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Autor(en): **Otofuji, Ken-Ichi / Miyamoto, Kiyoshi**

Objekttyp: **Article**

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

Band (Jahr): **11 (1980)**

PDF erstellt am: **21.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-11270

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Planning, Design and Construction of Expressway Bridges in Japan

Projet, calcul et exécution de ponts routiers au Japan

Entwurf, Berechnung und Ausführung von Autobahnbrücken in Japan

KEN-ICHI OTOFUJI
Executive Director
Japan Bridge and Structure Institute, Inc.
Tokyo, Japan

KIYOSHI MIYAMOTO
Head of Technical Department
Japan Highway Public Corporation
Sapporo, Japan

SUMMARY
Construction of expressways in Japan proceeds at a rate of approximately 200 km per year. The total bridge lengths forms 12 percent of the expressway length. This article describes the systematic working procedure for a effective planning, design and construction of the numerous bridges with a uniform quality. The basic principles for planning and design are also explained.

RESUME
La mise en service d'autoroutes au Japon représentant environ 200 km par année; la proportion de ponts et viaducs est de 12%. Cet exposé présente les principes fondamentaux de l'organisation permettant d'exécuter avec succès et avec une qualité uniforme le projet, le calcul et la construction des nombreux ponts.

ZUSAMMENFASSUNG
Jährlich werden in Japan ca. 200 km Expressstrassen gebaut, wobei die Brückenlänge ca. 12% ausmacht. Der Artikel beschreibt die systematische Arbeit, die nötig ist, um eine optimale Planung, Projektierung und Ausführung der zahlreichen Brücken zu ermöglichen. Grundprinzipien für die Planung und den Entwurf werden dargelegt.

1. INTRODUCTION

Construction of expressways in Japan is conducted by the Japan Highway Public Corporation since 1956 toward the total extension of 7,600 km. The condition of expressway construction and the length of expressway bridges on December 1979 is shown in Table 1. The total construction cost for superstructures of steel and prestressed concrete bridges by the Japan Highway Public Corporation amounts to some 10 percent of the total cost invested to bridge superstructure construction in Japan. The number of bridge engineers of the Corporation engaged in the construction of these numerous bridges is approximately 250. The number of engineers is rather limited compared with the quantity of construction works. This article is to report the outline of the systematic engineering management for construction of the numerous bridges of uniform quality without accidents in spite of the limited number of engineers.

Total Expressway Length Open in DEC 1979	2,524 km
Total Bridge Length	298 km
Ratio of Bridge Length to Expressway Length	12 %
Ratio of Bridge Construction Cost to Expressway Construction Cost	16 - 45 % varies with route
Rate of Bridge Length by Materials	
Steel Bridges	46 %
Prestressed Concrete Bridges	20 %
Reinforced Concrete Bridges	34 %
Average Expressway Length Open per Year	approx. 200 km
Number of Bridges Designed in Fiscal Year 1978	595
Total Bridge Design Cost in Fiscal Year 1978	6,500 Million Yen

Table 1 Outline of Expressway Bridges

2. WORKING FLOW AND ORGANIZATIONS FOR PLANNING, DESIGN AND CONSTRUCTION

The working flow diagram for planning, design and construction of bridges and the working organizations are illustrated in Figure 1. The left column indicates the normal working flow for the bridge construction. The great part of the bridges are constructed by this procedure. The right column indicates the working flow in case of the special long-span bridges, in which the more intensive and detailed studies are carried out. The head office, ten construction bureaus and 93 construction offices are engaged in the construction. The consulting engineers take part in the every stage of investigation, planning, design and construction to achieve the smooth progress of works and to ensure the quality.

