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Management of the Honshu-Shikoku Bridge Project in Japan

Gestion du Projet des Ponts Honshu-Shikoku au Japon

Aufbau und Verwaltung des Brückenprojektes zwischen Honshu-Shikoku in Japan

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SUMMARY
The Honshu-Shikoku Bridge Projects is a large-scale national project to connect Honshu and Shikoku by three routes. Since these will be operated on a toll system and two of them are designed for both road and rail traffic, the government has established the Honshu-Shikoku Bridge Authority as a public corporation to implement the project. The Authority is in charge of surveying, planning, construction and management at every stage. This paper outlines its methods of implementation and the project's features, with particular reference to the Kojima—Sakaide Route.

RESUME
Le projet de ponts entre Honshu et Shikoku est un important projet national destiné à relier ces deux régions par trois routes. Ces routes sont à péage et deux d'entre elles sont prévues pour le trafic routier et ferroviaire. Le gouvernement a créé le Service des Ponts Honshu-Shikoku entreprise publique chargée de l'exécution du projet: ses responsabilités sont l'étude, la conception, la construction et la gestion du projet à chaque stade. Cette communication résume les moyens d'exécution et les caractéristiques du projet, et traite en particulier de la route Kojima—Sakaide.

ZUSAMMENFASSUNG
Das z.Z. im Bau befindliche Brückenprojekt zwischen Honshu und Shikoku ist ein so gigantisches Projekt, dass es die Hilfe des Staates erfordert. Hierbei handelt es sich um zollpflichtige Brücken, die eine Verbindung auf drei verschiedenen Linien herstellen, unter denen auch zweigeschossige Strassen-Eisenbahnbrücken laufen werden. Die Regierung gründete deshalb die öffentliche Körperschaft für Honshu-Shikoku-Verbindungsbrücken. Diese fördert aktiv jeweils Undersuchungen, Planung, Entwurf, Bau und Verwaltung dieses Projekts. Im folgenden wird hinsichtlich dieses Projekts über Durchführungsmethoden und Besonderheiten der obgenannten öffentlichen Körperschaft — hauptsächlich in bezug auf die Route Kojima—Sakaide — berichtet.

1. THE ESTABLISHMENT AND ORGANIZATION OF THE HONSHU-SHIKOKU BRIDGE AUTHORITY

The land of Japan is composed of the four major islands, Hokkaido, Honshu, Shikoku and Kyushu, as well as the lesser surrounding islands. In order to make efficient use of the land and have the developments occur throughout the country in a uniform way, it is important to link these islands with major traffic roads.

Kyushu already has three undersea tunnels (one highway tunnel and two railway tunnels) and the Kanmon Bridge (center span length: 712m) that goes to Honshu, and the Seikan Railway Tunnel, which will link between Hokkaido and Honshu, is now under construction. The Seto Inland Sea separates Shikoku from Honshu and the only means of transportation between the two islands are ferry boats. The amount of transportation per day between the two islands has reached about 80,000 passengers and about 230,000 tons of cargo, and there is a tendency for an increase each year. The concept of constructing a bridge from Shikoku to Honshu has not only been a cherished desire of the four million persons living in Shikoku for many years, but also could be called a request for the national interest to connect the country. Upon receiving this request, a preliminary technical investigation was started from 1955 by the Ministry of Construction and the Japanese National Railways. With the great improvement in our country's economic power and the advances made in various technologies such as civil engineering, it became clear that this project was both technically and economically feasible so that the chances of the execution of this project became high.

Taking the following matters into consideration, the Japanese Government established the Honshu-Shikoku Bridge Authority in July 1970 as a government body by law for the main function of carrying out this plan.

(a) This is a major project of a national scale and the construction of a bridge on an international level would have to be conducted under severe circumstances such as typhoons, earthquakes, currents and so on. Therefore, it is necessary to combine the various technologies such as civil engineering and mechanical engineering under a single organization.

(b) Of the three routes, the two routes (Kobe-Naruto and Kojima-Sakaide) are to be bridges with combined a highway and railway lines. Therefore, it will be necessary to make total adjustments to consider the highway and railway lines as one while executing the project.

(c) As the bridges will be constructed and administrated as toll roads and a railway project, they will all link with the major traffic roads in the Honshu and Shikoku districts.

