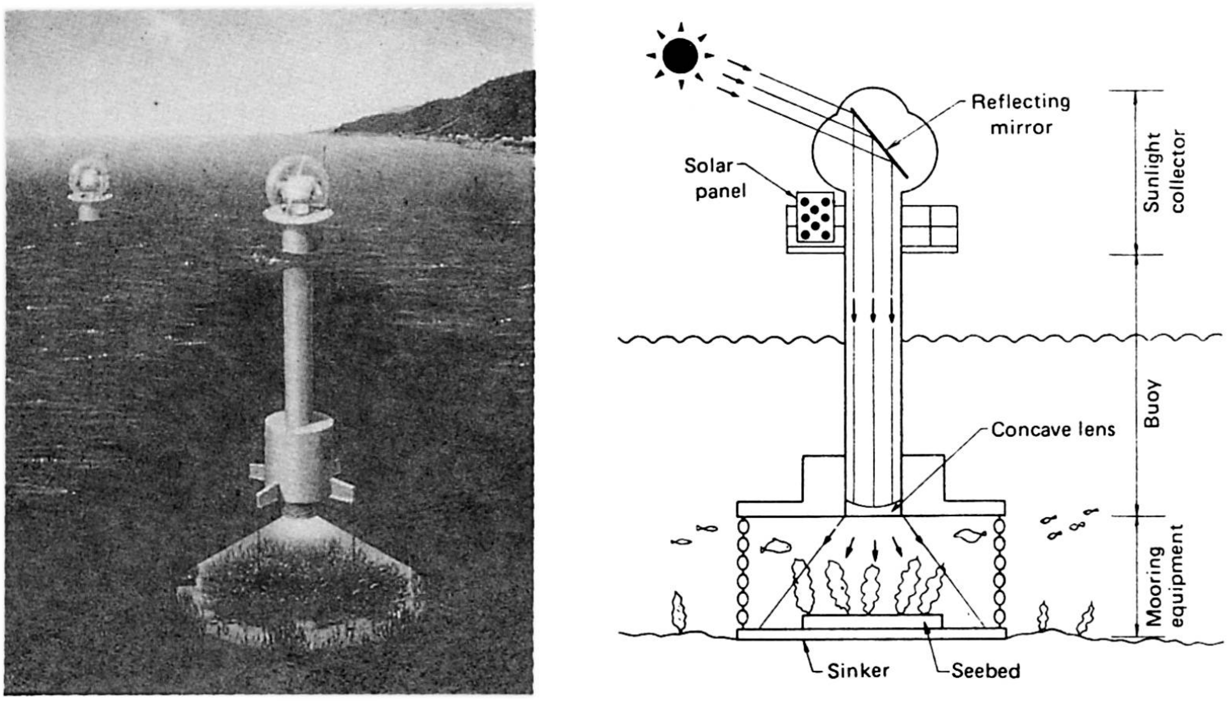


Fig.11 Image perspective of seaweed cultivation floating tower

4. COASTAL WATER CLEAN-UP SYSTEM

With the increase in waterfront development projects it has become necessary for positive measures to be taken for water quality improvement and preservation of sea areas, especially, large sea areas of enclosed nature. For this purpose, technology development is being done for sea water clean-up facilities and simulation of water quality variation prediction. Examples are given below.

4.1 Hybrid Clean-up Breakwater

A hybrid clean-up breakwater is a system consisting of a breakwater which also has the function of cleaning sea water. As shown in Fig.12, a wave arriving from the outer sea runs up the inclined wall of the breakwater and the sea water drops down on a gravel layer filling the interior of the breakwater, passes through the gravel layer, and flows out to the calm inner sea area. Dissolved oxygen in the sea water is increased during this process, while at the same time, organisms adhered to the gravel surfaces clean the water. This clean-up breakwater has low resistance to the passage of water so that water can get through by means of natural energy (tides, waves) or small-scale motive power, for low running cost. This is still at the experiment stage, but it has been clearly shown that substantial improvements in suspended solids (SS) levels, and improvement in chemical oxygen demand (COD) of approximately 30 percent can be achieved.

