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## **Safety and Quality Assurance in Honshu-Shikoku Bridge Project**

Sécurité et assurance de la qualité du projet de ponts entre Honshu et Shikoku

Sicherheit und Qualitätssicherung beim Bau der Brücken zwischen Honshu und Shikoku

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Iwao Yoshida, born in 1925, obtained his engineering degree and doctorate at the University of Tokyo, Japan. He has been engaged in many large bridge projects including Honshu-Shikoku Bridge Project, on which he is now working as one of the directors of the Public Authority.

### **SUMMARY**

This paper discusses characteristics of the safety and quality assurance in the Honshu-Shikoku Bridge Project which has been carried out successfully because of an excellent cooperation between the Public Authority and competent Japanese contractors.

### **RÉSUMÉ**

La communication traite des mesures de sécurité et d'assurance de la qualité dans le projet de ponts entre Honshu et Shikoku, projet qui est mené à bien sous la haute direction des autorités et avec la coopération des meilleures entreprises de génie civil du Japon.

### **ZUSAMMENFASSUNG**

Der vorliegende Beitrag beschreibt die Massnahmen der Qualitätssicherung beim Bau der Brücken zwischen Honshu und Shikoku, die aufgrund einer harmonischen Zusammenarbeit zwischen den staatlichen Behörden und fähigen japanischen Unternehmern zum Erfolg geführt haben.



## 1. INTRODUCTION

The Honshu-Shikoku Bridge Project is briefly introduced below. For Honshu-Shikoku bridges, three routes of Kobe-Naruto, Kojima-Sakaide and Onomichi-Imabari are being planned to connect Honshu and Shikoku. For this project, many long bridges must be constructed to cross straits in the Seto-Inland Sea.

The enormous scale can be seen in the fact that nine suspension bridges among the planned Honshu-Shikoku Bridges will be ranked within the longest twenty bridges in the world. At present, the entire Kojima-Sakaide route and two bridges belonging to other routes, viz. Ohnaruto Bridge and Hakata-Ohshima Bridge are being constructed, and two bridges of Ohmishima Bridge (1979) and Innoshima Bridge (1983) are already provided for service.

The Honshu-Shikoku Bridge Authority was established in 1970 as an organization to construct and to manage comprehensively and efficiently the toll roads and railways including the bridges between Honshu and Shikoku. The number of personnel in the Honshu-Shikoku Bridge Authority is about 700, and about 60% of them are engineers. The engineers include specialists of civil engineering and other various fields such as geology, machinery, electricity, architecture, oceanography, meteorology and environment. For the scale of the project, the organization is compact in work force and efficient.

The total budget of Honshu-Shikoku Bridge Project amounts to 3,360,000 million yen (as evaluated in 1982) and is roughly shared for Kobe-Naruto Route by 1/2, for Kojima-Sakaide Route by 1/3 and for Onomichi-Imabari Route by 1/6.

The project has progressed upto about 50%, and is now at the climax stage.