(d) The financing for this project is based mainly on the Bridge Authority's bonds which is purchased by the Government and banks, besides the investments by national and local governments. After completion, it shall be paid back by toll.

As a special corporation established by law, the Honshu-Shikoku Bridge Authority will execute the project as the main body in all stages from planning, investigation, designing, construction and administration. The Authority is supervised by the Ministry of Construction and the Ministry of Transportation. The project is carried out in cooperation with local governments and the JNR. Furthermore, technical advice will be obtained from J.S.C.E., as well as universities, research organizations, private organizations and so on.

The designing and construction work at the sites are conducted by contractors that have been contracted by competitive bidding, and there are many domestic contractors of various fields. The construction work is based upon the plans made with full consideration by the Authority and is divided into several stages. Contractors are supervised by the Authority. As the project is a large-scale, off-shore construction, great efforts have been made in the making of the contract.

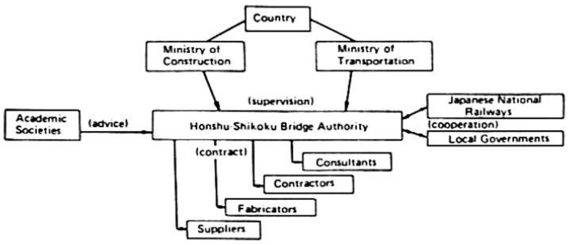

Fig. 1 Position of the Honshu-Shikoku Bridge Authority

2. THE PROJECT OF THE HONSHU-SHIKOKU BRIDGE AUTHORITY

1) Execution of the Project: Based on the report submitted to both the Ministry of Construction and the Ministry of Transportation in November, 1972, both ministries gave instructions for the basic plans in September, 1973. For the Kobe-Naruto Route (Route A) and the Kojima-Sakaide Route (Route D), combined highway and railway bridges were planned to be built, and for the Onomichi-Imabari Route (Route E), a construction for a highway bridge was also planned. The project is a super-scale one with a total project expense of 2,400 billion yen. The details of the project are mentioned in "Honshu-Shikoku Bridge Planning in Japan IABSE Symposium Zürich 1979".