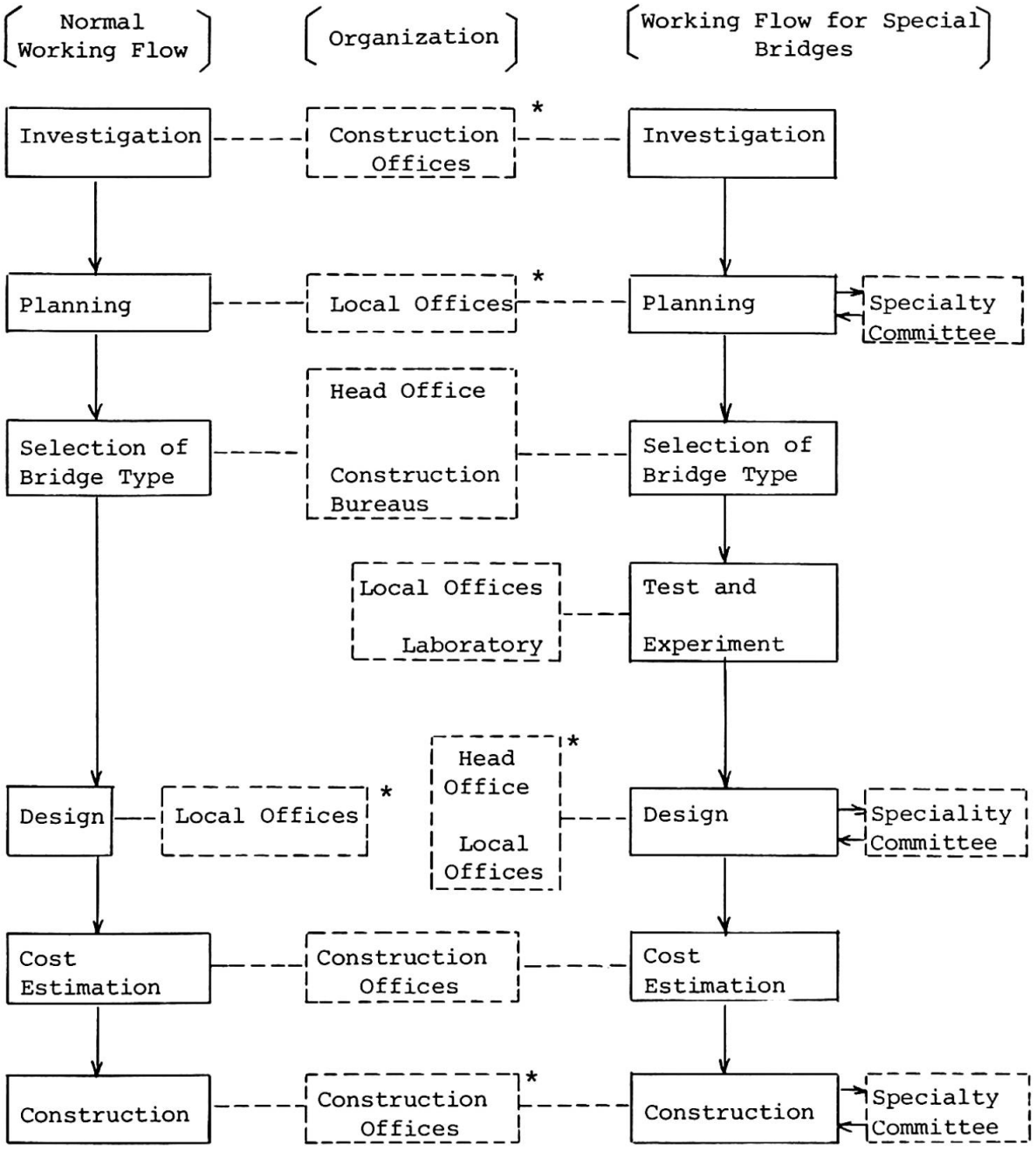

Figure 1 Working Flow and Organization
(* = by Contract with Consulting Engineers)

3. INVESTIGATION AND PLANNING

3.1 Role of Consulting Engineers

The various investigations required for bridge planning such as terrain and geological surveys, and the drawing of the general views or preliminary designs are carried out by the contracts with consulting engineers. The engineers in the Corporation conduct and supervise the works done by the consulting engineers.

3.2 Selection of Bridge Types

In case of the short span bridges or standard bridges, data for selection of bridge types are obtained from the general views drawn by referring to the previous examples. For the long bridges or bridges with large foundations, on the other hand, the optimum bridge types are adopted considering the economy and other factors through the preliminary designs made for the several possible types of bridges.

The types of the bridges planned at the local offices (construction bureaus and construction offices) are decided after examination in the head office. The examination in the head office is to be made through the discussion on the plans proposed by the local offices at many departments in the head office in order to evaluate the safety and rationality of the planned bridges and to establish the unified standard in the bridge project of the Corporation.

3.3 Specialty Committee for Large-Scale Bridges

At the planning of such unexperienced bridges as bridges with high piers or long-span bridges, or new bridge types (e.g. Kanmon Suspension Bridge, long bridges at Numata district), the decisions made by the engineers in charge are sometimes considered unsatisfactory. In these cases, the planning is made after the careful investigation on the design condition, design procedure, possible construction method and other various problems by the specialty committee organized by the experts inside and outside of the Corporation. The investigation by the specialty committee is carried out even in the construction stage as well as the planning and design stages.

