Realizing the world's first floating airport

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The six-year plan launched in 1995 to research and develop the Megafloat has entered its second phase. A 1,000 m by 60-121 m floating airport model has been constructed in Yokosuka Bay and is now ready for takeoff and landing tests. Thus, the world's first full-scale field trial of a floating airport has begun using this, the largest floating structure in the world built in Japan using the country's most advanced technology. The field trial is expected to have a major impact on new infrastructure development.

FROM BASIC RESEARCH TO APPLICATION TECHNOLOGY

The advantages of large floating marine structures, such as the ease with which artificial land can be developed even in deep waters and on a soft seabed, the ability to isolate earthquake motion, and relative environmental and ecological friendliness, have encouraged many firms to pursue research and development into the Megafloat concept since the 1970s. The realization that a large-scale field trial would be vital to the full actualization of a Megafloat led 17 major companies in the shipbuilding and steel industries to establish the Technological Research Association of Mega-Float in 1995 with support from the Ministry of Transport and the Japan Foundation. With the cooperation of relevant organizations in the industrial, government, and academic sectors, the association completed the development of the basic technology using a 300 m long floating model in the three years following 1995. Work to experimentally verify the Megafloat concept for airport use using a 1,000 m floating airport model commenced in 1998.

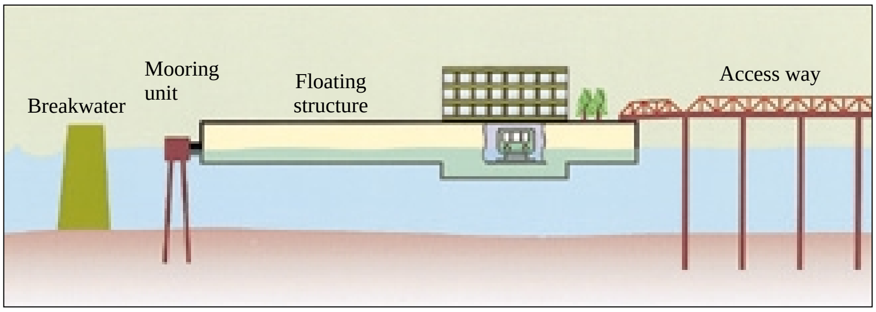

Fig. 1 Conceptual drawing of Megafloat

Table 1 Elastic response analysis programs

	Structural analysis	Hydro-dynamic analysis	Boundary conditions		Floating body configuration	
			Breakwater	Water depth	Top	Bottom
Simplified calculation	Beam theory	Strip method	—	Constant Finite water depth	Beam	Constant draft
Approximate 3-D analysis	Ritz method	Domain decomposition method	Possible	Constant Finite water depth	Rectangle	Constant draft
Detailed 3-D analysis	FEM	Domain decomposition method + FEM	Possible	Arbitrary seabed roughness and arbitrary water depth	Arbitrary	Arbitrary

DESIGN OF VERY LARGE LOW-PROFILE FLOATING STRUCTURE

A Megafloat consists of a breakwater, the main floating body, a mooring unit, and an access route to land, as shown in Fig. 1. Because the entire floating body, which is of unprecedentedly low-profile structure for its expanse, exhibits elastic behavior on a tiny scale under external loads such as wind and waves, new analytical techniques have become necessary. In the design phase, for example, various elastic response analysis programs were developed to analyze its behavior, as listed in Table 1. With respect to seismic loading in the form of waves, these programs take into account changes in water level and wave velocity. In many cases,

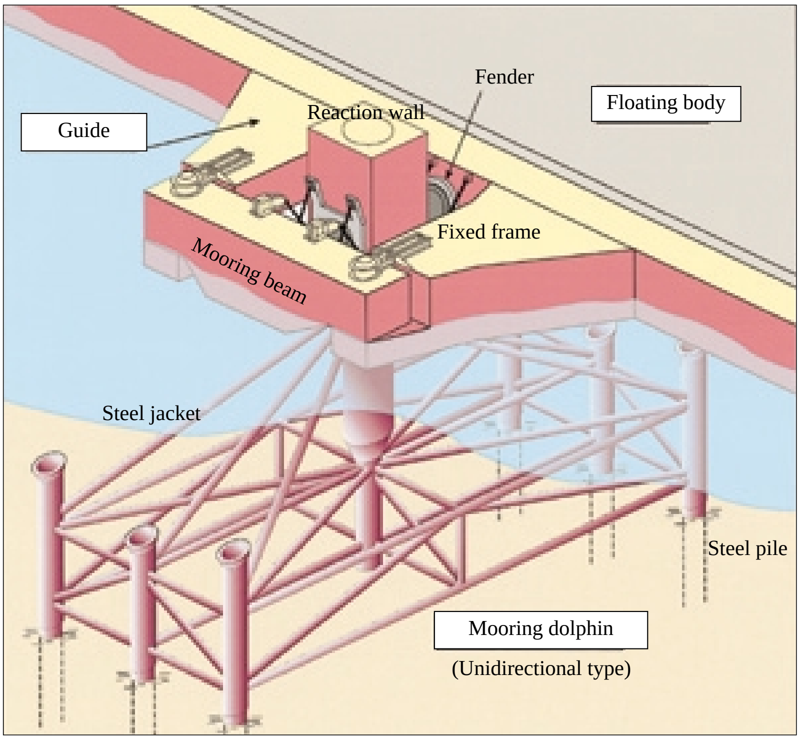

Fig. 2 Mono-pod fender-type mooring dolphin


Photo 1 Steel jacket of mono-pod fender-type mooring dolphin

the actual structure of a floating body to be deployed in a bay is determined by the waves that the bay experiences.