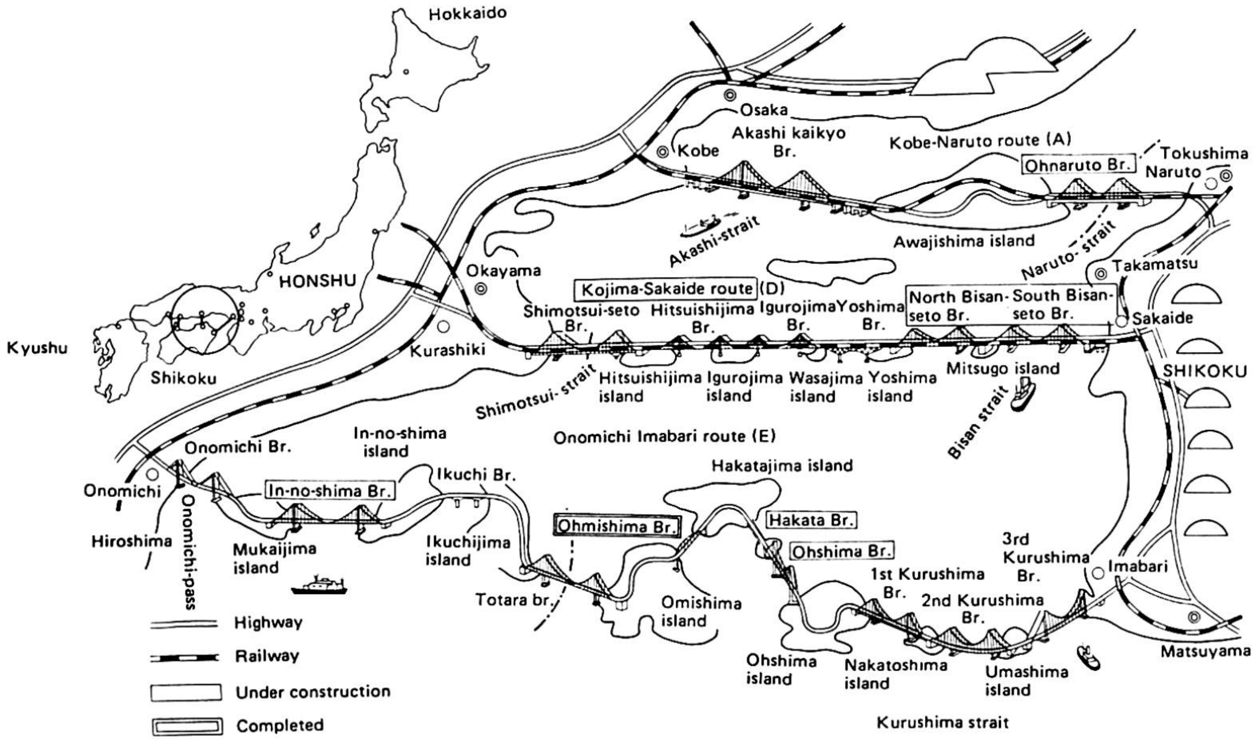

Fig. 2 Bird's-Eye View of the Honshu-Shikoku Bridges

Table 1 Length, Structural Standards and Construction Cost

Item	Category	Particulars	Kobe-Naruto R.	Kojima-Sakaide R.	Onomichi-Imabari R.
Length (km)	Highway		81.1	37.8	60.1
	Railway		89.8	49.2	———
Structual standards	Highway	Classification	Expressway	Expressway	Expressway
		Design speed (km/h)	100	100	80
		Number of lanes	6	4	4
	Railway	Classification	Shinkansen	Ordinary line and Shinkansen	———
		Number of tracks	2	2 + 2	———
Construction cost (billion yen)			1,150	840	410

Route D. which is the center of the project, has an extension of about 10 km at the strait. The general view of Route D. is shown on Fig. 3. The route is laid across two straits, the Shimotsui Strait (width: approx. 1 km, maximum water depth: 75 m) and the Bisan Strait (width: approx. 3.3 km, maximum water depth: 85 m), and goes from Kurashiki City to Sakaide City by over passing Hitsuishijima Island, Igurojima Island, Wasajima Island and Yoshima Island. The bridges at the strait are planned to consist of three suspension bridges with the scale of 1,000 m center span: the Shimotsui-Seto Bridge (SB), the North Bisan-Seto Bridge and the South Bisan-Seto Bridge (BB), two cable stayed bridges of a scale of 400 m between center spans: the Hitsuishijima Bridge and the Igurojima Bridge, and one continuous truss bridge: the Yoshima Bridge. All of them are to be double-decked bridges for both a highway and railway. In setting up both the design and construction plans of the bridges, there were many problems for both the super and substructures. We shall mention here about the substructure.