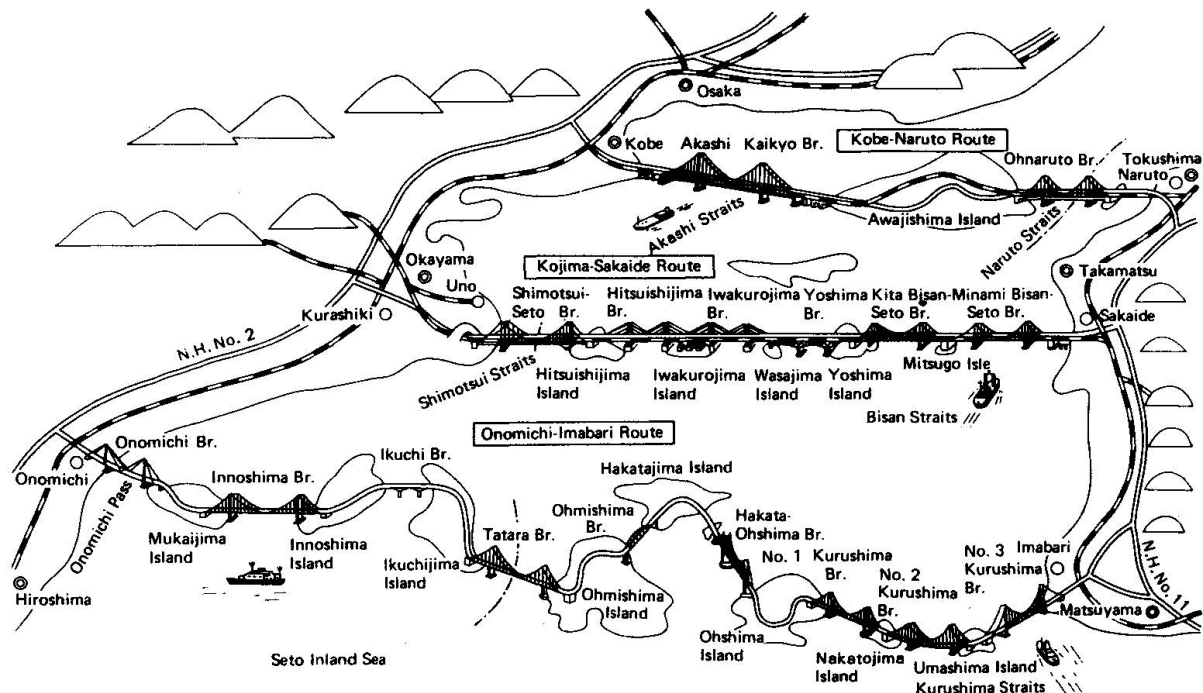


Fig. 1 The Routes of Honshu-Shikoku Bridges

Name of route	Planned amount (unit price in 1982 FY)		1983 fiscal year		1984 fiscal year	
	3 routes (A)	1 route and 4 bridges (B)	Total amount spent (C)	Progress rate in % (C)/(B)	Total amount esti- mated to be spent (D)	Progress rate in % (D)/(B)
Kobe-Naruto *1)	16,650	3,910	2,727	69.8	3,313	84.8
Kojima-Sakaide *2)	11,100	11,100	4,203	37.9	6,456	58.2
Onomichi-Imabari *3)	5,850	2,490	1,143	76.8	1,245	83.6
Total	33,600	16,500	8,073	48.9	11,014	66.8

## Remarks

\*1) Section relating to Ohnaruto Bridge (Tsuna IC ~ Naruto IC)

\*2) Whole section

\*3) Section relating to Innoshima Bridge (Mukai-higashi ~ Mukaijima IC ~ Innoshima IC)  
Section relating to Ohmishima Bridge (Ohmishima IC ~ Hakatajima IC)  
Section relating to Hakata Ohshima Bridge (Hakatajima IC ~ Miyakubo)

Table 1 Overall budget and progress of Honshu-Shikoku Bridge Project  
(in 100 million yen)



## 2. TENDERS AND CONTRACTS

### 2.1 Nominated Competitive Tender

There are two kinds of tender in which general bidders may be allowed or only nominated ones may be allowed. The Honshu-Shikoku Bridge Authority (HSBA) usually takes the latter, namely the competitive tenders by nominated bidders.

In this style of the tender, the owner previously examines technical aptitude, ability, past records of construction, etc. of applicants for nomination in each type of job, and nominates several qualified firms for tenders, considering the items, scales, etc. of the project beforehand. This method is very effective for large-scale construction, special construction, etc. where the owner must sufficiently be aware of the aptitude and ability of the contractor concerned.

The HSBA invites applications for the qualified bidders from those who wish to be nominated, twice a year, and examines the qualifications to grade the applicants for the items of constructions as shown in Table 2.

