Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 12 (1984)

Artikel: The Honshu-Shikoku Bridges project

Autor: Takahashi, Hiroatsu

DOI: https://doi.org/10.5169/seals-12108

The Honshu-Shikoku Bridges Project

Construction des ponts Honshu-Shikoku

Ausführung des Honshu-Shikoku Brückenbauprojektes

Hiroatsu TAKAHASHI
President
Honshu-Shikoku Bridge Auth.
Tokyo, Japan

Hiroatsu Takahashi, born in 1924, obtained his law degree at the University of Tokyo, Japan. After working for the Ministry of Construction, he has served the Honshu-Shikoku Bridge Authority as the president since 1982.

SUMMARY
This paper discusses the implementation system for the construction of the Honshu-Shikoku Bridges, one of the biggest transportation projects in Japan. The area of responsibility of the public authority, the relationship with other organizations, funding, contract, execution of work and related problems are explained.

RESUME
L'article présente le système pour l'exécution de la construction des ponts Honshu-Shikoku, un des plus grands projets de transport au Japon. L'identification administrative du maître de l'ouvrage, la relation avec d'autres organismes, le financement, les contrats et l'exécution des travaux sont présentés.

ZUSAMMENFASSUNG
Diese Arbeit befasst sich mit dem Ausführungssystem des Honshu-Shikoku-Brückenbauprojektes, das eines der grössten Projekte auf dem Gebiet des Verkehrswesens in Japan darstellt. Die Zuständigkeitsbereiche der öffentlichen Verwaltung, die Beziehung zu anderen Organisationen, die Vergabe der Aufträge und Durchführung der Arbeiten usw. werden erläutert.

1. PREFACE

Japan is mainly composed of four islands (Honshu, Kyushu, Shikoku and Hokkaido), and the effort to link them by permanent transportation facilities has been made.
Shikoku faces Honshu through the Seto-Inland sea, and mild climate in and around the sea has gathered people to let them live there from the ancient time.
Current transportation between Honshu and Shikoku (transportation a day: 80,000 passengers and 230,000 ton of goods) is borne by ships and airplanes both vulnerable to bad weather. Transportation by ships requires longer hours, and growing traffic volumes of ships due to the economical development around the Seto-Inland sea has induced more frequent maritime accidents. Air service has only limited capacity.
Therefore, three routes of Honshu-Shikoku Bridges (H.S.B) have been planned to eliminate these disadvantages and to bring convenient life of people and well-balanced development of the area.
On the other hand, Honshu and Kyushu have been linked by a bridge and three undersea tunnels, and an undersea tunnel (planned completion 1986) has been drilled between Honshu and Hokkaido.