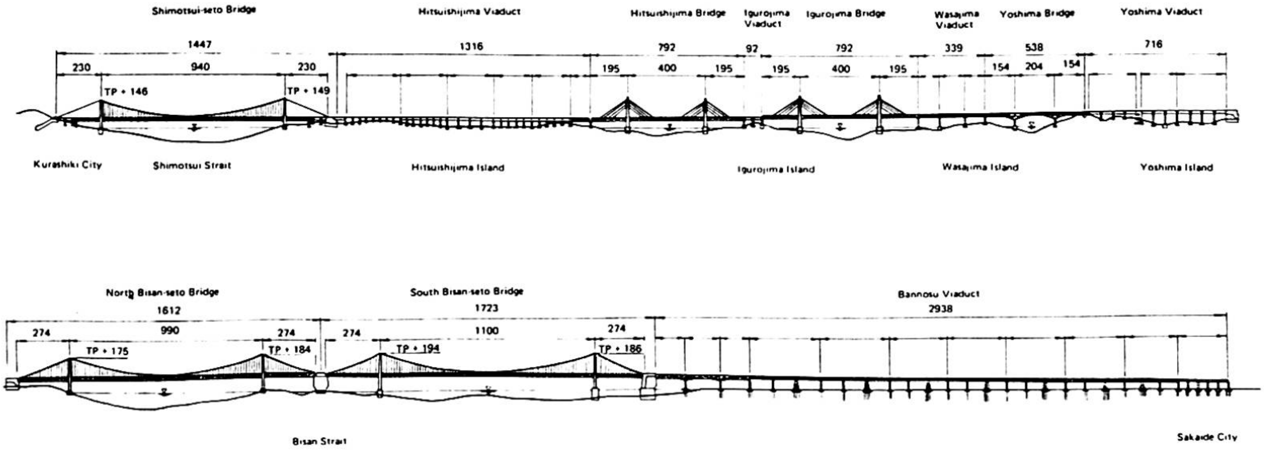

Fig. 3 General View of the Kojima-Sakaide Route

In the construction of the bridge substructure crossing the strait, it would be necessary to secure the safety of the navigating vessels passing the straits and overcome complicated natural conditions such as the geological features, waves, and high-speed current. Thus, large-scale excavation of the bottom and a large amount of underwater concrete work are necessary. The Authority devised the Laying-Down Caisson Method, Multi-Column Foundation Method, Special Cofferdam Method and so on, as major means for the underwater foundations.

Table 2 Details for Major Foundation of Route D

Name	Type of Super Structure	Span Length	Substructure							
			Designation	Size of Foundation Length x width x Height	Depth of Foundation	Construction Method	Depth of Current	Maximum Tidal Current	Excacation	Concrete
		(m)		(m)	(m)		(m)	(m/s)	(m^3)	(m^3)
Shimotsui-Seto Bridge	Suspension Br.	230+940+239	SB2P	20.0x54.0x30.0	-25.0	Pneumatic Caisson	-	-	22,000	18,000
			SB3P	20.0x54.0x14.0	-6.0	Cofferdam	-	-	28,000	15,000
Hitsuishijima Bridge	Cable Stayed Br.	185+420+185	BB1P	ϕ28.0x31.5	-5.0	Cofferdam	-	-	2,000	12,000
			BB2P	24.0x46.0x14.5	-25.0	Laying-down Caisson	-9~-22	2.1	22,000	37,000
			BB3P	31.0x46.0x43.5	-35.0	Laying-down Caisson	-13~-22	2.1	59,000	61,000
Igurojima Bridge	Cable Stayed Br.	185+420+185	IB2P	18.0x46.0x23.5	-18.0	Laying-down Caisson	-8~-16	2.1	7,000	19,000
			IB3P	22.0x46.0x32.5	-25.0	Laying-down Caisson	-3~-21	2.1	24,000	32,000
			IB4P	36.0x38.0x19.0	-12.0	Laying-down Caisson	-3~-11	2.1	17,000	36,000
Wasajima Viadact	Truss Br.	102+132+107	Wva1P	20.0x32.0x58.0	-15.0	Laying-down Caisson	-3~-11	2.1	5,000	16,000
Yoshima Bridge	Truss Br.	154+204+154	VB2P	20.0x34.0x49.0	-20.0	Laying-down Caisson	-4~-16	2.1	10,000	30,000
North and South Bisan-Seto Bridge	Suspension Br.	North Br. 274+990+274	BB2P	23.0x57.0x20.0	-10.0	Laying-down Caisson	+4~-8	1.0	22,000	24,000
			BB3P	23.0x57.0x20.0	-10.0	Laying-down Caisson	+10~-4	2.3	42,000	24,000
			BB4A	62.0x57.0x15.0	-10.0	Laying-down Caisson	+16~-8	3.0	58,000	329,000
		South Br. 274+990+274	BB5P	27.0x59.0x42.0	-32.0	Laying-down Caisson	-21~-24	2.8	32,000	63,000
			BB6P	38.0x59.0x55.0	-50.0	Laying-down Caisson	-32~-36	1.5	126,000	129,000
			BB7A	59.0x75.0x55.0	-50.0	Laying-down Caisson	-13~-20	1.0	597,000	473,000

The geological features of strait of Route D are mainly granite with a weathered surface layer but the Bisan-Seto had diluviums and alluviums that flowed there from Shikoku and piled up upon the granite. The speed of the tidal current at the strait is an average of 1.5 m/sec (maximum of 2.2 m/sec). As it is at an inland sea, the waves are not too high. The Shimotsui Strait and the Bisan Strait are important navigation courses and the amount of vessel traffic is very high with about 1,000 vessels a day passing through at each strait. Considering such conditions, the Laying-Down Caisson Method with a preliminary excavation of major portions was adapted as a underwater foundation. As there were few experiences for large-scale underwater construction, the Authority conducted experimental construction work on the various methods. New vessels and machinery for these methods were developed by gathering wide variety of technology in many areas. The laying-Down Caisson Method, used at the Route D, is an advantageous for shallow embedment on the rock and it is adaptable to high water depth. The site construction period could be comparatively short because the work is simple even when the scope of the construction is large. The main construction technologies constituting this method are excavation of the sea bottom, steel caisson, underwater concrete work and the installing of facilities that make these constructions possible. For over ten years, through confirmations and improvements the construction method had been established, and the details are explained as follows:

