

Overview of Mega-Float and Its Utilization

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The Mega-Float, a very large offshore floating structure, is regarded as material for structuring of social capital in the new future. Experiments using an actual-scale model 1 000 m long were carried out by Technological Research Association of Mega-Float under Director-General Kentaro Aikawa, Mitsubishi Heavy Industries, Ltd. (MHI) Senior Corporate Advisor. Examples of Mega-Float use include as an airport and as a rescue base for disaster. MHI is conducting unique studies and development in antiwave performance, joining technology for floating units, environmental assessment, very-long-term endurance, and the pursuit of total design by synthesizing respective technologies considered to be keys for realizing practical Mega-Float use.

1. Introduction

Japan is an island country surrounded by sea on all sides and has long benefited from geographical features such as relatively stable climate, marine products, sea transport and many others.

Because the level ground available in Japan is extremely limited, it has been necessary to look for more efficient use of the waterfront to cope with problems such as the rapid increase in population and progress of industry. The progress of technical development has enabled various designs to be implemented in coastline zones and has succeeded in completing infrastructures to meet the needs of the times.

At the beginning of the new century, there is now a growing need to change our sense of values in various aspects. In considering ideal uses of waterfront areas, it is necessary to pay particular attention to conserving the gift of the sea, bearing in mind the basic relationship between human beings and the sea, utilization of seawater as a natural means of supporting heavy weights, modification of reclaimed land in size and shape to flexibly meet future needs, removability of waterfront structures for restoration of the natural coastline (sea-surface restoration) as a possibility in the distant future, as well as recycling of materials resulting from removed structures. All of these requirements suggest the utilization of a very large offshore floating structure (Mega-Float) (**Fig. 1**).

This paper details technical viewpoints regarding the Mega-Float as a new social asset.

2. Features and safety considerations of Mega-Float

The term "Mega-Float" refers to an overall system comprising a very large offshore floating structure inclusive of its mooring and access facilities (bridges, etc.).

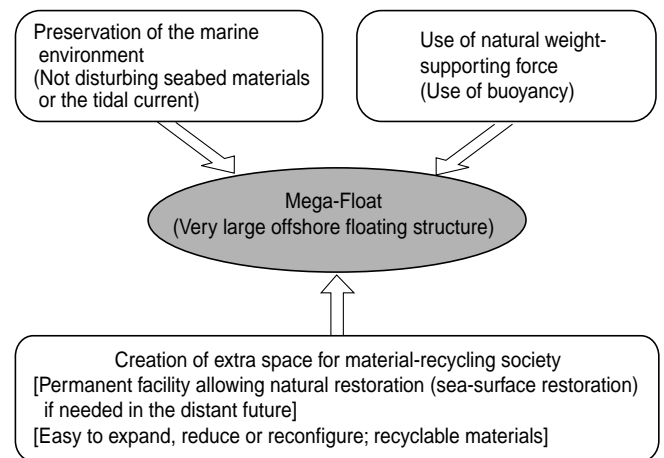


Fig. 1 Features of Mega-Float

This figure shows that Mega-Float has features meeting the needs of the new era.

The Technological Research Association of Mega-Float (Director General, Kentaro Aikawa, Senior Corporate Advisor of MHI), in which MHI participates, carried out the research and development of Mega-Float during the six-year period from 1995 to 2000, constructed a 1 000 meter-long floating structure for verification tests at Yokosuka, Japan in 1999 and collected the data needed for application to a floating airport, on which it had spent about one year by the end of 2000. **Fig. 2** shows a general view of the floating structure constructed for verification tests.

As the top surface of Mega-Float, unlike vessels, is used as the ground, the floating structure should provide a very large surface area. For this reason, it must be constructed by joining the necessary number of floating units together. The Mega-Float construction flow is shown in **Fig. 3**.

Planning and construction of Mega-Float is characterized as follows:

- # It can be constructed with the environmental load kept to a minimum, including little effect on seabed materials and tidal current.

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Fig. 2 General view of Mega-Float model

A 1000 meter-long floating structure was constructed off the coast of Yokosuka for collection of basic data needed for airport application.