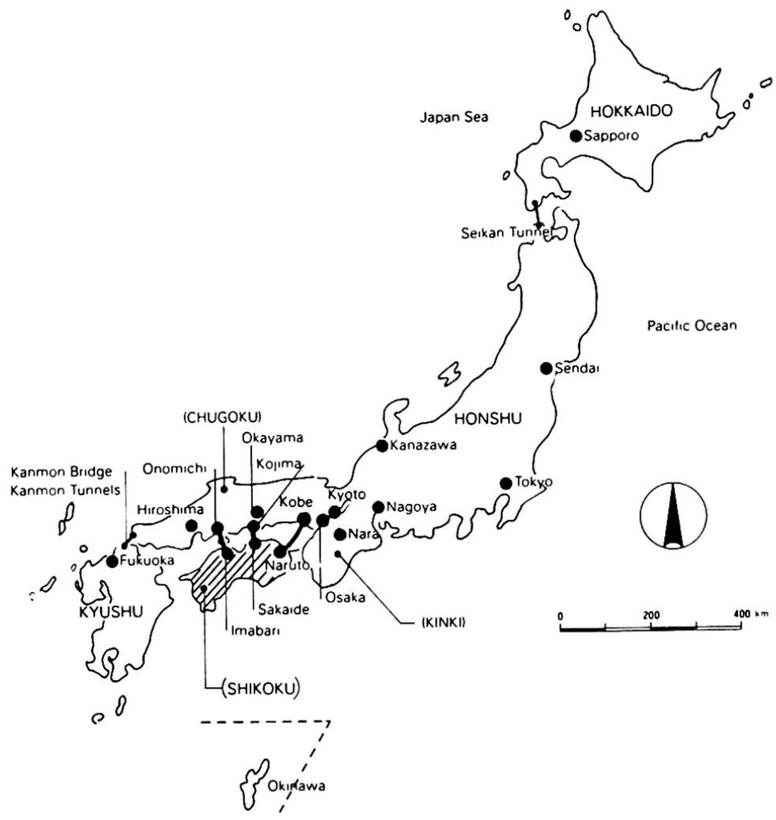


Fig. - 1 Japanese archipelago & 3 routes of the Honshu-Shikoku Bridge project

2. OUTLINE OF THE HONSHU-SHIKOKU BRIDGE PROJECT

Outline of the H.S.B. project is as shown in Table-1 and 2. Kobe-Naruto route and Kojima-Sakaide route are highway-railway combined bridges, and the latter railway is dual ordinary line and Shinkansen. Onomichi-Imabari route is only for highway. All the highways are expressways.
The project is currently carried out for Kojima-Sakaide route which is given the first priority by the government and other four bridges (Ohnaruto Br. in Kobe-Naruto route, Innoshima Br., Ohmishima Br. and Hakata-Ohshima Br. in Onomichi-Imabari route) which are judged to have strong regional developing effects, and Innoshima Br. and Ohmishima Br. among them have been put into service. This is called "1 route and 4 bridges policy" Japanese government has

Item	Category	Particulars	Kobe-Naruto	Kojima-Sakaide	Onomichi-Imabari
Length (km)	Highway		81.1	37.5	60.1
	Railway		89.8	32.4	-
Structural 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)			1665	1110	585
Construction cost (billion US$)			7.24	4.83	2.54

(estimated in 1982, 1US$ ≒ 230 yen)

Table - 1 Summary of the project

Route	Name	Type	Span length (m)	Situation		Year of completion
				Under construction	Completion	
Kobe - Naruto	Akashi Kaikyo Bridge	Suspension	890+1,780+890			
	Ohnaruto Bridge	Suspension	93+330+876+330	○		1985
Kojima - Sakaide	Shimotsui-seto Bridge	Suspension	230+940+230	○		1988
	Hitsuishijima Bridge	Cable stayed	185+420+185	○		"
	Iwakurojima Bridge	Cable stayed	185+420+185	○		"
	Yoshima Bridge	Truss	175+245+165	○		"
	Kita Bisan-seto Bridge	Suspension	274+990+274	○		"
	Minami Bisan-seto Bridge	Suspension	274+1,100+274	○		"
Onomichi - Imabari	Onomichi Bridge	Cable stayed	85+210+85			
	Innoshima Bridge	Suspension	250+770+250		○	1983
	Ikuchi Bridge	Prestressed Concrete girder	150+250+150			
	Tatara Bridge	Suspension	300+890+300			
	Ohmishima Bridge	Arch	297		○	1979
	Hakata - Ohshima Bridge	Girder	90+145+90	○		1988
		Suspension	140+560+140			
	1st Kurushima Bridge	Suspension	80+190+860+194			
	2nd Kurushima Bridge	Suspension	110+550+110			
	3rd Kurushima Bridge	Suspension	260+1,000+260			

Table - 2 Main bridges in the project

ordered Honshu-Shikoku Bridge Authority (H.S.B.A.) to execute so far, because the financial situation of Japan has been tight after the oil-crisis in 1973. Fig.-2 shows all the bridges in straits section, highway-railway combined section, of Kojima-Sakaide route whose construction is enthusiastically conducted. The section continues for 13 km with sophisticated structures of various types. Railway service of this route for a while after the completion in 1988 will be limited for only the ordinary line.

