The Importance of Design and Technical Management in International Bridge Construction Project from Contractor’s Point of View

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ABSTRACT: These days a lot of international bridge construction projects are carried out all over the world. The aspect is that the project size is becoming larger compared with the past, on the other hand the project duration to reach full-completion is required to short from social needs. Furthermore there are many cases that you have introduced the new structural type of bridge, design and construction methodology in order to achieve those requirements.
Japanese contractors marketed in this business segment thirty years ago. At the beginning they focused on the projects which Japanese and local governments set up as official development assistance (ODA) projects, and then they have been learning by experience and accumulating the know-how to build bridges with local people in other overseas countries, with introducing Japanese original technology sometimes.
However, they also moved in the large-scale Design and Build projects in newly-emerging countries to explore new business market where they tried to wide their sphere of activity.
The most important issue is how to manage Time, Cost, Quality and Safety based on the international construction management manner. The key to achieve success is the management of design and technology.
The authors are trying to describe the importance of design and technical management in international bridge construction project from contractor’s point of view, showing several experimental examples and finally taking up a new role which Japanese contractors are trying to act.

1. INTRODUCTION

These days a lot of international bridge construction projects are carried out all over the world. The aspect is that the project size is becoming larger compared with the past, on the other hand the project duration to reach full-completion is required to short from social needs. Furthermore there are many cases that you have introduced the new structural type of bridge, design and construction methodology in order to achieve those requirements.

Japanese contractors marketed in this business segment thirty years ago, and learned by experience and accumulated the know-how to build bridges with taking part in Japan’s ODA projects, however, they also moved in the large-scale Design and Build project business segment in newly-emerging countries. Those projects are managed with international construction management manner. It is said that Japanese contractors are weak in management style based on contract sense. Meanwhile, design and technical management in international bridge construction project is the other key.

This paper discusses the importance of design and technical management in international bridge construction project from contractor’s point of view, showing several experimental examples by the authors, finally taking up a new role which Japanese contractors are trying to act.

2. PROJRCT LIFE CYCLE IN INFRASTRUCTURE DEVELOPMENT

2.1 Typical Sequence of Phases in a Project Life Cycle

Project life cycle in infrastructure development is typically shown in Figure 2.1[1)]. In manufacturing

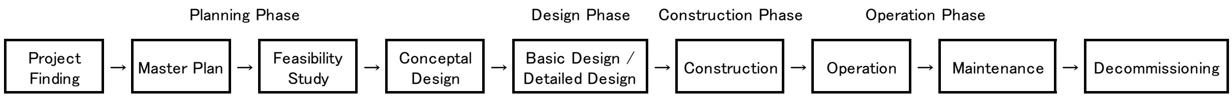

Figure 2.1 Typical Sequence of Phases in a Project Life Cycle[1)]

Table 2.1 Project Stakeholders' Role [1)]

	Feasibility Study	Plan	Design	Construction
Employer	◎	◎	○	
Designer		○	◎	
Contractor				◎

◎ initiative
○ subsidiary

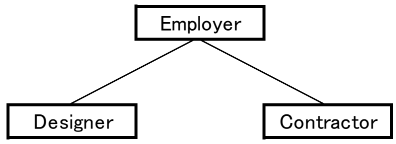

Figure 2.2 Project Stakeholders' Relationship[1)]

industry, both designer and manufacturer are normally working in the same company. On the other hand, in construction industry, contractor and designer are acting independently. Therefore the independent designer is essential for a construction project. The roles of three stakeholders are shifting as to a project life cycle accordingly (Table 2.1)[1)].

In case of an ordinary project, project stakeholders are formed by Employer, Designer and Contractor based on Design and Construction separation principle, as shown in Figure 2.2 [1)].

2.2 Project Life Cycle in the Bridge Construction Project

Project life cycle, the roles of stakeholders and the relationships between them in the international bridge construction project are also described same as 2.1.

Meanwhile, these days a lot of Design and Build projects have been formed in large-scale traffic infrastructure development project field in newly-emerging countries. The reasons are that there are needs from those clients, to short the project duration achieving full-completion and to minimize the project cost. Although owners and designers take an initiative in carrying out the project at planning and design phases in a traditional project style, contractors are involved in the project from those beginning phases as one of major stakeholders in Design and Build project. Moreover there are many cases that owner side demands a contractor to organize finance.