(1) Underwater Excavation: The surface of the seabed rock is weathered considerably so that it has to be removed. The excavation has to be conducted to a depth of adequate bearing strength. Furthermore, excavation has to be conducted until the surface is fairly levelled in order to set the steel caisson in position and to prevent mortar leakage during prepacked concreting. It is executed by underwater blasting and large-scale grab dredgers. Therefore, the Authority has conducted the following experiments:

(a) Large-scale simultaneous underwater blasting and delay blasting tests by wireless initiation and seabed rock drilling test by the OD Machine.
(b) Bedrock excavation tests by large-scale grab dredgers.
(c) Level excavation tests using percussion drilling machines or rotary drilling machines.

From the above-mentioned tests, the construction method for various large-scale deep-water blastings were established. Furthermore, it was possible to develop an estimation method on the effects to the surrounding areas by the underwater blasting. The excavating of seabed rock after blasting could be conducted by conventional dredge technology to a depth of 50 m. For this large-scale off-shore construction work, there were many contributions that owed to SEP, grab dredgers and explosives for underwater blasting and to the advancements in construction technologies. Thus, it was possible to gain an outlook on the underwater excavating required in the Laying-Down Caisson Method.

(2) Steel Caisson: Steel caisson is required to be cofferdam and form for the underwater concreting, and it has to float stably until setting on the specified seabed.

During excavation, the large-scale steel caisson which is equipped for mooring and setting is completely prefabricated at a yard. It is towed to the site during calm weather conditions. Then it is moored by an anchor line and set on the position by pouring water in several partitions individually and by winch operation. The allowance of setting caisson is expected to be within ±50cm in position.

For the towing, mooring and setting of caisson, there were many contributions that owed greatly to the shipbuilding technology of our country. The complete prefabrication of BB-7A, the largest laying-down caisson may not be so difficult if shipbuilding and steel-structure technology is employed.