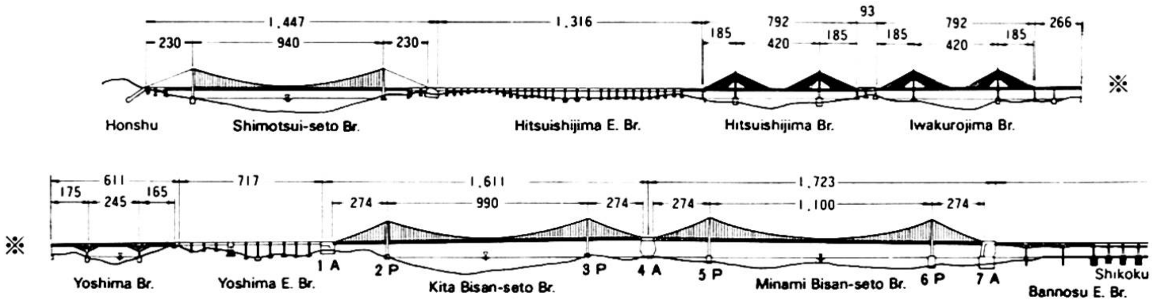


Fig. - 2 Side view of the bridges over straits of Kojima-Sakaide route

Technical characteristics of H.S.B. project are to construct long-span highway-railway combined bridges which are capable to sustain regular high-speed trains at straits with severe natural conditions such as sea-depth, tidal current, typhoon, earthquake, etc. (an example is shown in Table-3).

What enables this is long-lasting research and survey since 1955, which was first separately conducted by both sides of highway and railway but has been unitedly executed after the establishment of H.S.B.A. in 1970.

Sea depth at a site of a main pier	Tidal current speed at a main pier	Basic wind speed (10 minutes average at 10 m above the sea surface) *	Seismic acceleration at the base rock *
35 m (at 6P)	2.7 m/s (at 3P 4A & 5P)	43 m/s	180 gal

* recurrent interval = 150 years ∿ 100 years

Table - 3 Severe natural conditions for Minami & Kita Bisan-seto Bridges

3. IMPLEMENTATION SYSTEM FOR HONSHU-SHIKOU BRIDGE PROJECT

3.1 Identification of Honshu-Shikoku Bridge Authority

3.1.1 Background

Japan has two kinds of highway system. One is general free-highway managed by the Ministry of Construction or local governments with taxes, and another is toll-road which is constructed by an official agent with borrow money and whose borrowed money and interest are paid back from the toll. A big project which concentratedly needs great amount of money is often carried out as a toll-road. Table-4 shows the main toll-road systems in

Classification	Service area	Executing organization	Total planned extension *	Extention in service *
National expressway	Nation wide	Japan Highway Public Corporation	7,600 Km	3,400 Km
Urban expressway	In & around Tokyo	Metropolitan Expressway Public Corporation	250 Km	160 Km
	In & around Osaka	Hanshin Expressway Public Corporation	220 Km	120 Km
Honshu-Shikoku expressway	Between Honshu & Shikoku	Honshu-Shikoku Bridge Authority	180 Km	20 Km

As of Jan. 1984

All organizations are authorized by laws.

Table - 4 Main toll road systems in Japan

Japan. Trunk railways in Japan are operated by Japanese National Railways (J.N.R.) to which the facility constructed by H.S.B.A. will be rented.

3.1.2 Reasons and advantages of new establishment of H.S.B.A.

Long-lasting feasibility study revealed that the H.S.B. project was feasible and appropriate from viewpoints of engineering and national economy, respectively, and in 1970 the H.S.B.A. was newly established by a law as the executing body for the project. H.S.B.A. conducts as an official agent all affairs relating to the project such as planning, research and survey, design, order-superintendence-inspection of work, maintenance, funding, etc. under general directions from the government. And main advantages gained from such a manner to execute the project effectively are;

① The H.S.B. project is large in size and to construct long bridges at straits with severe natural conditions. Necessary technology in various engineering fields to construct the bridges can be integrated under a consistent responsibility by the single official agent.
② Although highway and railway belong to different administrative sections in Japan, combined bridges can smoothly be constructed and maintained without serious discrepancy under the single body which is able to adjust the both.
③ Great amount of money for the project is mainly funded as borrow money. The fiscal investment and loan funded by Japanese government is available, and the central and local governments locating in the region concerned can invest and subsidize the H.S.B.A., because it is an qualified official agent.
④ The H.S.B. will link trunk highways or railways in Honshu and Shikoku at the both ends and will greatly change the current traffic system. Cooperation and adjustment with the central and local governments can be facilitated to lessen the drastic change and to arrange effectively the access highways or railways which will function with the H.S.B.; and
⑤ So many people have lived in the narrow land of Japan, and the sea is also utilized for fishery or navigation. Various administrative measures necessary to execute the large project in such circumstances can be taken by the H.S.B.A. as an official agent.