- # Construction costs will not be greatly affected by installation conditions such as depth of water, foundation bed, etc.
- # There will be no need to consider ground subsidence.
- # Its earthquake-proof performance (lateral seismic factor: 0) permits construction of the superstructure with less reinforcement against earthquakes (fewer constraints on design and layout of the superstructure).
- # The overall construction period including installation work can be reduced, because installation work is completed by simply joining the floating units together.
- # It can be easily expanded, reduced or relocated and is capable of conforming flexibly to any change of city planning or bay area planning that may be enforced in the future.
- # It provides a very large interior space that can be used as required.

To construct such a large floating structure, it will be necessary to obtain public understanding and recognition on some points for example:

(1) Is there a possibility that it will sink?

As Mega-Float is very large, it will not capsize like a ship. The interior of the floating structure is divided into many buoyancy air-chambers to cope with any accidental leaks of water. Even if water leaks in one or two buoyancy air-chambers, the neighboring chambers will provide sufficient buoyancy to completely protect the entire assembly of Mega-Float⁽¹⁾.

(2) Will it roll with the movement of waves?

Ships and floating piers pitch and roll with waves when their entire structures ride on water

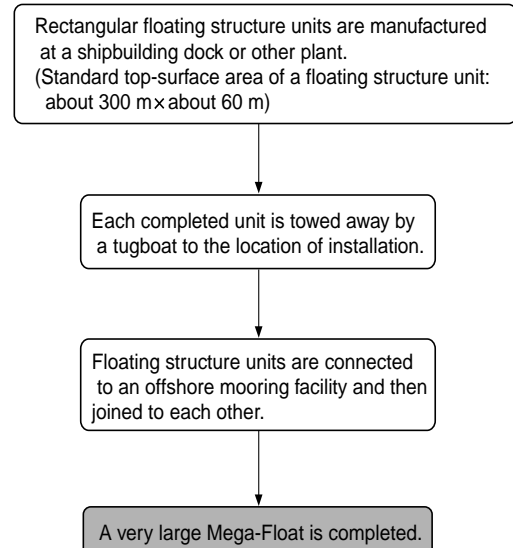


Fig. 3 Flow of construction of Mega-Float

The distinctive feature of Mega-Float is that it is assembled on the water surface by joining the necessary number of floating units together.

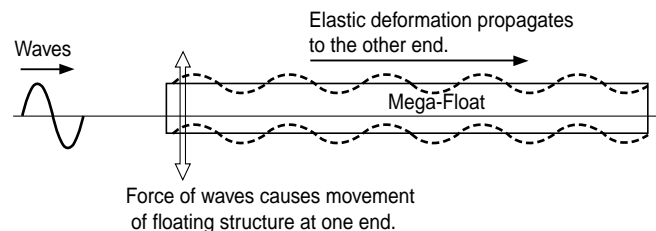


Fig. 4 Mechanism of elastic response (conceptual profile)
Elastic response means dynamic, elastic deformation of structure.

surface in vertical motion or on an inclined water surface. However, in the case of Mega-Float, its very large structure covers many cycles of wave crests and wave troughs, causing the waves to cancel each other out, and is therefore not affected by the movement of waves under it.

A very small local deflection phenomenon, which is obscured by overall movement in the case of ships, occurs in Mega-Float. This phenomenon, known as "elastic response"⁽²⁾⁻⁽⁵⁾, is an oscillatory propagation of local deflection caused by waves from one end of the floating structure to the other, as shown in **Fig.4**. Though the movement caused by this phenomenon is so slight that it can hardly be noticed, it will be taken into account to assure the function of the superstructure. Furthermore, metal fatigue is being studied to ensure the durability of Mega-Float for longtime service.

(3) Tsunami is one of the most dangerous types of wave. Will Mega-Float be safe even in the event of tsunami?

Generally, the wave height of tsunami reaches its maximum level at the moment when the waves race up on to the shore, due to the shallow water

effect. As the waves of a tsunami have tremendous kinetic energy, they can go far on to the land and cause heavy damage. Because Mega-Float is installed on the water surface where the depth of water is sufficient to support it, the tsunami waves passing under the floating structure act on it as the water surface gently moves up and down at such a long periodic time as some tens of minutes. Accordingly, the floating structure will move up and down gently following the movement of the water surface, and the tsunami waves will not immerse or apply any destructive force to the floating structure.