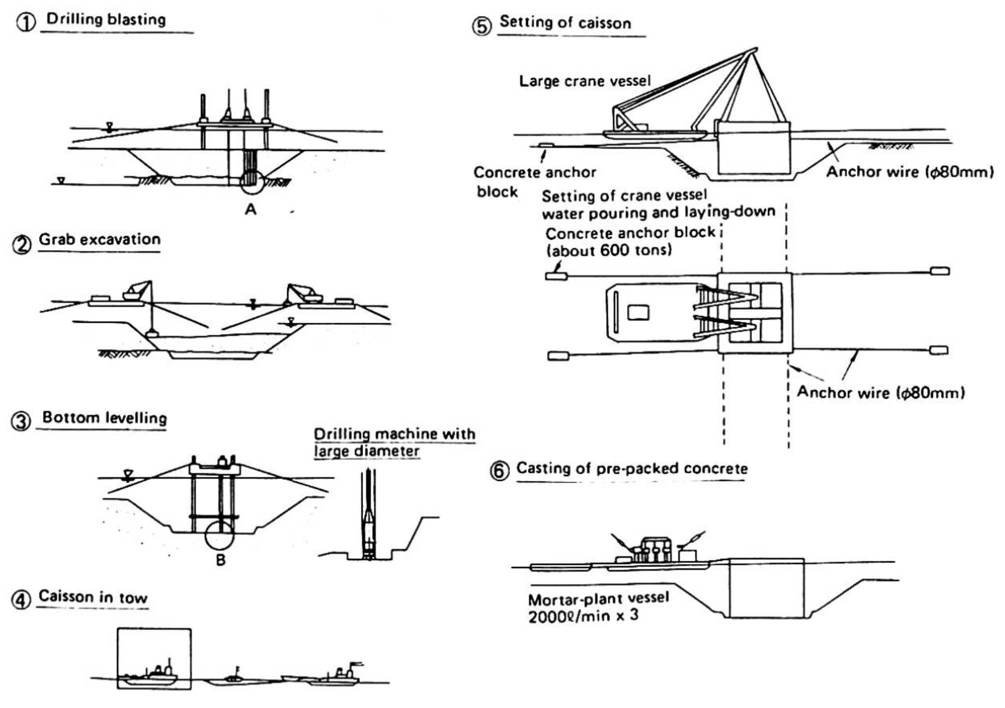

Fig. 4 Procedure of the Laying-down Caisson Method

(3) Underwater Concrete: Among the foundations in Route D, there are 33 foundations that are completely underwater. Four of them are constructed at a water depth of 30 to 50 m. The amount of concrete necessary for these underwater foundations is 20,000 m^3 to 250,000m^3 per foundation and about 700,000 m^3 for all the foundations. For such a mass concreting at such water depth, the pre-packed concrete method was employed

because of its advantages for reliability and efficiency.

Taking the example of BB-5P, the underwater concrete quantity is to be 55,000 m^3 (underwater concreting height: 34m), the designed standard strength of the concrete to be 200 kg/cm^2, and the construction is outlined as follows:

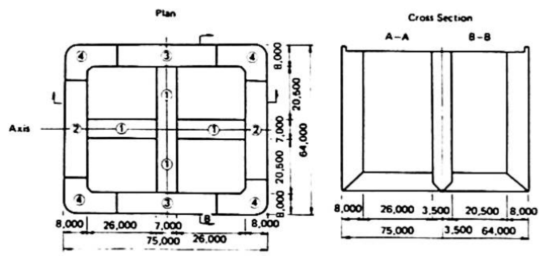

Fig. 5 Dimensions of the BB-7A Caisson and Partitions for Pouring Water

(a) The pouring of the pre-packed concrete has to be kept at a fixed speed constantly without stopping. The grouting is limited to three or four days because of the weather conditions.
(b) As caisson is divided into two partitions, (the inner and outer), the grouting is conducted in the order of the inner and then the outer partition. Therefore, the capacity of the mortar mixing plant is required to be around 4,000 ℓ/min.
(c) The total amount of the coarse-aggregate is put in advance.
(d) The supplying of the cement, sand, and water to the plant vessel will be conducted by a barge once a day.

In order to establish such concreting work, a series of research experiments were conducted from 1965. Many problems such as the mortar grout mechanism, the quality of concrete, efficiency and simplification of the work, the machines and equipments, and the work supervision were studied and developed. Based on the fruits of these researches, the working plans of this substructure construction was decided upon, and the mortar plant vessel with a maximum capacity of 6,000 ℓ/min. has been built in 1978 and is now ready to be used.