3.1.3 Relationship with other organizations

During implementation of the project, the H.S.B.A. has various relationship whose scheme is idealistically shown in Fig.-3 with the central government, local governments, J.N.R., academic societies, private farms, etc.
Many engineers have traditionally belonged to owner official agents in Japan, and official agents have played stronger role than consultants or contractors throughout the entire phase of a project in many cases.

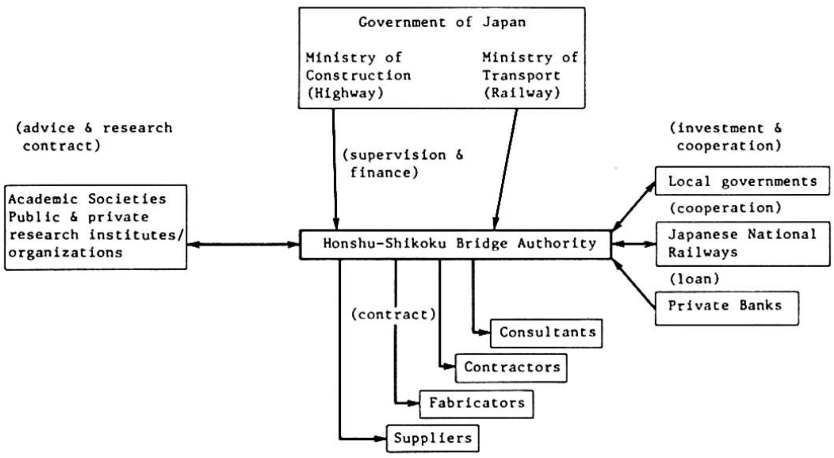


Fig. - 3 Relationship with other organizations

Table-5 shows the comparison between this in-house engineering method traditionally carried out in Japan and the conventional method widely applied in the U.S.A. or Western Europe. It should also be pointed out that insurance system for the public work is somewhat unperfect in Japan.

In the case of the H.S.B. project, stronger leadership of the owner than that for ordinary projects in Japan is required to adjust mutually different kinds of work from viewpoints of time and place, because the project has peculiar technical characteristics and complex concentration of type, schedule and place of the work and because a construction method is sometimes specified by the H.S.B.A. as described in 4.2.

Phase of the project	In-house engineering method			Conventional method		
	Owner	Consultants	Contractors	Owner	Consultants	Contractors
Feasibility study	○	△		△	○	
Decision of go/no go	○			○		
Final plan	○			○	△	
Detailed design	△	○		△	○	
Specifications	○			△	○	
Tender & checking tender documents	○		○	○	△	○
Construction & superintendence	○	△	○	△	○	○
Maintenance	○		△	○	△	△

Note, ○ : mainly conducted by
△ : subordinately conducted by

Table - 5 Comparison of engineering system

3.2 Organization of Honshu-Shikoku Bridge Authority

The H.S.B.A. is organized as shown in Fig.-4 to exert effectively the power, responsibility and demanded adjusting functions as described in 3.1. The head-office in Tokyo is conducting the planning and adjusting the project and common research. There are construction bureaus as intermediate managing organization in each route, and construction offices to engage construction work directly and a management office to maintain the opened facilities are arranged beneath the bureaus.