(4) What could constitute a critical situation that would endanger the safety of Mega-Float?

It is believed that the design safety features of Mega-Float ensure against any foreseeable risks arising from meteorological or marine conditions. However, as Mega-Float is a novel structure in various senses involving innovative techniques, the question is how to anticipate and cope with the occurrence of phenomena that exceed the foreseeable scale of nature. It is planned to discuss this problem from the methodological and logical viewpoints, dividing it roughly into the following

two categories:

(a) Multistage reliability

The reliability of Mega-Float should be ensured in a multiple fashion by combinations of: applying an adequate safety factor under design conditions, a failsafe system for avoidance of a catastrophic situation, and recovery of facilities by checking and repairing activities.

Fig. 5 shows an example of the concept of multistage reliability against risks of an airplane accident when Mega-Float is used as an airport.

(b) Monitoring and feedback program

Because Mega-Float is a novel structure, conducting a follow-up survey of the actually operating facility and feeding back the data thus collected for use in improvement of maintenance will be a very effective means of ensuring the definitive safety of Mega-Float. Therefore, the detail principles of such monitoring and feedback activities should be established beforehand.

For the longtime durability of Mega-Float, MHI will make decisions on the basis of the data collected from various longtime durable floating structures con-

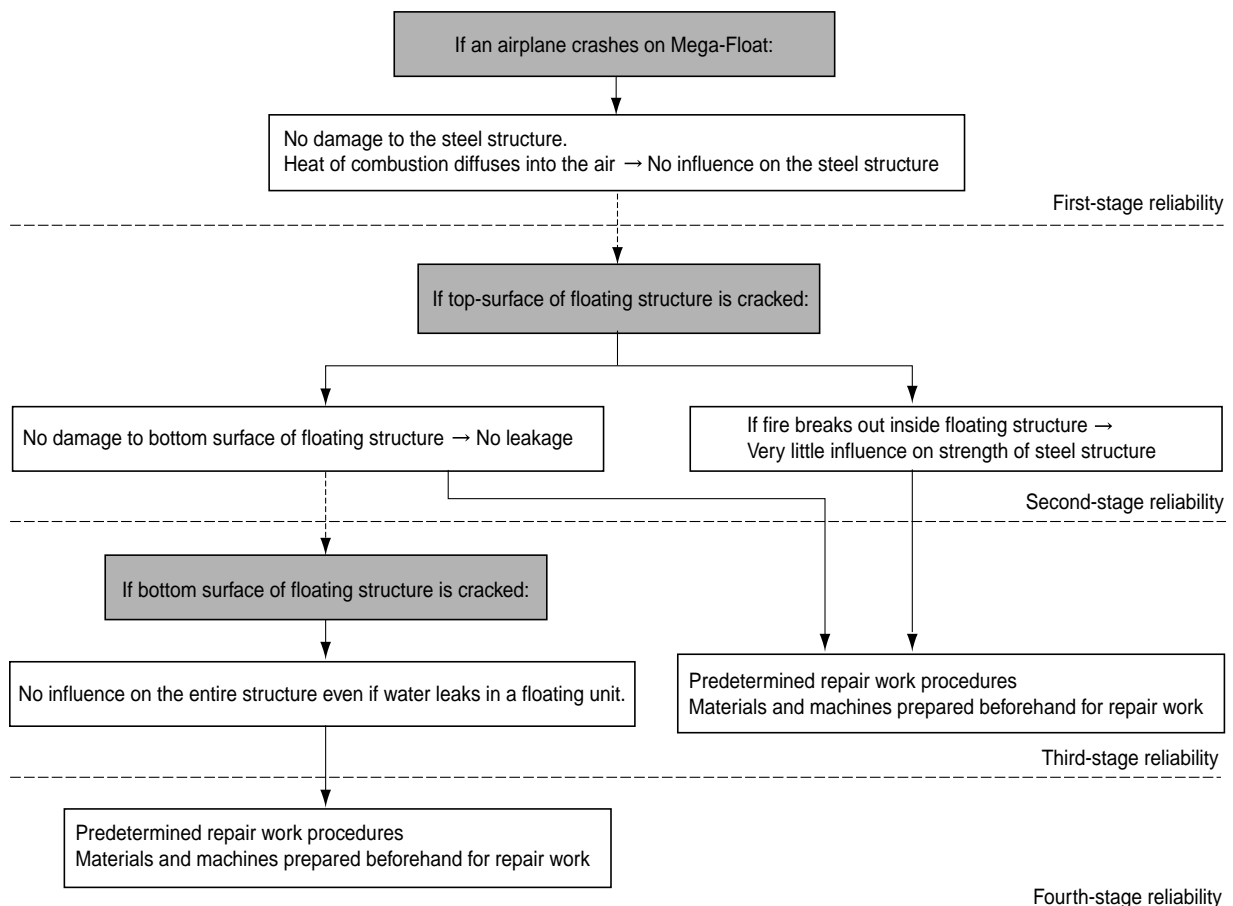


Fig. 5 Conceptual example of multistage reliability (an example of the measures against airplane accidents)
As Mega-Float is a novel structure, careful considerations must be given to structural design, especially to securing it against damage in case of airplane accident.

Table 1 Examples of moored floating structures constructed by MHI

Name	Type	Year of construction	Start of mooring	Location	Use