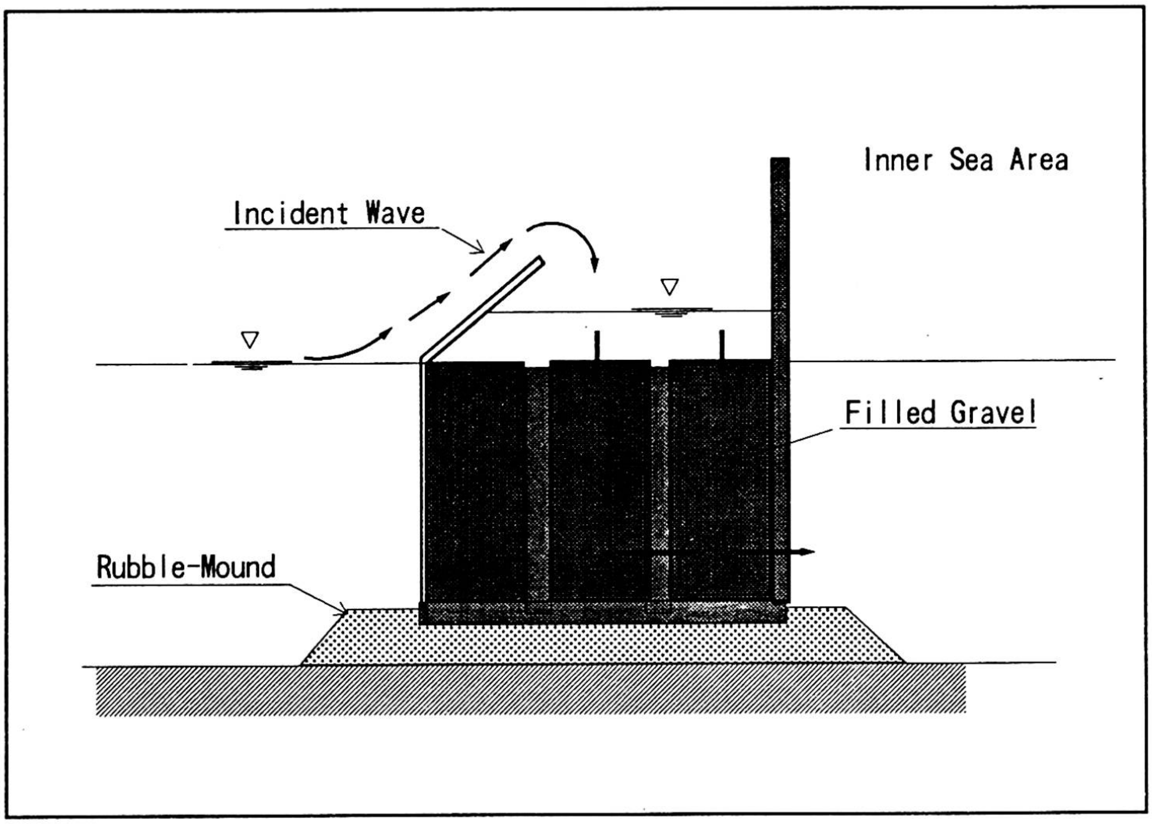


Fig. 12 Conceptual drawing of hybrid clean-up breakwater structure

4.2 Marine Environment Assessment Technology

By marine environment assessment technology is meant a system for grasping current states of water quality, beaches, etc., predicting future changes, or evaluating maintenance and control. This system is still in the process of development, but Fig.13 gives an example of an assessment made of the possibility of water quality preservation in case of a large-scale marine resort development in Nagasaki Prefecture, where a simulation was made of sea water exchange and distribution through tides in artificial channels. Such water quality prediction and techniques for simulation of seashore changes will become increasingly needed at the planning stage of marine development.

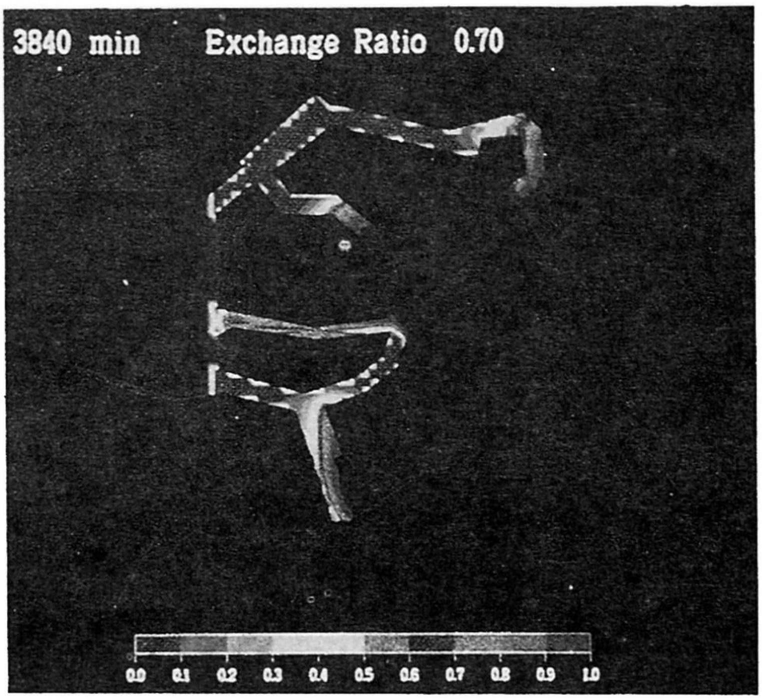


Fig.13 Simulation of sea water exchange distribution in artificial channels

5. CONCLUSIONS

The examples which have been given here are all of technologies or facilities with specific purposes or functions. However, the respective basic conceptions are not for only functional properties, or economic natures to be given first priority; they have the features of "creating an environment compatible even the least bit with the lives of people and ecology." From a technical standpoint, the principal aim is to overcome severe natural conditions such as great water depths, high waves, and very soft ground, but considerations are also given to ecological systems of sea areas. However, these measures are very inadequate as yet, and the technologies now available are still insufficient. For example, these short-comings must be met through introduction of advanced technologies such as biotechnology and new base materials, with these ingeniously combined to fit regional needs.

As a backup for this, it is indispensable for there to be R&D through cooperation between industry, government, and academe of civilian leadership type and cooperation between different fields of business. Lastly, at this time when the topic of the global environment has become a matter of international concern, the author wishes to state that it is his desire to deal with marine development carrying from the point of view of creative engineering friendly to the marine environment." It would be gratifying if this paper were to provide some kind of hint in contemplating marine development of the future.

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