The main requirement of the mooring unit is that it should constrain the large floating body safely under the forecast natural conditions while keeping movement of the body within safe limits that meet the requirements of its application. Typically, a fender-type mooring dolphin allowing little movement is suitable. In the case of the floating airport model, a mono-pod fender-type mooring dolphin was adopted as the mooring unit. With this design, the fender fitted to the floating body acts against a reaction wall at the top of the dolphin to limit back-and-forth movements, as shown in Fig. 2 and Photo 1. The ultimate strength of the mooring unit was calculated by push-over analysis as the ultimate state was approached, as shown in Fig. 3, and it was verified that the unit had a sufficient margin of safety.

JOINTING LARGE FLOATING UNITS AT SEA

The floating units comprising the Megafloat were pre-fabricated at multiple shipyards, and so a challenge for the shipbuilders was to ensure accuracy. While fabricating the nine floating units of the 300 m model used in the 1995-1997 experiment, it was verified experimentally that a predetermined accuracy of ±5 mm in length could be achieved through the use of common gauges and carrying out temperature compensation.

The major challenges to joining these floating units at sea were to cope with thermal deformations, wave-induced motion, the need to weld steel components in a marine environment, and cumulative errors arising during installation. In working toward a solution to these various challenges, the following methods and jigs, as illustrated in Fig. 4, were developed: a winch-equipped pontoon method, a jig for controlling up-down motion, a deck-mounted device for drawing in a floating unit with jacks, and a semi-circular jig for joining floating units with prestressing tendons. To correct cumulative errors arising during installation, a method of accurately joining the units while correcting errors was developed using absolute position data obtained from the Global Positioning System (GPS). During the field trial, it was shown to be possible to correct for cumulative errors by a process of on-site cutting and joining, and this method opens up the prospect of linking floating units into long floating structures up to several kilometers with an accuracy of a few centimeters. Photo 2 shows a public demonstration of how floating units are joined at sea.

100-YEAR DURABILITY

Megafloat will be expected to have a lifetime of more than 100 years, as is the case with most large-scale infrastructure, so corrosion protection and maintenance methods were developed to ensure it would

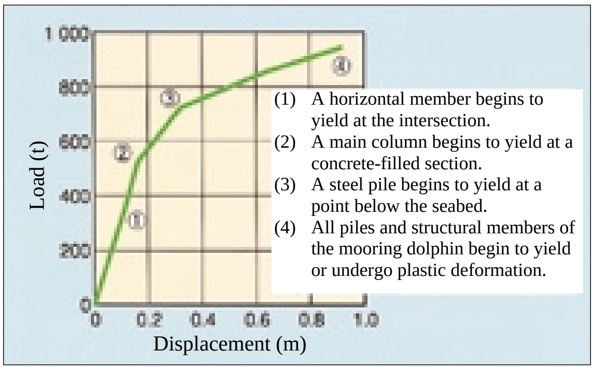

Fig. 3 Ultimate strength of mooring dolphin

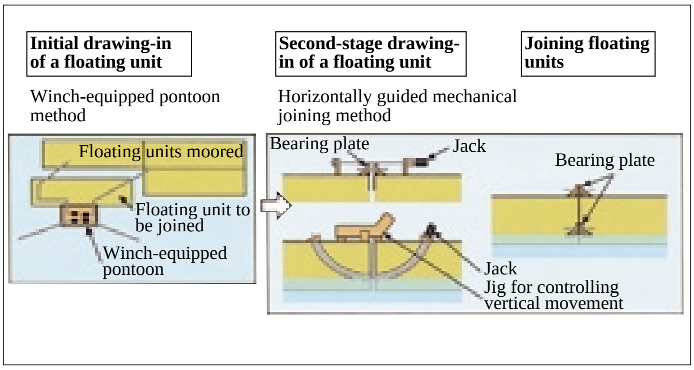

Fig. 4 Methods of drawing and joining floating units

last this long. The situation is different from ship maintenance, which may be carried out in dock, since Megafloat maintenance must take place at sea. Accordingly, maintenance-free corrosion protection methods, such as titanium cladding of splash zones, were adopted, and a monitoring system of welds and the submerged underbelly on site were developed. The practicability of these methods was validated during the field trial. Photo 3 shows an underwater welding machine, as developed for implementing underwater repairs, during experiments in overhead work.