Hikawa Maru (Oceangoing passenger ship)	Vessel	1930	1961	Port of Yokohama	Preservation
Hakkouda Maru (SEIKAN ferryboat)		1964	1990	Port of Aomori	Memorial ship
Mashuu Maru (SEIKAN ferryboat)		1965	1991	Port of Hakodate	Memorial ship
Taisetsu Maru (SEIKAN ferryboat)		1965	1996	Port of Nagasaki	Hotel ship
AQUAPOLIS (Okinawa EXPO)	Offshore structure	1975		Okinawa	Marine city model
Kamigoto Island, offshore oil storage vessel		1986		Kamigoto, Nagasaki	Offshore oil storage system

(Note) Shirashima Offshore Oil Storage Vessel (Fukuoka), a large recently constructed floating structure, is not included in this table.

structed by MHI, as listed in **Table 1**.

3. Utilization of Mega-Float

Generally, construction of Mega-Float is executed using the most suitable method for the type of facility and taking into account the economic, technical and environmental protection requirements. Mega-Float offers the following uses:

(a) Large airports

In planning the construction of a new airport close to an urban district, a location slightly offshore is in many cases advantageous to the construction site of the airport in view of the problems of aircraft noise in the residential area and the allocation of flight zone for other existing airports. However, in cases where the reclaimed land has extended far into the sea, the area of its frontage is in deep water and includes weak ground. In such cases, construction of Mega-Float can provide an advantageous solution.

(b) Local and island airports

When sufficient level ground is not available for

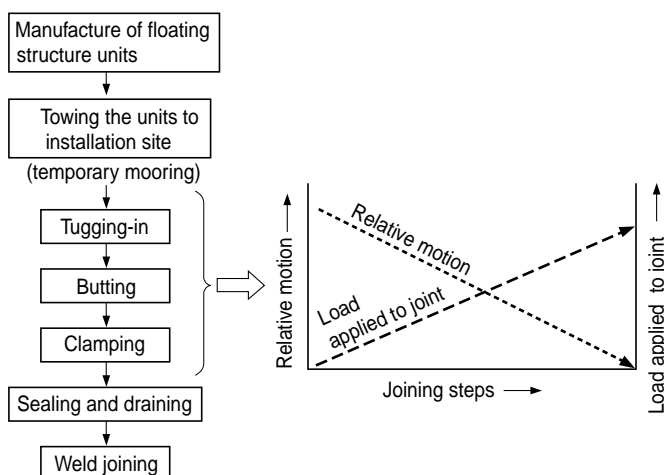


Fig. 6 Floating joining procedure and relation between load applied to joint and relative motion of floating unit

Load applied to constraint mechanism increases with constraint of relative motion of floating structure units.

the construction of airport, a mountainous zone or the sea will be selected for the construction site. In this case, construction of Mega-Float will be advantageous from the viewpoint of conservation of natural resources.