3.4 Cooperation with Research Iustitutes

The cooperative investigations, experiments or analyses with the research institutes (the research laboratory-Japan Highway Public Corporation, the public works research institute-Ministry of Construction) are efficiently made to solve the problems in design, construction and maintenance, and the unclear-technical items. The results obtained by these cooperative works are adoped in the design manuals for future use.

3.5 Basic Principles in Planning

Planning are carried out under the following basic principles taking account of design, construction, operation and maintenance.

3.5.1 Improvement of Drivability

-The excellent geometric route alignment is the primary condition for a high speed driving. Therefore, the bridge is planned in the whole route alignment as one of the components of the expressway. The bridges are often the control points in the route planning because of the steep terrain and high density of land use in Japan, and the bridges are often situated in the complex of circular and closoid curves and a vertical curve. Generally, the bridge planning is made to give precedence to the geometric route alignment for the safety in a high speed driving.
-The deck type bridges are normally selected as expressway bridges because it is not preferable for a high speed driving to emphasize the existence of massive structures. Actually, the through and half-through types are adoped only a few cases where inevitable.
-The continuous girder types are employed to reduce the uncomfortability when passing over expansion joints. It also contributes to reduce a noise, to save

maintenance and repair, and to improve aseismicity.

3.5.2 Unity and Standardization of Planning

The unity and standardization of planning are effective to achieve the efficient planning, design and construction maintaining a constant quality.

For the unity of planning, basic principles to select the bridge types are regulated in the design manuals, which is to simplify the selection of bridge types, to avoid the errors and to achieve the general unity of plannings.

For the standardization of planning, the standard designs are prepared for the common bridge types. In the similar local conditions, the plannings are made effectively by utilizing the standard designs. The standardized working procedure simplifys to keep the quality also in design and construction.

3.5.3 Planning for Simplification of Construction Management

It is effective to simplify the construction management in order to supervise a large quantity of construction works as well as to maintain a constant quality by means of a limited number of engineers. Thereupon, the following schemes are carried out.

a) Simplification of Construction Management by Prefablication
-A steel bridge is the most advanced prefablicated type, and simplifies the management at the construciton site. This type is applicable for a rapid erection and is used widely.
-On prestressed concrete bridges, the simplification of scaffoldings and frame works and the uniform quality are achieved by employing precast beams.

On a number of overbridges with similar types, a precast block method is often adopted. Since each piece of beam blocks is produced at the yard, the excellent quality control and construction management are obtained and the period required for erection at site can be saved. Thus, it can be simplified to adjust the working plan with the earth work simultaneously progressed in the site.

b) Repeated Work
In cast-in-place PC and RC bridges, the simplification of site works, construction management and working progress control is attained by means of empoying repeated works such as the traveling form, cantilever erection and incremental launching methods.

3.5.4 Planning for Simplification of Operation and Maintenance

The repair works of bridges open for traffic are dangerous, as they are often obliged to be carreid out in a limited time under the traffic control. They are also expensive compared with the initial construction works due to poor working conditions. The following items are considered in planning in order to simplify the operation and maintenance.

a) Reduction of Repainting of Steel bridges
Repainting due to weathering and corrosion is a serious problem on both cost and labor in bridge maintenance. It is clear that this problem becomes more serious with the progress of expressway length. The following measures are considered in this respect.

-The standard specification of the painting classes provided according to

surrounding conditions is to improve the durability of the painted surface and thus economy.
-The use of hot dip galvanizing is tried in several steel bridges to reduce a number of repainting.
-Concrete bridges are favorably adopted rather than steel bridges to reduce the maintenance cost when the initial construction costs are nearly equivalent.

b) Reduction of Maintenance of Bridge Accessaries
-Expansion joints: Damages of expansion joints due to an increase of heavy traffic always raise a problem in maintenance. According to data obtained, carefully installed steel finger joints perform excellent durability, and the use of this type is highly recommended. Several types of rubber joints and cut-off joints are used according to bridge types, amounts of expansion and contraction, surrounding conditions, and so on. However, the rubber joints performing excellent durability cannot be found so far. The improvement of expansion joints is an important subject in the future.
-Bearing Shoes: Bearing Shoes are easily corroded by the water leakage from expansion joints and the moisture of snow flakes blown into. Normally the repainting work of bearing shoes is difficult due to the limited working room available. The parts difficult to be repainted or easily corroded are hot dip galvanized to reduce the maintenance work.

3.5.5 Seismic Design

The seismic design is the one of the most important problems in bridge planning because Japan has more earthquakes than many other countries in the world. The sufficinet study is made at the planning stage to work out the most effective seismic structural type, span length, and earthquake-resistant location and structure of abutments and piers, according to the terrain and geological condition.