Grade	General civil engineering work		Steel bridge superstructure work		Pavement work	
	Range of planned contract amount	Number of firms qualified as bidders	Range of planned contract amount	Number of firms qualified as bidders	Range of planned contract amount	Number of firms qualified as bidders
A	600 million yen or more	59	300 million yen or more	49	150 million yen or more	27
B	300 to 600 million yen	199	Less than 300 million yen	139	20 to 150 million yen	126
C	100 to 300 million yen	206			Less than 20 million yen	241
D	20 to 100 million yen	173				
E	Less than 20 million yen	365				

**Table 2** Classification of firms qualified as bidders for the nominated tenders of Honshu-Shikoku Bridge Project

### 2.2 Lump Sum Contract and Unit Price Contract with Described Total Amount

Under a lump sum contract, construction is contracted based on a certain amount of money to the extent specified in the drawings and specifications concerned, and the contract amount is not changed in principle.

Under a unit price contract with described total amount, the unit price for every item which becomes basic unit for payment is established between the owner and the lowest bidder of the total amount.

This contract has following advantages:

- 1) The design and contract can be modified efficiently.
- 2) Construction can be executed smoothly without trouble between the owner and the contractor.

This contract can be said to be flexible compared with the lump sum contract. For large-scale construction as undertaken by HSBA, it is important that the contents of construction be smoothly changed during the execution of works depending on natural conditions, etc.

Therefore, the above named contract system is used by HSBA to cover the changed contents of construction and to make appropriate payment.

### 2.3 Features of Contracts

As a feature of every contract, a changed condition clause is provided to let the contract be changed, when the situation at the site is different from the conditions expected at the time of contract or when any unexpected situation occurs.

Furthermore, a sliding-scale clause is provided as compensation for inflation to let the revision of the contract amount be made when the amount has been recognized to be improper because of variance of wages and commodity prices after lapse of 12 months from the date of contract.

### 2.4 Situations of Contracts

The expenses invested to one route and four bridges by HSBA have amounted to 1,000,000 million yen as of 1984, and the numbers of contractors participating in this large project are as shown in Table 3. The large-scale construction as made in the Honshu-Shikoku Bridge Project contains various items of construction and takes long periods of time. Partly because of budgetary restriction, a work which includes a group of sub-works well-bound from view points of the schedule and place and whose term is about 2 to 4 years is usually ordered as one contract.

Route	600 to 2,000 million yen		2,000 million yen or more		Total	
	Number of orders	Total amount of orders in 100 million yen	Number of orders	Total amount of orders in 100 million yen	Number of orders	Total amount of orders in 100 million yen
Kobe-Naruto Route	39	425	32	1,188	71	1,613
Kojima-Sakaide Route	55	550	67	3,341	122	3,811
Onomichi-Imabari Route	18	171	9	359	27	530
Total	112	1,146	108	4,888	220	6,034

Table 3 Numbers and amounts of orders in Honshu-Shikoku Bridge Project



### 3. QUALITY ASSURANCE AND SECURITY OF SAFETY

Quality control, accuracy control, execution control, schedule control and safety control are important factors to attain quality assurance and security or safety. The details are specified in the individual specification attached to the contract. To effectively keep them in constructing a specified structures, the supervision and guidance by the owner are important.

#### 3.1 Quality Control

Quality control is made as follows;

- 1) All the materials to be used shall confirm to Japanese Industrial Standards (JIS).
- 2) Fabrication of steel structures shall conform to the "Design Standard for Road Bridges" established by the Japan Road Association and the "H.S.B. Standard for Fabrication of Steel Bridges" established by HSBA. Especially for the welding of thick high tension steel plates to be used for long bridges, only welders whose skill is qualified in test shall do welding.
- 3) Concrete to be used for a structure shall be produced by authorized JIS concrete plants. Especially for the prepacked concrete for undersea foundations of Minami and Kita Bisan-Seto Bridges, large-sized coarse aggregate produced by the plant newly built by HSBA was supplied to the contractor, and a mortar plant burge for mortar injection built by HSBA was lent to the contractor to facilitate the quality control of large volumes of concrete.