(c) Rescue base in event of disaster

Due to its complete earthquake-proof feature and high mobility to heavily damaged disaster areas, Mega-Float can function as an efficient rescue base for disasters (pilot facilities have been completed already in the bays of Tokyo, Ise and Osaka).

(d) Other applications

In addition to the above, Mega-Float can be used as a distribution center, plant facility, amusement facility and others. The Mega-Float technique, now nearing completion, will soon be a new alternative means of constructing marine facilities.

4. Floating execution technology

Construction of Mega-Float is carried out afloat by a combination of ocean civil engineering and shipbuilding technology which have been refined by the industries of Japan. It should be noted especially that a floating joining technique is used to join the units of floating structures together. There have been some examples of similar construction work executed in past shipbuilding operations, though they were smaller in scale. MHI is conducting further research and development of various techniques needed to satisfactorily construct a large-scale Mega-Float in more violent sea conditions.

Floating joining work is carried out in steps, as shown in **Fig. 6**. The following are the key techniques used in these steps⁽⁶⁾⁽⁷⁾.

(1) Tugging-in step to clamping step

The load applied to the constraint mechanism increases with the number of floating units to be clamped to it. Therefore, there is a need to develop a new constraint mechanism that will allow the floating units to be clamped to it efficiently one

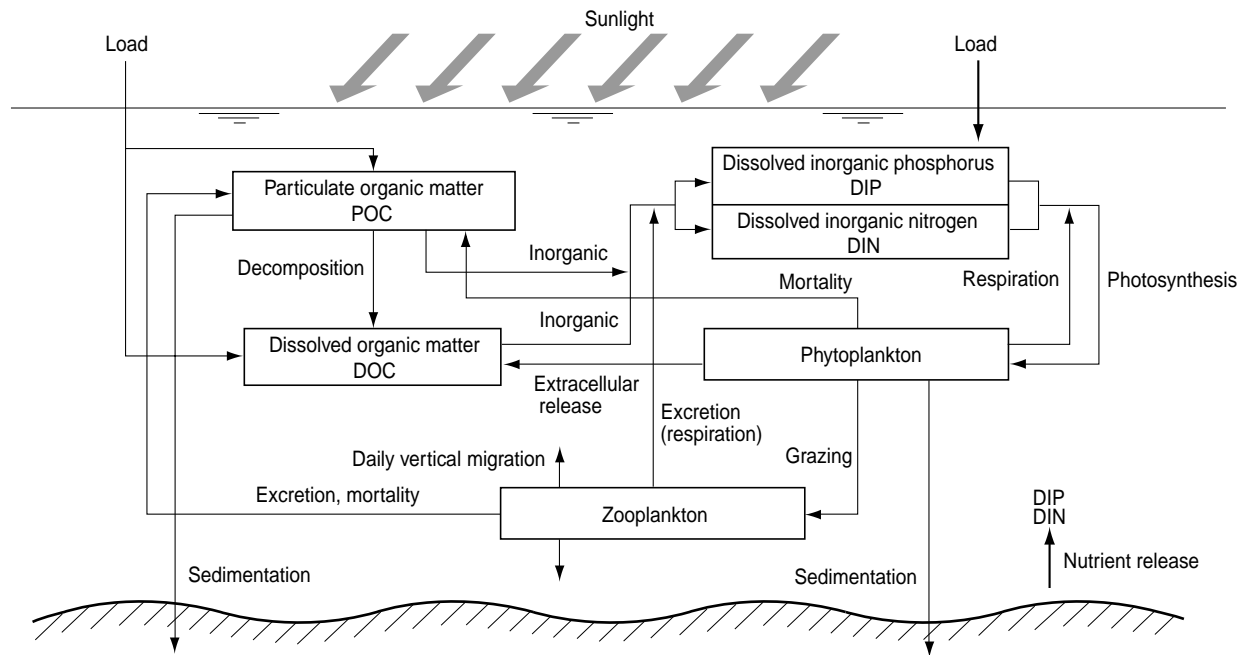


Fig. 7 Concept of coastal marine ecosystem model
Ecosystem model shows interactions taking place in each compartment.

after the other.

