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A New Movable Floating Bridge Project in Osaka City

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Summary

The world's first swing and floating bridge is under construction in the Port of Osaka. It will be completed in the year of 2000 to connect two reclaimed islands. The bridge rests on two hollow steel pontoons and is supported horizontally by rubber fenders and dolphins. Investigated herein are many impotant engineering problems such as the dynamic response to the wave, wind, earthquake and vehicle loads. The bridge can be regarded as a high-tech bridge based on the advanced technology opening vistas onto the 21st century.

1. Introduction

A new movable floating bridge is under construction in the Port of Osaka. The main function of the bridge is to connect two reclaimed islands(i.e., Maishima and Yumeshima) across a waterway for the development of these islands. Though Yumeshima island is presently being reclaimed, it will serve as a residential and commercial area. The width of the waterway between the two islands is about 400m. This sub-waterway called "Noth waterway" will replace the main waterway of the Port of Osaka nearby in the case of the occurrence of some unforeseen accidents or events there. On such an occasion, large-sized vessels will need to pass the sub-waterway. In addition, the soil foundation of the reclaimed islands does not seem to have enough rigidity to resist the horizontal movement in case of the conventional bridge. Therefore a movable floating bridge with two pontoon foundations and at the same time swing type has been conceived for its functional and economical reasons. In addition, the construction period is short because the erection is done in a dock by the temporary supproting method and the nearly completed bridge will be towed to the erection site by the tugboats.
Presented herein is a brief summary of planning and experiments conducted.

2. Characteristics of Bridge

The ordinary fixed bridges or movable bridges with foundations fixed to seabed, such as swing bridge, bascule bridge, rolling bridge or transporter bridge have been investigated and assessed. It is concluded from the comparative study that those ordinary bridges will be difficult or economically infeasible; in stead, a bridge with two pontoon foundations of the swing type(Fig.1) is proposed to be adopted as the first of this kind in the world.

The new bridge has been temporally named "Yumeshima-Maiahima Bridge" after the name of the reclaimed islands near the site (Fig.2). It has the total length of 940m and the width of 38.4m with 6 lanes as shown in Fig.3. The floating part has the length of 410m and the main span length of 280m with double-arch rib construction standing on two steel hollow pontoons. The transitional bridges are installed at the both ends of the floating bridge to connect the approach bridges supported on the grounds and the floating bridge following the change of sea surface due to tidal change.

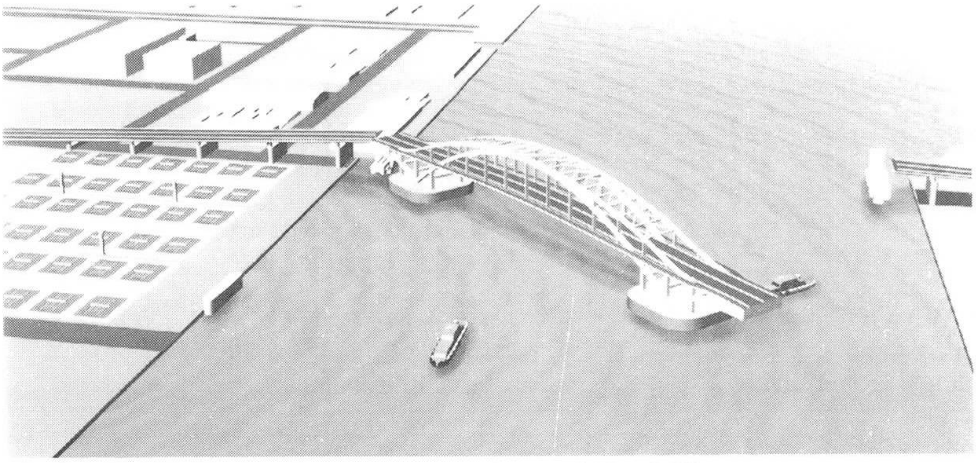


Fig. 1 The Yumeshima-Maishima Bridge and North Waterway

From the view point of the use of lands, only relatively small ships are usually allowed to pass the waterway under the bridge. However in the case of occurrences of some unforeseenable accidents or official events there, this waterway is to replace the main waterway nearby. The bridge will swing about the axis near the end of the floating part at Maishima side and the width of 200m in sub-waterway will be secured to pass large-sized vessels on such occasion.