3.5.6 Appearance

In bridge plannings, a structural beauty included in the bridge itself and a harmony with the surrounding scenery are important problems as well as the safety, economy, workability and durability. There are difficult condiitons to construct bridges with good appearance. For instance, the structures cannot be slender due to seismic design considering numerous earthquakes in Japan. The crossing conditions are generally complex due to highly developed land use. However, every effort is made to obtain the excellent appearance through the consideration both in the selection of bridge types and in the design of structural details. Especially, in the beautiful scenery in the national parks the consideration for appearance is often the primary factor in the selection of bridge types.

4. DESIGN

The following methods are taken in order to carry out a large quantity of the effective and reliable designs by means of a limited number of engineers.

4.1 Role of Consulting Engineers and Classification of Design

Designs are done by contract with consulting engineers. Basic principles, design methods and drawings are appreciated by the Corporation's engineers through the meetings with the consulting engineers.

The contracts for the construction of RC bridges and π-shaped PC overbridges

are called after the final designs are completed. The contracts for the construction of PC and steel bridges, however, are called by the primary designs and the final designs are carried out by the contractors. The primary designs are checked by the contractors through the final design. The structural details are decided by the construction companies, which clarifies the responsibility of the construction work.

4.2 Design Manuals

The design of highway bridges in Japan is based on the specifications provided by the Japan society of Civil Engineers and the Japan Road Association. The Japan Highway Public Corporation also has its own design manuals, which are to indicate the basic principles and structural details. The designs done at the local offices are maintained at the unified level and are made efficiently by the use of the design manuals.

4.3 Unified Design and Save of Efforts by Standard designs

Standard designs are prepared for the common type of superstructures and substructures, and structural details of bridge slabs, expansion joints, bearings and drainage systems. Standard designs are effective to realize the unified design and to save the efforts.

4.4 Computer and Design

The most parts of the calculations in design are now processed by electronic computers. The complex calculations beyond human power can now be executed by the computer. The realistic analysis of the behavior of the actual structure can be made unless the errors in the analytical asumptions and programs or the mistakes in input data. In the design calculation done by the use of the multi-role program, simple mistakes can be eliminated. Thus, the efforts of engineers can be concentrated to check the input conditions and drawings.

5. CONSTRUCTION

The following affairs are conducted at the construction stage in order to maintain a constant and excellent quality and to achieve a smooth progress of construction works.

5.1 Construction Management by Cooperative Work with Consulting Engineers

The supervision and inspection of construction works are carried out by means of a construction management consignment system. Consulting engineers working in the construction offices manage the construction works cooperatively with the Corporation's engineers. Approximately 880 Corporation's engineers and 550 consulting engineers are engaged in the construction works including the works other than bridge construction.

5.2 Confirmation of Conditions on Investigation and Planning and Alternation of Design

The applicability of the local conditions (terrain, geology etc.) obtained in the investigation and planning stages are confirmed during construction works. The alternation of the design is executed when necessary to ensure the safety of bridges.

It is of importance in maintaining the quality and controlling the working

process to deal with the adequate and smooth alternation of the design when required.

5.3 Confirmation of Quality

The conditions of the quality control for materials and structures are reported by the contractors according to the specifications. The conditions are confirmed by the Corporation's engineers when required.

Materials, slump and strength of concrete are the examples of the former case, and the fabrication and installation of reinforcement bars and forms and the excavation length of piles are the examples of the latter case.

5.4 Negociations with External Organizations

In Japan where the land use is highly developed, it is necessary to establish the negociations with the external organizations and residents on the conditions and methods of construction work prior to the beginning of the work. These negociations are cooperatively done by the Corporation and contractors to achieve the smooth progress of works.

6. CONCLUSION

The construction of expressway in Japan is being progressed at a rate of approximately 200 km per year. The construction works of numerous bridges are carried out with the extension of the expressway length. Since bridges are expensive compared with earth works and are difficult to be reconstructed when damaged, the especially accurate planning, design and construction are required. The management system in order to construct a large quanity of bridges maintaining the constant quality and accuracy by a limited number of engineers has been described herein. The principal concepts are summarized as follows.

-In case of the normal bridges, the uniformity of designs and constructions, and labor savings are attained by means of the prepared design manuals and standard designs. The quality of designs and constructions are maintained by means of the cooperative works with consulting engineers.

-In case of the special bridges, the intensive planning, design and construction are made by the more consolidated local organizations than in case of the normal bridges. The specialty committees are organized to examine the problems to take the safest measures.