It will also be important to precisely analyze the thermal deformation of the floating unit and its motion with the waves, and reflect this effect in the construction of floating structures.

(2) Sealing and draining

In order to ensure the accuracy of welding for joining structural members located below the water surface, welding work will be performed in the air after removing sea water from the inside of the structure using a suitable draining method.

(3) Weld joining

For the purpose of quality assurance, work and inspection procedures are being prepared for weld joining work performed under special circumstances.

The key techniques described above have been basically verified by constructing a floating structure for verification tests, but they will be improved further through continued research.

5. Environmental assessment technology

The offshore floating structure proposed here provides a very large top-surface area, but its influence on water flow in the peripheral area is believed to be relatively small because of its small draft with respect to the depth of water. Regarding influence on the ecosystem, where there is sufficient flow of water through the location of the floating structure, even if phytoplankton just below the structure temporarily becomes less active, it will regain its activeness immediately after drifting away from the bottom of the floating structure. Similarly, the quality of water and seabed materials just below the floating struc-

ture will not be influenced if water flows in the sea area for the installation.

The influence of a floating structure on the natural environment, as mentioned above, relates closely to the topography of the seabed in the installation area and the flowing condition of sea water in the peripheral area and other conditions. To estimate the influence of a floating structure on the natural environment, it is first necessary to understand the possible effects of the floating structure on the flowing condition of sea water in the installation area through experiments⁽⁸⁾⁽⁹⁾ and calculations. The experimental method will give direct data but it requires equipment and time. Therefore, the numerical calculation method (e.g. ⁽¹⁰⁾) is used in many cases, because the necessary data can be obtained within a relatively short period of time by use of computers, the performance of which has recently made rapid progress.

Fig. 7 shows a conceptual model of a marine ecosystem. Various phenomena of a marine ecosystem which may occur in the sea area selected for installation of a floating structure can be predicted and evaluated by analyzing the interactions of the ecosystem-related phenomena in respective domains. **Fig. 8** shows a calculated result⁽¹¹⁾ of changes in the distribution of phytoplankton if Mega-Float were to be installed in Tokyo Bay. The result of calculations suggests that the installation of Mega-Float has little effect on the natural ecosystem.

It has been verified that the predictive calculation method used here is accurate enough for practical applications by comparing the calculated results with

those obtained from hydraulic model testing and experiments conducted in the actual sea area. This method can therefore be used for the environmental assessment of any other sea area where Mega-Float is planned to be constructed in future.

6. Trends of development of new technologies

6.1 Expansion of applicable sea area

As has been mentioned, elastic response is the key feature to Mega-Float in strength and performance. Depending on the surface conditions of the sea area, a breakwater may need to be built to reduce the elastic response of Mega-Float. However, building a breakwater considerably reduces the advantages of Mega-Float technology, because a breakwater will hinder replacement of seawater and its building cost varies with the depth of sea and composition of the seabed.

For the purpose of fully utilizing the advantages of Mega-Float, research is being carried out to find a possibility of eliminating or minimizing the breakwater to the extent of allowing ingress of high wave height and long wave period by adding an ancillary structure (response suppression mechanism) to the floating structure itself so as to reduce elastic response⁽¹²⁾. **Fig.9** shows the efforts directed to the development of a response suppression mechanism for suppression of elastic response.

A mooring facility is required to hold a floating structure accurately in the given position. The so-called "Dolphin-fender system" is used to moor

Carbon content derived from phytoplankton (mg/m³)