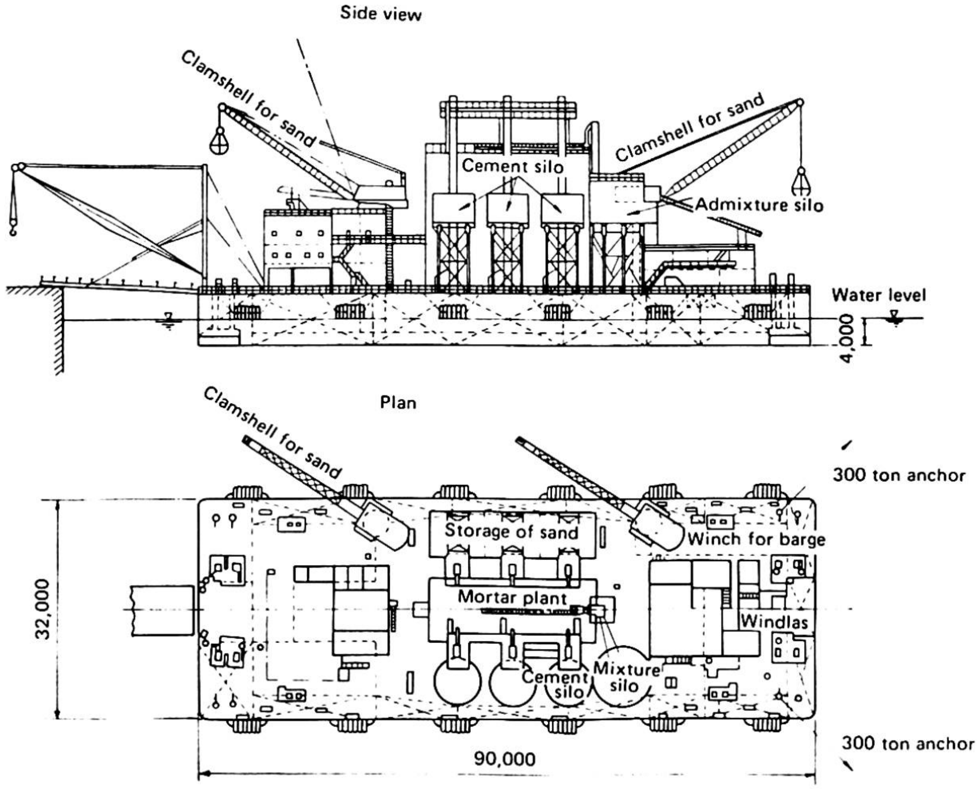

Fig. 6 General View of the Mortar Plant Vessel

(4) The Working Yard: In order to construct long-span bridges at the strait, it is necessary to gather a great amount of material and many workers to a limited space in a short period of time. For this, working platforms, vessels for transportation, and facilities on land will become necessary.

Especially for the construction of the substructure, the most important matter is the stable supply of aggregate for concreting both in quality and quantity. In order to do this, facilities for adjusting the grading, weighing, loading, port facilities for transporting vessels and operation vessels, and water supply facilities for the construction will become necessary. Furthermore, it will be necessary to construct working yards with many functions and installations for the steel members of superstructure and temporary facilities. The Authority secured working yards beforehand and contractors utilize them for the smooth progress of the construction work. The working yards for the Route D are shown in Table 3 and Fig. 7.

Table 3 Working Yards of the Kojima - Sakaide Route

		Major functions	Area, Pier
Working Yard	Sei	1. The yard for all construction in the strait, as well as the center of operation. 2. Stockyard for materials and equipmente for all work at the strait. 3. Supply source of fine-aggregate for the concrete. 4. Supply source for the water required for the construction. 5. Main port for various operation vessels. 6. Treatment of waste water and wates.	area: 130,000m^2 pier: 400m
	Mizushima	1. Supply source of coarse-agregate for the concrete. 2. Main port for vessels carrying coarse-aggregate.	area: 134,000m^2 pier: 150m

Fig. 7 Working Yards for the Route D

The construction of the substructure in the Honshu-Shikoku Bridge is not only a large-scale one but also has to be conducted underwater. Therefore, there are significant differences with construction work of bridge substructure on the land and furthermore, has two or three problems in the work that must be mentioned.

1) The Preservation of the Environment During Construction: Types of construction affecting the environmental factors are shown in Table 4.

Table 4 Effects to the Environment by the Construction

	Type of Construction Work	Environmental Factors
Living Environment	o Underwater blasting o Consolidation of working platforms	Vibrations of ground
	o Grab-dredging o Underwater concreting	Moisture
Natural Environment	o Underwater blasting o Grab-dredging o Underwater concreting	Acquatic life

For the preservation of the environment, construction methods with the minimum effects on the environment should be selected, with adequate supervision to be conducted during the construction and immediate countermeasures to be taken when the unexpected occurs. The preservation of the environment is considered to be related to the safety of the construction and improvement of the content, and this must be considered to be of great importance in the work.

2) Safety Measures of the Construction: As the off-shore work will be conducted in severe natural conditions, the safest and wisest measures are required. Reflecting the experiences of the various types of experimental construction works held in the past, it will be necessary to set the construction method and period suited to the conditions. The work must be done after fully adequate safety facilities are made according to the conditions of the site. For the weather and sea conditions which will influence the work, it will be necessary to manage the construction by using a forecast network to secure accurate information.

As security measures for navigation, guidance will be secured by government bodies such as the Maritime Headquarter. The information supervision center that will constantly observe the working area will provide the information to operation vessels. Prior to each construction stage, discussions will be held with prople involved in maritime affairs at Navigation Safety Measures Committee in order to indicate the area of the construction work, lighting, position of the alert vessels, and the construction information. By these ways, considerations are made to secure the safety of navigating vessels.