The bridge is usually held securely by the clamped walls through the rubber fenders provided on the webs of the girders(Fig.4). The design specifications and dimensions are shown in Table 1.

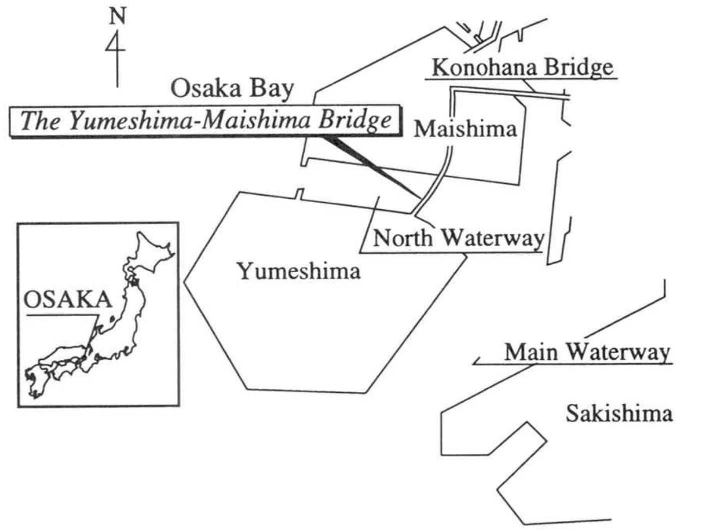


Fig. 2 Reclaimed Islands of Maishima and Yumeshima

The dynamic responses to the waves, winds and strong earthquake

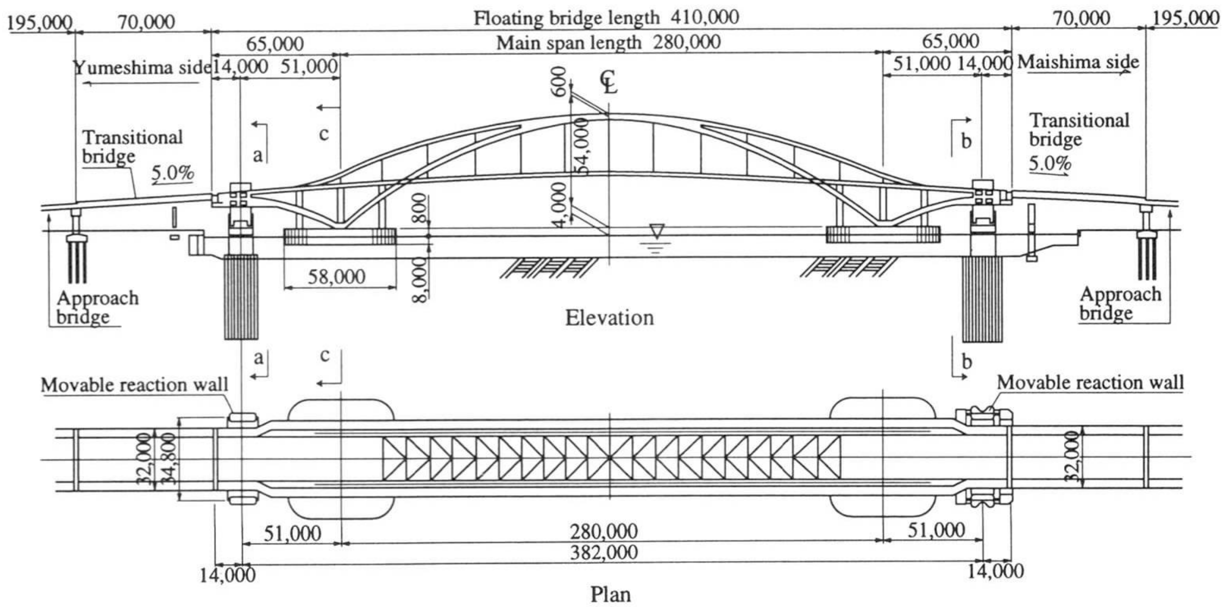


Fig. 3 The General View of The Yumeshima-Maishima Bridge

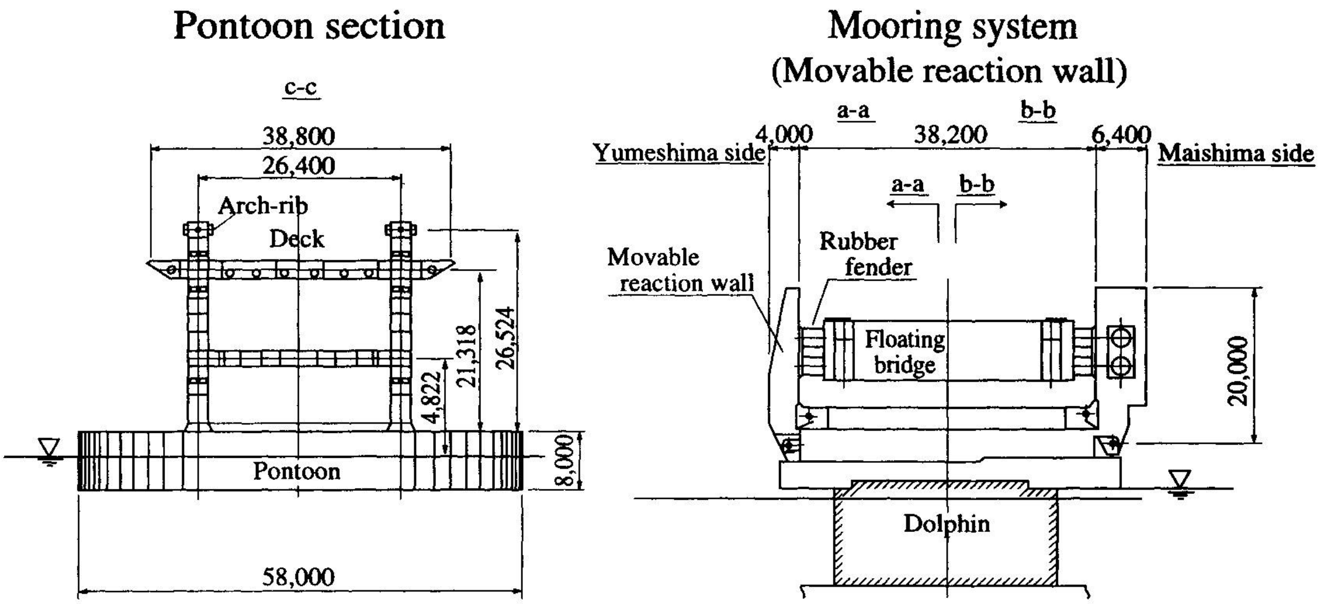


Fig. 4 Pontoon & Mooring System

Table 1. Design specifications and approximate steel weight

Bridge type	Movable swing floating bridge			
Road standard	Grade 4, Type 1			
Live load	B live load	Wind load	V_{10}=42m/s	
		Waves	$H_{1/3}$=1.4m, $T_{1/3}$=5.7~7.7s	
Bridge length	410m			
Effective width	31.2m (6-lanes roadway with 2-side walks)			
Length between supports	65.7m+280.0m+65.7m			
Lane width	When closed	135.0m	When open	200.0m
Under clearance		DL+26.0m		——
Super elevation	2% straight line			
Longitudinal gradient	5% both grades (V.C.L140m)			
Pavement thickness	Roadway/80mm Walkway/40mm			
Earthquake load	Level I	Bridge axis direction/Kh=0.05 Direction perpendicular to bridge axis/Kh=0.13		
	Level II	Bridge axis direction/Kh=0.11 Direction perpendicular to bridge axis/Kh=0.36		
Approximate steel weight (Unit in tons)	Pontoon	6,800		
	Floating bridge	19,400		
	Mooring structure	7,800		
	Total	34,000		

are one of the prime concerns. Besides, the dynamic responses are also studied when the heavy traffic vehicles run from the transitional bridge to the floating bridge over the expansion joins to connect them. The following numerical simulation methods have been developed to solve them.

1) The ordinary simulation method (i.e.,OSM) which incorporates the non-linear characteristics of the rubber fender mooring system gives time-domain responses of 6-degree-of-freedom motion due to waves and winds using the rigid model[2]. This method is extended to deal with the responses during the swinging procedure.