Considering the above background, the project life cycle and relationship between all required study, planning, design and engineering (technical study) in the international bridge construction project are mapped on Table 2.2. In this paper, all design and technical works, not only known detailed-design but also engineering works which a contractor normally carries out prior to construction, are defined as Engineering.

3. OVERSEAS BRIDGE CONSTRUCTION PROJECT BY JAPANESE CONTRACTOR

Japanese contractors marketed in this business segment thirty years ago, and got jobs ordered by local governments or financed by the World Bank. At the early 1990s, Japanese government increased the infrastructure development project as Official Development Assistance (ODA), and inevitably a number of projects for bridge construction. In line with the above movement, Japanese contractors focused on getting such projects, learning by experience and accumulating the know-how to build bridges with local people in overseas countries, with introducing Japanese original technologies sometimes.

However, they also moved in the large-scale Design and Build projects in newly-emerging countries to explore new business market where they tried to wide their sphere of activity.

Some bridges projected by Japan's ODA were adopted relatively new structural types of bridge to fit the given project conditions[2)]. For example, the Second Mandaue-Mactan Bridge was constructed with the type of extradosed prestressed concrete bridge, and the Palau New K-B Bridge was the extradosed composite steel-concrete bridge.

In Japan, in-house engineers of owner side, especially Nippon EXpressway COmpany (ex Japan Highway Public Corporation), have been leading technical research and development in bridge construction industry. Contractors also have

Table 2.2 Project Life Cycle and Design, Engineering

Design and Engineering in Project Life Cycle	Phase	Stage	Item	Output	before Tender Call	Tender Call	prior to Tender	Tender	L/A	DCP2	DCP3	DCP4	Shop Drawings	Commencement		As Built Drawings	Handover	After Handover
										Project, Design Phases and Stakeholdrs →								
	Planning Phase	Master Plan			The Engineer (Employer's Consultant)													
		Feasibility Study																
		Conceptual Design	Rail Alignment and Configuration Plan															
			Station Arrange Plan															
			Structural Arrange Plan															
			Structural Design	Structural Drawings Prestressing Layout Drawings														
			E&M Plan															
			Rail System Plan															
	Design Phase	Basic Design	Rail Alignment and Configuration Plan (including Review)															
			Station Arrange Plan (including Review)								Contractor's responsibility for all							
			Structural Arrange Plan (including Review)															
			Structural Design (Levelling up to Basing Design)	Structural Drawings Prestressing Layout Drawings Re-bar Arrangement Bridge Accessory Drawings			Civil Contractor's Subconsultant											
			E&M Design															
			Rail System Design				Rail Contractor											
		Detailed Design	Survey (for Detailed Design)							Civil Contractor's Subconsultant								
			Geological Explorations (for Detailed Design)															
			Rail Alignment and Configuration Plan															
			Station Arrange Plan															
			Structural Arrange Plan															
			Structural Design (Detailed Design)	Structural Drawings Prestressing Layout Drawings Re-bar Arrangement Drawings Bridge Accessory Drawings							Civil Contractor's Subconsultant							
			E&M Design															
			Rail System Design								Rail Contractor							
	Construction Phase	Design and Engineering for Construction	Erection Analysis and Design	Erection Analysis and Design Check Camber Calculation Prestressing Calculation														
			Design for Temporary Works	Design for Temporary Works Design for Machine and Equipment							Subcontractor							
			Drawing and Documentation	Shopdrawings Re-bar arrangement and Schedule As-built Drawings														
	Operation Phase	Operation	Maintenace Manual												Civil Contractor's Suconsultant Rail Contractor			
		Maintenance	Maintenance Plan															