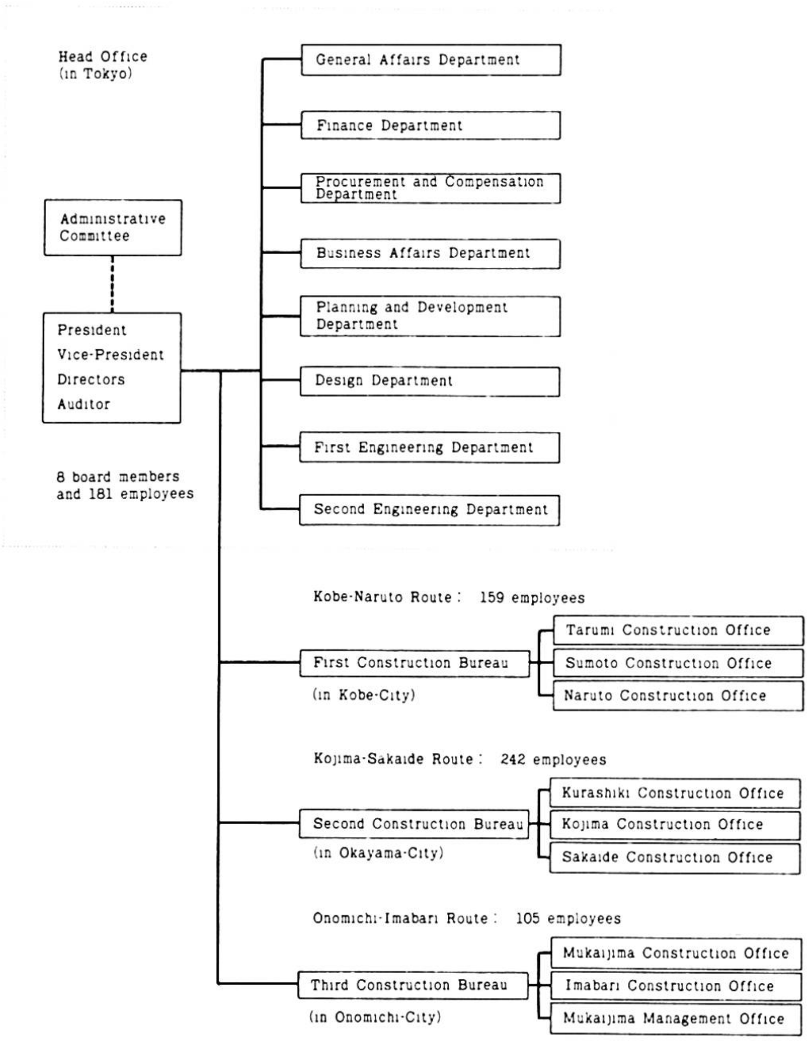


Fig. - 4 Organization of the Honshu-Shikoku Bridge Authority

Total man power of the H.S.B.A. is about 700 persons. Sixty percent of them are engineers whose speciality vary from civil engineering, geology, electronics, architecture, maritime affairs, climatology to environmental science. However, the H.S.B.A. has less man power compared with other organizations in spite of the size of the H.S.B. project.