Photo 4 shows a prototype submerged maintenance machine for use in the inspection and repair of the underbelly. This unit proved able to move into a desired location, replace sacrificial anodes, or cut away and weld exterior plates under dry conditions.

FIELD TRIAL WITH FULL-SCALE MODEL AIRPORT MODEL

The idea of using a huge floating structure as an airport was first proposed in the 1920s. Finally, for the first time in the world, a full-scale floating airport has been constructed as a model and a field trial using actual aircraft is now under way to determine whether such an airport is actually workable. The model airport has a 1,000 m runway for use by commuter aircraft and floats in an average water depth of 20 m, thus fulfilling the requirements of a trial.

After completing a geological survey in June 1998, the fabrication of floating units for the airport began in July 1998. Field work then started in May 1999, and the 8.5-hectare floating structure was completed in late August, 1999. A control tower and instrumentation room have been built on the floating units, and the airport will be ready for takeoff-and-landing trials upon completion of the runway pavement.

An instrument landing system (ILS/LLZ, GS) and precision approach path indicator (PAPI), as used at land-based airports, have been installed, and these are now being tested to see if the system is capable of providing the air-traffic services needed for aircraft to use the floating airport. Photo 5 shows a low-approach flight tests using a flight checker aircraft designed to check the instrument landing system for proper functioning.

Further, a general-purpose approach to the simulation of airport functions has been developed, and this will be tested during the field trial to verify that Megafloat can be scaled up to international airports capable of handling large jetliners. In advance of this verification work, the vertical displacement of the air-


Photo 2 Public demonstration of joining operations in July 1996

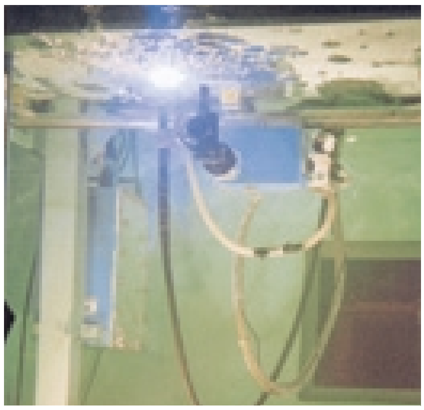
Photo 3 Underwater welding machine during experiment in overhead position

port model due to tidal changes and the swaying of navigation beams due to wave motion are being modeled on a flight simulator, as shown in Photo 6, as used for training Boeing 747-400 pilots. The simulator is now in use to train active pilots and check the view of approach lights and deck movements during landing. Photo 7 shows a view from the cockpit of the flight simulator when landing on the floating airport.

There are no real-world examples of paved floating runways, although the runway is similar to a paved, steel floor slab bridge, so a joint research study was carried out with the Runway Research Section of the Port and Harbor Research Institute of the Ministry of Transport. As shown in Fig. 8, an automatic-loading traveling test machine with a loading capacity of 93 tons, which is equivalent to the load imposed by the main landing gear of a Boeing 747, was used to carry out durability tests on various types of runway pavement.

FUTURE PROSPECTS

We anticipate that the Megafloat concept will find widespread application in major international airports. For this to happen, however, the current field trial investigating the safety of aircraft landings and take-offs will have to be augmented by investigations of the constructability and functionality of airport facilities such as passenger service facilities, flight terminals, airplane maintenance facilities, fuel supply and storage facilities, and air freight facilities. Technical studies are scheduled to move forward to cover these issues in the future.

For the Megafloat concept to find its place among the infrastructure, safety and reliability will have to be fully reviewed, and changes will have to be made to laws. The Committee on Commercialization of Megafloat was established within the ministry to discuss utilization technology for airports, a comprehensive reliability evaluation system, and law amendments aiming at actualization of Megafloat systems.

More about Mega float on the website at: http://www.dianet.or.jp/Mega-Float/

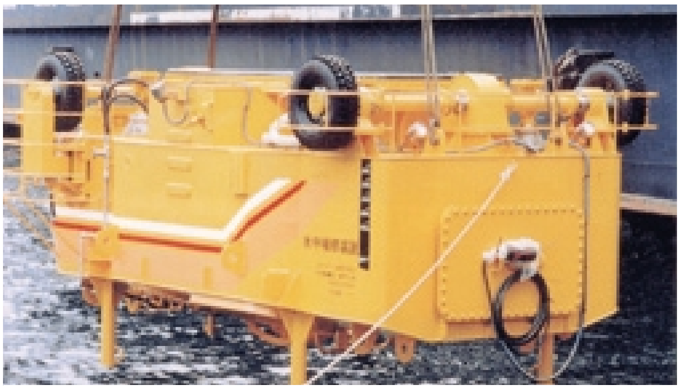

Photo 4 Prototype underwater maintenance machine

Photo 5 Low-approach flight tests to check proper functioning of instrument landing system on floating airport model

Photo 6 Flight simulator

Photo 7 View from cockpit of flight simulator during landing on floating airport

Photo 8 Durability test on pavement of floating airport runway model