500 1500 2500 3500 4000

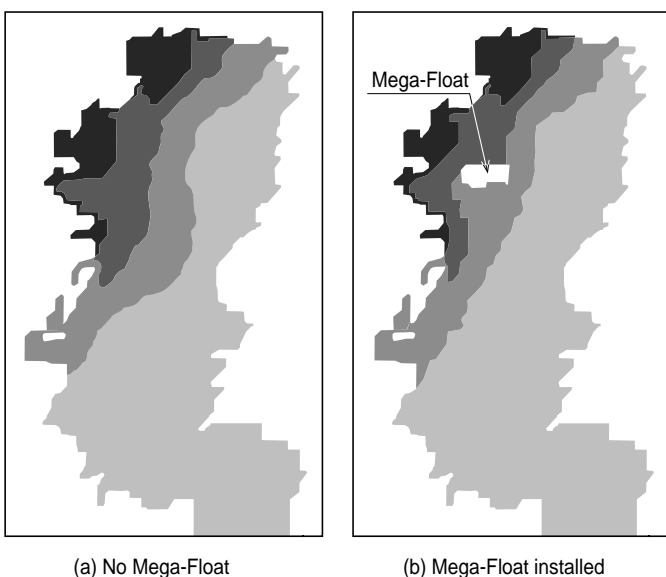


Fig. 8 Effect of Mega-Float installation on horizontal distribution of phytoplankton

This figure shows that Mega-Float installation has little effect on ecosystem (phytoplankton).

floating structures in a location relatively near the land, and this has been practically applied for mooring the floating oil-reserve systems constructed offshore from Kamigoto Island and Shirashima Island. The adoptability of this mooring system will be limited by the constraints of civil engineering and substantial increase in construction cost when the depth of water is 30 meters or more. In offshore areas deeper than 100 meters, the catenary (suspension-chain) mooring system is widely used for oil drilling rigs and similar facilities. However, it is difficult to ensure the safety of this mooring system when used in shallower areas with violent wave conditions, because its mooring mechanism is subjected to excessively large force.

Taking into account the mooring techniques currently available, MHI will direct research for the completion of a next-generation mooring system suitable for use in shallow sea areas ranging in depth from 30 to 100 meters with ingress of ocean waves and, at the same time, having good cost effectiveness and reliability⁽¹²⁾. MHI's effort directed to the development of a new mooring system is shown in **Fig.10**.

6.2 Operation for joining many floating units together

6.2.1 Joining mechanism

Mega-Float is assembled on the sea surface by join-

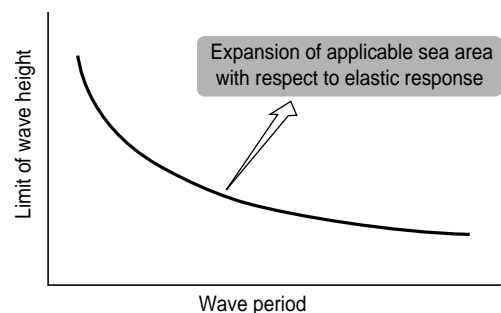


Fig. 9 Conceptual direction of development of measures for reduction of elastic response by attached structure

Aiming at development of a damping mechanism against ingress of slightly high waves with long periodic time.

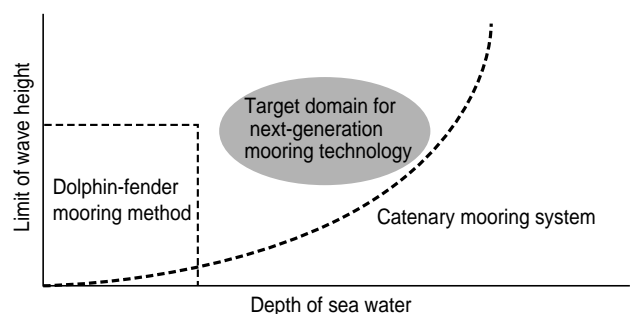


Fig. 10 Conceptual direction of development of next-generation mooring technology

MHI aims to complete of a next-generation mooring system suitable for use in sea areas 30 to 100 meters deep with ingress of ocean waves.