4. EXECUTION OF PROJECT

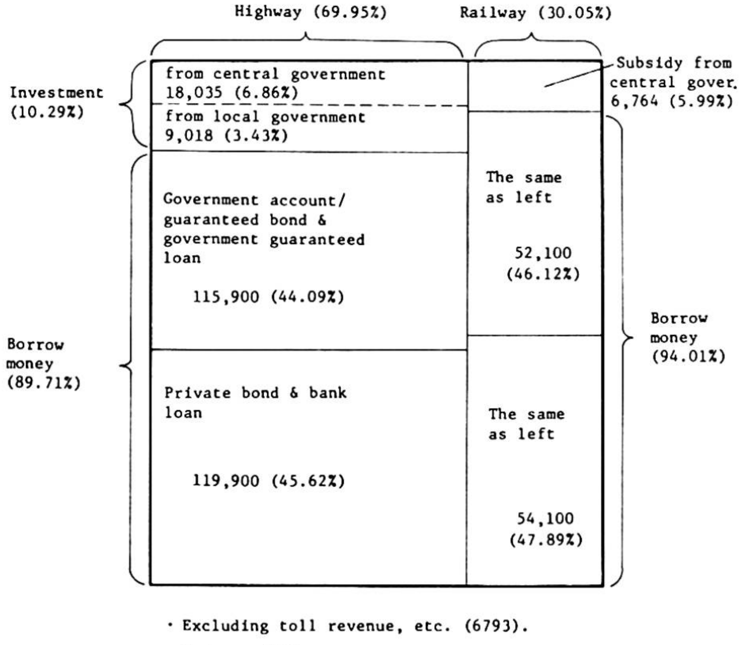
4.1 Funding and repayment

Annual budget of the H.S.B.A. is requested to the Ministry of Finance through both ministries of Construction and Transport, and comes into force after the budget draft which is submitted by the government based on the basic draft by the Ministry of Finance is approved by the National Diet. This procedure is common to all other governmental agencies. Table-6 shows the expense budget for fiscal year (April to March) of 1984 when the construction of 1 route and 4 bridges reaches the climax. Although H.S.B. project is a combined project simultaneously carried out for highway and railway, the account is separately kept by a designated allocation method. Almost of all necessary money except investment or subsidy from the central or local governments is funded as borrow money as shown in Fig.-5. All expense to construct and maintain the facility and its interest are paid back from the toll and the rental after the facility is opened for traffic. As for the H.S.B. highway, repayment will be finished by about 30 years after the opening on condition that the debt-cost i.e. effective interest is 6.15% and toll for the bridges over straits is fixed to approximately equal to the ferryboat charge. It is a common requirement for the toll-road project in Japan that the repayment can be finished within about 30 years against the debt-cost around 6%. In respect of the H.S.B. railway, suitable rental is going to be paid by J.N.R.

Items	Highway	Railway	Total
Construction, etc.	178,113	81,873	259,986
Maintenance & operation	467	-	467
Others	89,913	32,244	122,157
Total	268,493	114,117	382,610

Note: · Unit: million yen.
· Major part of others is payment of interest and re-funding for previous bond and loan.

Table -6 Expense budget for fiscal year of 1984



· Excluding toll revenue, etc. (6793).
· Unit: million yen

Fig. - 5 Revenue sources for fiscal year of 1984

4.2 Contract

Contract style for construction work of the H.S.B. project is the unit price contract with described total amount. In this contract, the unit price for every item which becomes basic unit for payment are established between the owner and the lowest bidder of the nominated competitive tender with several firms (or several joint ventures). During the work term, intermediate payment whose amount is determined from the sum of the contracted unit price multiplied by the completed quantity is made about four times a year. These inspection of the completed quantity and superintendence of the work are carried out by different engineers belonging to the H.S.B.A., but assistants are dispatched from contracted consultants to help day-to-day affairs of the superintendence.
Contract for public facility work of Japan generally contains the changed conditions clause that the contract can be modified when different conditions from those specified by the original contract are found, so, change of conditions of work, change of the quantity of work, etc. are frequently balanced. In addition, the cost over-run due to the inflation can be balanced. Therefore, these two balances are taken in the contract of the H.S.B.A., too.
Construction of long span bridges such as the H.S.B. project requires various kinds of work and long duration. Thus, a work which includes a group of sub-works well-bound from viewpoints of the schedule and place and whose term is about 2 to 4 years is usually ordered in one contract.
Guarantee of the quality of the work for the bridges over straits is required 10 years for the substructure and 5 years for the superstructure.
Choice of the construction method usually belongs to the contractor. However, in the case of the H.S.B. project which seems to challenge the limit of the civil engineering in the way of constructing huge structures at straits with severe natural conditions, the H.S.B.A. frequently specifies a construction method to which the H.S.B.A. can find reliability based on long-lasting research and survey. The contractor in this case is oblidged to execute this specified method. Although there are advantages as well as disadvantages in construction work by specified method, this is judged to be a good way for the H.S.B. project because of its technical characteristics.
In the next sub-chapter, an example of a work actually executed in the H.S.B. project will be discussed.

4.3 An example of work - undersea foundation works for Minami and Kita Bisan-Seto Bridges

4.3.1 Laying-down caisson method

Minami and Kita Bisan-seto Bridges are dual suspension bridges as shown in Table-2 and Fig.-2, and require 6 undersea foundations as shown in Table-7 from the viewpoint of bridge planning. As construction method for undersea foundations, the cofferdam method, the open-caisson method, the domed-caisson method, etc. have been conventionally available. However, these were judged to be unsatisfactory at the time of the feasibility study because they had difficulty to meet conditions such as water depth, geology, tidal current,

Items	2P	3P	4A	5P	6P	7A
Depth of water (m)	-10	-5	-5	-25	-35	-20
Foundation level (m)	-10	-10	-10	-32	-50	-50
Width (m)	57	57	62	59	59	59
Length (m)	23	23	57	27	38	75
Volume of excavation (m^3)	19,600	41,500	58,000	32,000	122,000	598,000
Volume of concrete (m^3)	13,000	13,000	36,000	49,000	105,000	235,000
Steel weight of caisson (t)	700	700	1,600	3,700	8,600	16,000

Note: Quantities of work is based on the laying-down caisson method.