2) The hybrid simulation method (i.e.,HSM) which is composed of a computer, a tri-axial compression equipment and the models of the rubber fenders has been developed[3]. HSM deals only with the two dimensional dynamic motions and was used to verify the results of OSM.

3) A multi-degree-of-freedom analysis using the elastic model in water waves has been developed. The method is based upon spectrum method then uses the linearized model of the rubber fenders. It has cleared up the effect of flexibility of the bridge[4].

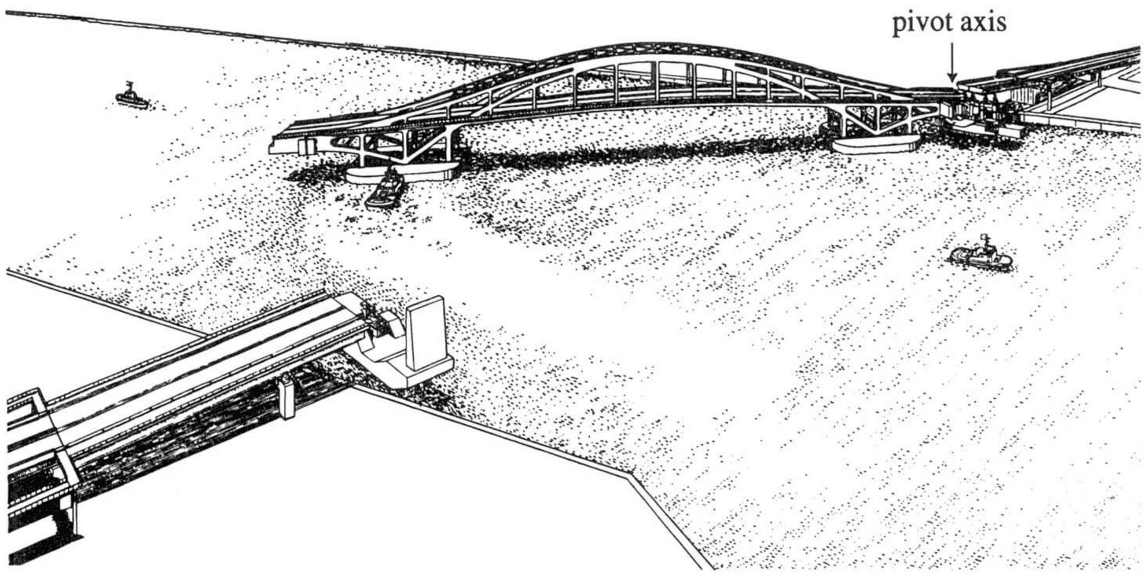


Fig. 5 Swinging Procedure

3. Swinging Procedure

The swing system is prepared to let large-sized vessels pass the sub-way in an emergency as mentioned previously. The swinging procedure is as follows:

A pivot axis is inserted and the transitional girders are lifted up by jack-up units. Then the reaction walls which are usually in the standing-position to moor the bridge are released and rotated, thereby completing preparation for swinging.

The bridge is swung about the pivot axis by tugboats(Fig.5).

After the swinging is completed, the bridge is temporarily moored and the opening operation of the bridge is finished. Then large ships can navigate the sub-waterway freely.

The procedure of the bridge closing is the reverse of the one just described.

4. Erection

The following erection method has been chosen in a dock yard(Fig.6):
The super structure with pontoons is assembled in a dock.
After the completion, the deck is filled with water and the bridge is towed to the erection site by tugboats.
The bridge is installed immediately to the mooring system by tug winch operation.
The superstructure and the substructure can be constructed at different places simultaneously. In this way, the construction period is remarkably reduced.

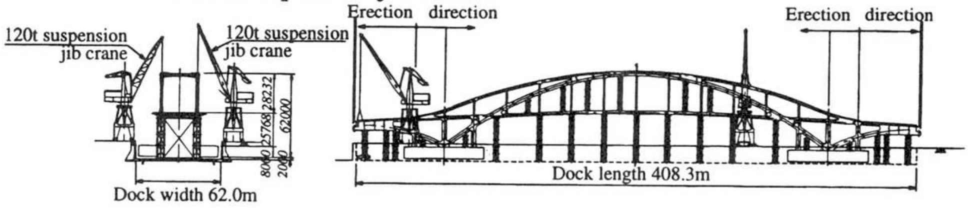
5. Experimental Study

Many experiments have been performed to ensure the safety and serviceability of this bridge. Main items of the experiments are as follows:

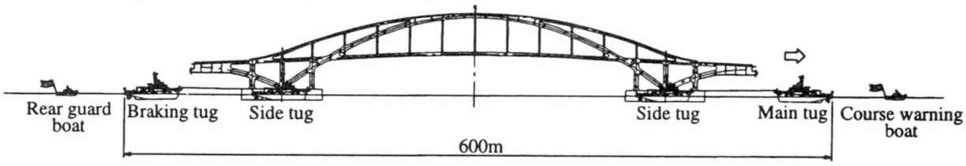
(1) The rigid-body motions of the floating bridge model(scale:1/80) against water waves and winds were examined in a large-scaled water tank to compare with the OMS(Photo.1).

(2) The swinging and temporary mooring operation were ensured by using the above-mentioned rigid model(Photo.2).

(STEP 1) Erection is done in a dock by the temporary supporting method, using two 120t suspension jib cranes.



(STEP 2) The bridge is towed to the installation position by a formation of 8 tugboats in the 3,600 horsepower class.



(STEP 3) The floating bridge is connected to the mooring equipment via tug winch operation.

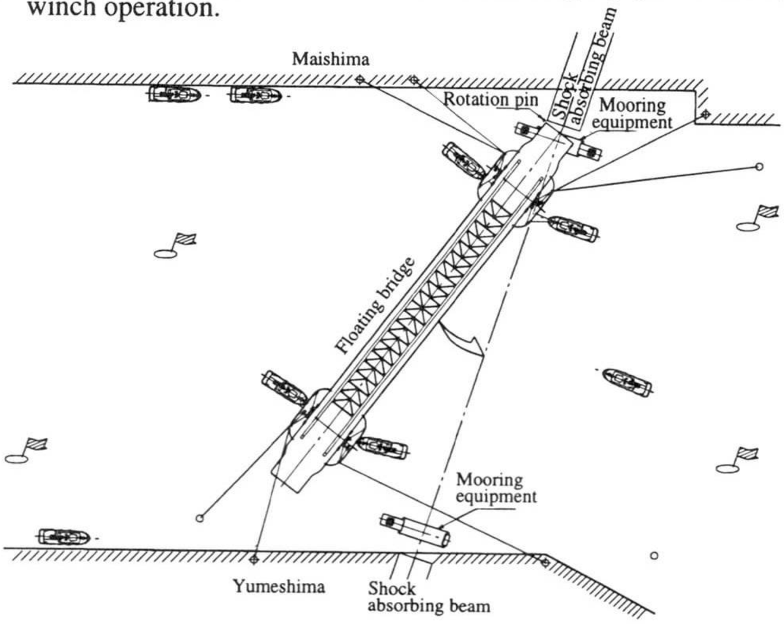


Fig. 6 Erection Steps

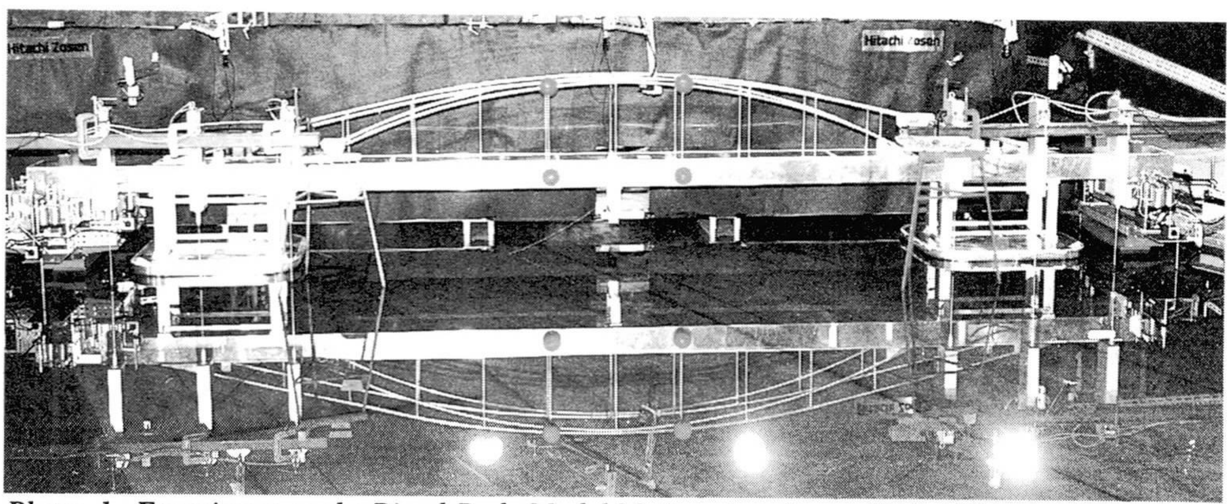


Photo. 1 Experiment on the Riged-Body Model Motions in a Large-Scaled Water-tank

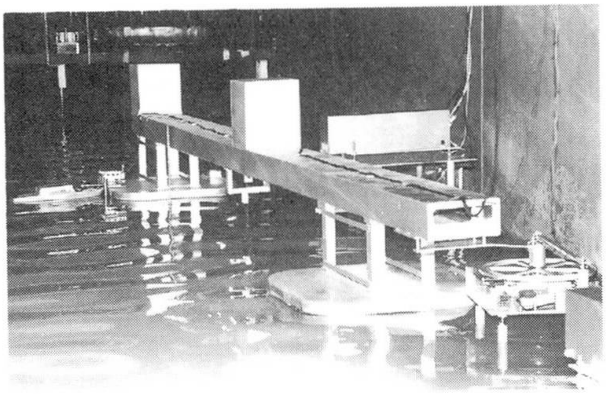


Photo. 2 Swinging and temporary mooring experiment (Scale: 1/80)

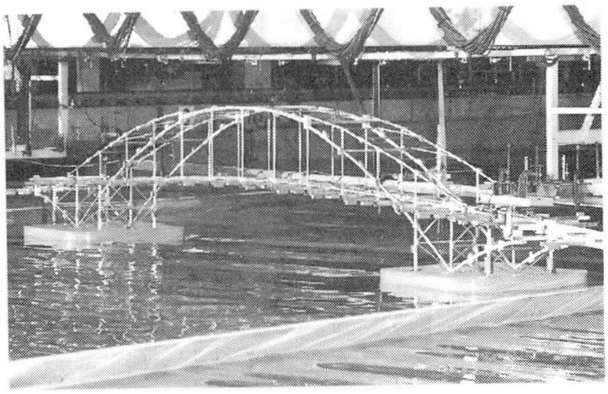