#### 3.2 Accuracy Control

As for accuracy in stage of the design and construction, natures of errors must be sufficiently understood under an intention to make total quality control. The accuracy control is made as follows;

- 1) Erection error or execution error shall be minimized in each stage of construction.
- 2) Error caused in one stage of construction shall be absorbed in the next stage in order to eliminate the influence as far as possible.
- 3) For error which is judged to be inevitable in view of construction method and difficult for elimination, the influence shall be considered in the stage of design.
- 4) Allowable error for each stage of construction is specified.

#### 3.3 Execution Control

Execution control is concretely made as follows;

- 1) For a newly developed method of construction, trial execution or trial construction is made till the contractor acquires full understanding and becomes confident of the execution. Trials have been made for such items as mortar injection, fabricating pilot members of truss chords, spanning pilot ropes across the sea by a floating crane, extending a prefabricated wire strand, etc.
- 2) Criteria for the erection accuracy or execution accuracy of the structures confirmed by the trial execution or construction are specified in the individual specification.
- 3) The erection or execution method established by trial execution or construction shall be stated in the work execution plan prepared by the contractor, and is thoroughly checked by HSBA. When any imperfect point is found in the plan, the HSBA orders the contractor to change the plan so that intention of the HSBA may be fulfilled.

### 3.4 Schedule Control

Since special large-scale construction is involved, HSBA makes orders for respective items of construction.

For example, a suspension bridge is divided into foundation work, main tower work, cable work and suspended structure work, which are awarded to different contractors. Especially for the process of construction, etc., HSBA adjusts the time of orders for the respective parts of construction so that least contractors may concur at the site. However, it often takes place that different items of work concur, then HSBA advises the contractors to make them cooperate each other for smooth progress of construction.

### 3.5 Safety Control

Safety control includes two problems: security of safety in construction and preservation of environment.

The safety of construction is secured in a way that contractors are obliged to keep relevant laws and ordinances such as Construction Enterprise Law and Industrial Safety and Hygiene Law. Also with regard to problem of the environmental preservation such as the pollution of seawater by submarine blasting, noise of construction machines, etc, the standards are satisfied, since contractors are obliged to keep relevant laws and ordinances such as Water Pollution Prevention Law and Noise Prevention Law.

### 3.6 Establishment of Standards

For perfect execution of quality control, accuracy control, execution control, schedule control and safety control, standards have been established. Design standards cover superstructures, substructures, wind-proofness, earthquake-proofness and other various fields and have been endorsed by large-sized model experiments, site experiments, etc. Characteristic standards out of those for execution of work are for the mass concrete of substructure, the fabrication of superstructure by high tension steel, etc. These standards which have been established with cooperation of societies and associations in Japan such as Japan Society of Civil Engineers and Japan Road Association, etc. are widely applied also for other long bridges in Japan. The number of standards and specifications concerning design and execution of work established by HSBA reaches 51.

## 4. CONCLUSION

The methods for quality assurance and security of safety in the tenders and contracts of Honshu-Shikoku Bridge Project can be summarized as follows;

- 1) Competitive tenders by nominated bidders have been positively adopted.
- 2) As for characteristic of contract type, the unit price contract with described total amount has been adopted to let the contracts be flexible.
- 3) Various standards and individual specification are set up to encourage the contractors toward the quality assurance of the structure and security of safety of the construction.
- 4) A system such as supplying materials purchased in packages by HSBA and lending large equipment to the contractor, etc. has been adopted.
- 5) The work execution plans are thoroughly checked before start of construction, and the execution in conformity with the contents has been made an obligation of the contractors.
- 6) The setting of allowable errors in erection work and accuracy control have been specified in the standards and specification.





- 7) With regard to the schedule control between different items of construction, HSBA has made coordination and asked cooperation of the respective contractors concerned.

The Honshu-Shikoku Bridge Project requires the powerful comprehensive management of HSBA and the cooperation of competent contractors, and while newer technical developments are being tackled under the cooperative work of the both parties, so, the project makes a successful and steady progress.