Table - 7 Dimension and quantity of under-sea foundations for Minami and Kita Bisan-seto Bridges

dimension and setting depth of foundations and requirement of shorter term, and the laying-down caisson method was newly proposed.
The procedure of this laying-down caisson method is;

1. Sea bed at the site is excavated until fresh and sufficiently strong bed-rock appears, and then the bedrock is smoothly and horizontally finished. During these excavations, whole shape of a steel caisson is built in a shipyard.
2. The steel caisson being afloat or hoisted is transported to the site, and then is set at the designed position on the finished bedrock; and
3. Inside the caisson is filled with undersea concrete while the caisson acts as a form, and then the foundation is completed.

Various technical problems accompanying this method are solved as shown in Table-8 by research, survey and experimental work lasting more than 10 years and by integration of technical achievement in various engineering fields. And this method has been specified for 11 undersea foundations (including 6 of Minami and Kita Bisan-seto Br.s) out of 13 of Kojima-Sakaide route.

4.3.2 Execution of construction work

Because the quantity of works for 6 undersea foundations of Minami and Kita Bisan-seto Br.s is as huge as shown in Table-7, contracts were separately awarded to different joint ventures in the manner of 4 sections of (2P), (3P, 4A, 5P), (6P) and (7A).
On the other hand, fabrication of the steel caissons and the positioning system for setting caisson (composed of the automatic measuring system and the mooring system) were directly awarded to special firms (shipbuilders). These direct orders from the H.S.B.A. could make the quality of the caissons and the performance of the positioning system higher than they would be by the subcontract