Photo. 3 In-wave elastic model experiment (Scale: 1/40)

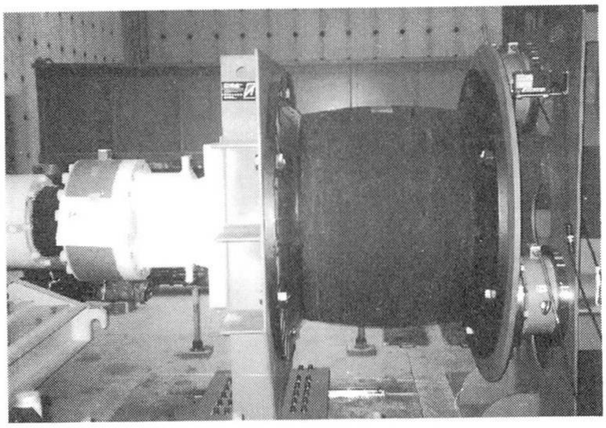


Photo. 4 Mooring fender characteristic test

(3) The effect of the flexibility as compared with the rigid body of the floating structure against wave loads was examined by using the elastic model(scale:1/40) and the effect was proved to be very small(Photo.3)
(4) The characteristics of the mooring rubber fender were clarified(Photo.4).
(5) The six static coefficients were measured by the wind tunnel tests and the wind drag force was reduced by changing the configuration of the girder.

6. Conclusions

The world's first floating and swing bridge is under construction in the Port of Osaka, Japan. This movable floating bridge is an all-steel bridge with two pontoons to connect two man-made islands of Maishima and Yumeshima. To suport the pioneering bridge work, many field observations are being planned both during and after construction for future constructions of similar floating bridges.

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