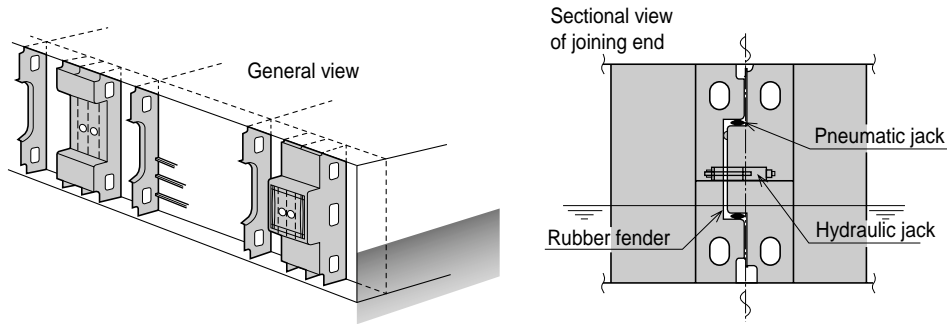


Fig. 11 Proposed joining method
 An example of joining mechanism which was used in the floating structure for verification test and showed good separating performance.

Table 2 Patterns of joining and separation

Operating pattern	Normal use	Separated	Joined	Joined
	Relocation	Separated	Separated	Separated
	Disaster use	Joined	Separated	Joined
Scheme				
Concept	Outline (example)	Normal use: Used as floating parks or similar facilities of adequate size in some urban areas. Disaster use: Towed to a heavily damaged disaster area and joined together to form a wide-area rescue base.	Normal use: Used as playground and sports facility. Disaster use: Separated and towed individually to disaster areas along rivers or waterways to form local rescue bases. Loaded with power generators, water supply plant, emergency necessities and other materials inside the floating structure.	Maintained as a well prepared wide-area rescue base with trained crew in normal times. Featuring high mobility for relocation to heavily damaged disaster areas or other places as needed.
	Versatility for normal use	○	○	
	Mooring to the most convenient place in case of disaster use	○	○	○
	Dispatch to other places	○		○

ing the floating structure units together, as already mentioned. MHI is studying a system that will make it possible also to separate part or whole of the floating structure.

The basic plan is to eliminate welding work from the joining procedure afloat and apply a tougher coupling mechanism to join the floating units together.

The welding-free mechanical joining method has already been put to practical use for many floating structures, but it is not always designed on the assumption that they can be separated without difficulty in high wave conditions. The joining method being developed by MHI is intended to allow both joining and separating of floating units as desired, thus enabling the applications of floating structure to be increased.

Fig. 11 shows an example of a joining mechanism⁽⁷⁾ that was used on a floating structure for verification tests and showed satisfactory performance.

6.2.2 Example of use as disaster rescue base

As an example of a new application, a floating structure can be used as disaster rescue base by combining the floating unit separating technique now under development and the mobility of a floating structure. Relocation of a large structure such as Mega-Float can be realized when the technique to join and separate floating units is completed. In a sense, the mobility of large-sized floating structures depends largely on this joining and separating technique.

As shown in **Table 2**, the operation of Mega-Float is roughly divided into three different patterns by joining and separating mode. They are: (1) Separated for normal use and joined together for disaster use, (2) Joined together for normal use and separated for disaster use, and (3) Joined together for normal and disaster use but separated during towing for relocation. Typical features of each operating pattern are outlined in this table. In connection with the topics

of discussion concerning "wide-area rescue support" in the event of disaster, "utilization of floating structure for normal times," etc., the separable large-sized floating structure proposed here will be an important means of arranging wide-area rescue bases for emergencies.

7. Conclusion

In addition to conducting research⁽¹³⁾ as a member of the Technological Research Association of Mega-Float, MHI is developing its own technology in this field of industry. For this purpose, MHI regards the following subjects as elementary technologies:

- # Technology to improve anti-wave performance
- # Floating unit joining technology
- # Environmental assessment technology
- # Very longtime endurance technology

In addition to the above, MHI attaches great importance to consolidating these elementary technologies in pursuance of a total design suited to meet the needs of present-day society.

In the rearrangement of social assets for the new age without hindrance from conventional ideology, what society most requires in the technological development sector will be the creativity of dreams, consolidated technological competence in making effective progress by means of conventional technologies, and the ability to communicate with society for the realization of developed technologies.

Paying attention to each of these points, MHI will continue to contribute to the realization of the construction of Mega-Float in cooperation with the parties concerned.

In closing this paper, MHI expresses its sincere thanks for the use of some of the results of research conducted by the Technological Research Association of Mega-Float.

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