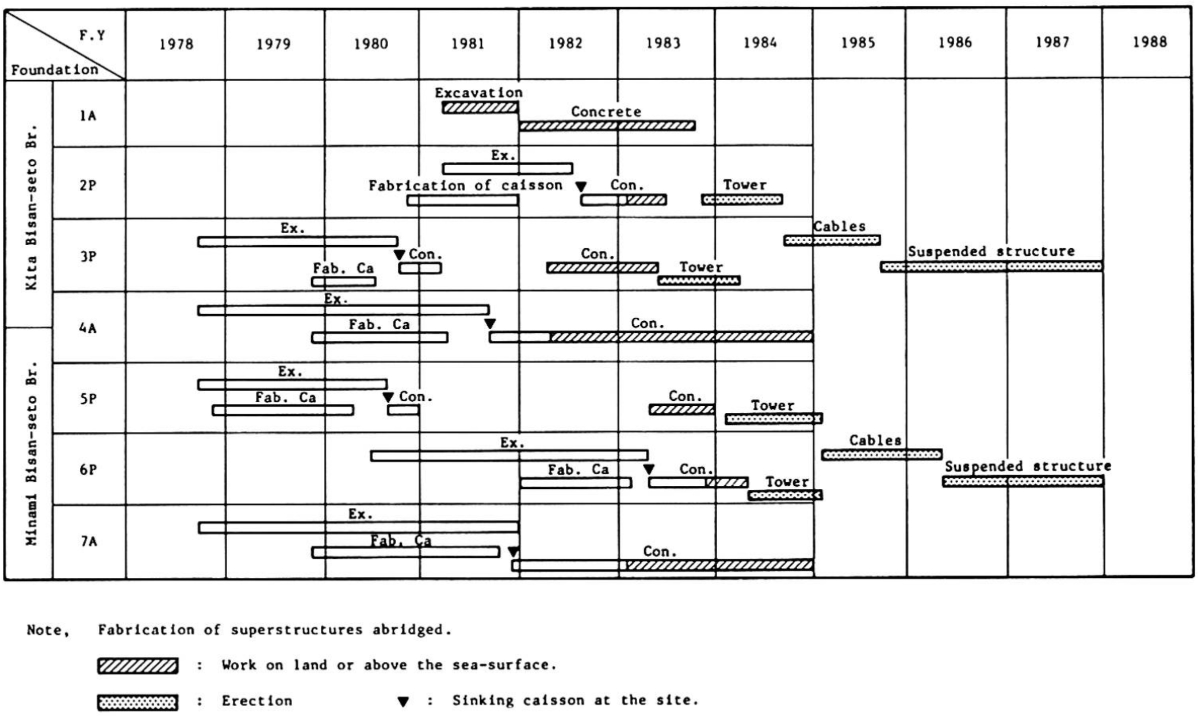


Fig. - 6 Actual/planned schedule for Minami & Kita Bisan-seto Bridges

Technical problems	Solution	Note
1 Underwater excavation	a) Underwater blasting up to 50 m below the sea level by S.E.P. (Self-Elevating Platform). The blasting is executed before the sediment atop the rock is removed to lessen the blasting shock to adjacent structures or fishes (The overburden drilling and blasting method).	• 3 kinds of detonation method are suitably selected.
	b) The sediment and cracked rock are excavated by large grab dredgers.	• Max. grab: 13 m^3
	c) Final surface of the bedrock is finished by large diameter drilling machine mounted on S.E.P.	• Achieved finished uneveness: a few c ntimeters
2 Underwater form and shore	d) The whole shape of a steel caisson which acts as form and shore is built in a shipyard, and then transported to the site, being afloat or hoisted by a floating crane.	
	e) The caisson is set at the designed position by the positioning system which composes of 8 winches and measuring devices for the location, draft, inclination, etc. of the caisson.	• Cap. of a winch: 130t • Mooring wires: 8-ϕ76mm • Weight of anchor blocks: 700 ∿ 900t • Achieved setting error: a few centimeters
3 Underwater concrete	f) By the prepacked concrete method. Specification for mix proportion of mortar, size and grading of the coarse aggregate previously packed, injection speed of mortar, interval of injection pipes for mortar, etc. were determined from a series of experiments.	σ_{ck} = 200 Kgf/cm^2
	g) A mortar plant burge capable to produce mortar of 360 m^3/hr (max.) is built and owned by H.S.B.A. to produce large amount of mortar continuously and stably.	• Usual capacity: 240 m^3/hr (equivalent to 500 m^3/hr of concrete)
4 Prevention of leakage of mortar from the gap between the caisson and the bedrock	h) Finishing the surface of the bedrock (by the method described in c)).	
	i) Rubber cushion is attached to the lower edge of the caisson, and around the caisson is previously sealed by the prepacked concrete.	

Table - 8 Technical development for laying-down caisson method

from the joint ventures. The mortar plant burge for the prepacked concrete was also constructed and owned by the H.S.B.A. and could be given the capacity of continuous-mass-production of the mortar, which in turn made it possible to cast the entire prepacked concrete of an undersea foundation unitedly from the bottom to the top without any horizontal junctions (1 to 7 blocks for casting were planely arranged depending on the plane area of foundations). The construction and the ownership of these two by the H.S.B.A. bring advantage to the redemption, because the redemption can be considered in the entire Kojima-Sakaide route.
In addition, production of the coarse aggregate of large diameter for the prepacked concrete and adjustment of grade and washing fine aggregate (sea sand) were separately awarded from the H.S.B.A., because the direct contracts made it easier for the H.S.B.A. to secure the quality and preservation of the environment. As for working bases, they are rented without charge from the H.S.B.A. which once borrowed them from the local governments who built.
As mentioned above, the H.S.B.A. separately awarded the prime works and the subordinate works, and could complete all the six undersea foundations in the duration between 1978 and 1983 as shown in Fig.-6 with lasting effort to secure the quality, schedule and safety as well as to adjust the relation between various works.
The organization in the H.S.B.A. directly in charge of these undersea foundation works was Sakaide Construction Office, the Second Construction Bureau. At the climax of the works, 15 engineers belonging to 3 sections of the above named office were engaged in superintendence with 24 assistants from 3 consultants.

5. CONCLUSION

The current construction work for 1 route and 4 bridges has been smoothly progressed so far by the implementation system described above, and at March 1984, digestion of the budget reached 51% of the total for 1 route and 4 bridges. In 1988, Honshu and Shikoku are going to be first united as expected.
The work for the left bridges belonging to other 2 routes are expected to start around 1988 when 1 route and 4 bridges are completed and to finish by the end of the 20th century. Among the left bridges, Akashi Kaikyo Bridge which will become the world's largest suspension bridge is included.

Leere Seite
Blank page
Page vide