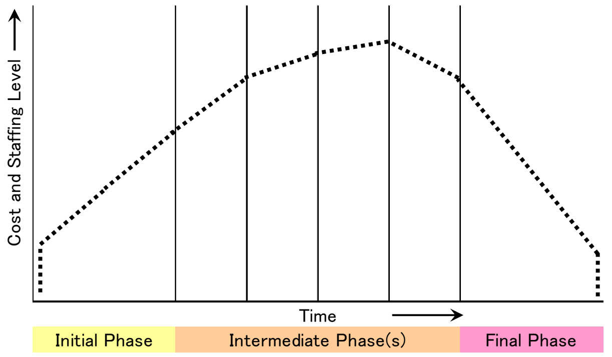

Figure 4.1 Typical Project Cost and Staffing Level across the Project Life Cycle[3)]

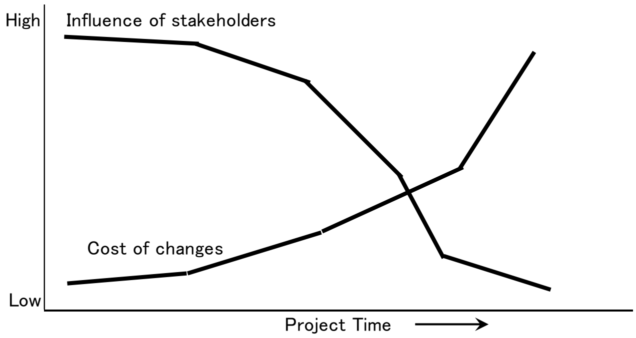

Figure 4.2 Stakeholders' Influence over Time [3)]

been learning engineering and construction know-how. The above both new types were taken form in Odawara Blue Way Bridge Project (1994), Kiso and Ibi Bridge (Twinkle) Project (2001) planed by Japan Highway Public Corporation.

4. THE IMPORTANCE OF DESIGN AND TECHNICAL MANAGEMENT AT EARLY STAGE OF PROJECT

Textbook, for example, PMBOK[3)] argues typical project cost and staffing level across the project life cycle and stakeholders' influence over time, as shown in Figures 4.1 and 4.2.

1) Cost and staffing levels are low at the start, peak during the intermediate phases, and drop rapidly as the project draws to a conclusion,
2) The level of uncertainty is highest and, hence, risk of failing to achieve the objectives is greatest at the start of the project. The certainty of completion generally gets progressively better as the project continues.
3) The ability of the stakeholders to influence the final characteristics of the project's product and the final cost of the project is highest at the start, and gets progressively lower as the project continues. Figure 4.2 illustrates this. A major contributor to this phenomenon is that the cost of changes and correcting errors generally increases as the project continues.

Looking at construction projects, there are many unfavorable, uncertain risks at early stage. Judging from the above arguments, the most important management for construction project is how to reduce uncertainties with involvement in all stakeholders, giving them much satisfaction. For bridge construction, especially, the role of design and technical management is in a significant position.

5. SECOND MANDAUE-MACTAN BRIDGE CONSTRUCTION PROJECT IN THE PHILIPPINES

5.1 Project Outline

The Second Mandaue-Mactan Bridge[4)] is a 4-lane bridge with a total length of 1,010m, which links the Cebu main island of Metro Cebu, the central city of Visayas region in southern Philippines, and the Mactan island where Cebu international airport and industrial manufacturing zone are located (Figure 5.1).

The main bridge spans Mactan channel which requires shorter tower due to maximum allowable top elevation as established by the airport, a vertical structure clearance so that ships can pass through under the girder and aesthetics as landmark. Consequently, extradosed prestressed concrete bridge was selected to suit these requirements (Photo 5.1).

5.2 Project Data

Bridge Length (Span): 410.0m (111.5m＋185.0m＋111.5m)
Total Width: 21.0m
Owner: Department of Public Works & Highways, Republic of the Philippines
Funding Source: The Overseas Economic Cooperation Fund (Japan's ODA Yen-Loan)
The Engineer: Katahira & Engineers International

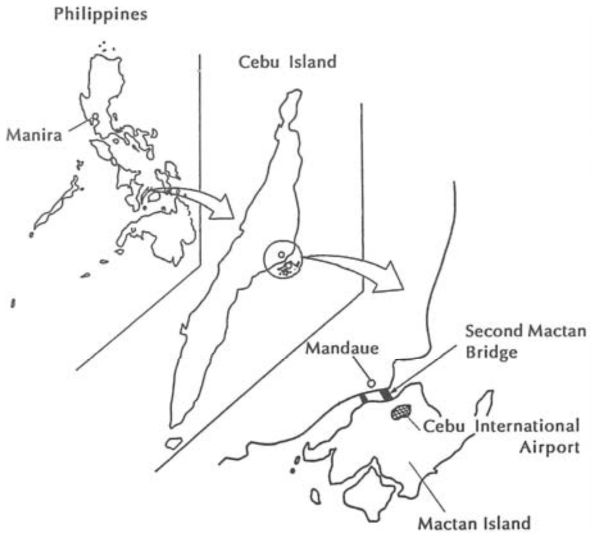

Figure 5.1 Second Mandaue-Mactan Bridge Project Location

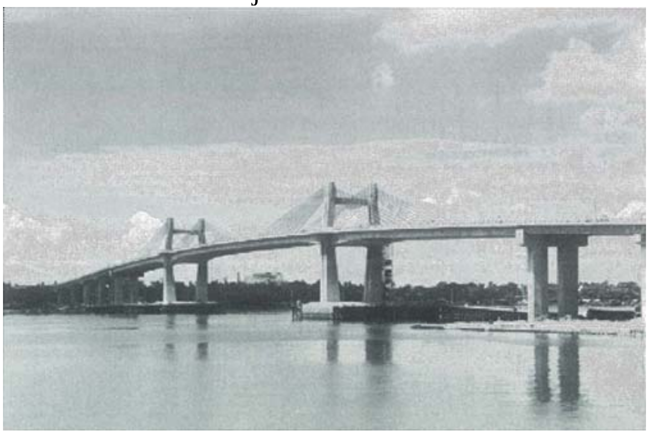

Photo 5.1 Second Mandaue-Mactan Bridge

Contractor: Kajima Corporation and Sumitomo Construction Co., Ltd. JV
Construction Period: Oct.1996 – Oct.1999

5.3 Design

The main bridge is a 3-span continuous extradosed prestressed concrete bridge with 410m of total length and 21m of road width. The center-span is 185m, which was the largest span by extradosed prestressed concrete bridge in the world at that time. The main girder is 3 box-type prestressed concrete structure with a height at the tower section of 5.1m and at the standard section of 3.3m and width of 20.8m.

Design is based on "Specifications for highway bridges" (Japan Road Association). Type of Foundation of tower is multi-pile foundation with 23 large reinforced concrete bored piles. Earthquake resistance of tower and pier structures was checked by dynamic response analysis forced AASHTO's seismic load. A stay cable consists of 48 epoxy-coated strands with a diameter of 15.2mm. For offshore structure, the triple protection is guaranteed by epoxy-coated strands, cement grout and high density polyethylene pipes.

5.4 Construction

Bearing layer of tower foundation are hard clay at Cebu side and irregular alternation of strata consists of hard limestone and soft gravel layer at the Mactan island side. The casing tube rotary Method (CTRM) was adopted to construct piles to avoid a collapse of soil during piling. At the head of pile, triple rebar, D51-D38 are arranged. Then, flowable concrete which has a flow value of 55cm using super plasticizer, was poured to ensure that no voids would form.

Main girder which has 17 blocks at each side of the towers was constructed by the balanced cantilever erection method with 4 large-sized formtravellers having 4 frames at the same time. Block length varies from 3.0m to 5.25m. 20-ton cranes were put-up on the bridge surface for use in lifting construction materials, erection of HDPE pipes for stay cable and installation of prestressing jacks.

The second Mandaue-Mactan bridge project was the first large-scale prestressed concrete bridge construction project in the Philippines. The construction work was executed by local Filipino engineers and workers under Japanese engineer's supervision. Finally, the project has contributed not only a high level quality structure construction, but also technology transfer to the Filipino people[5)].

5.5 Challenge and Technical Management

The contractor tried several challenges related to alternative proposals in order to meet the client and social demands, as shown in Table 5.1. Since it was the prestigious project for local people, the government wanted us to contribute much toward local economy. Having lots of stakeholder's management meetings, we finally agreed that the design changes were carried out to lead the client's satisfaction and to avoid facing unfavorable risks.

One more issue on this construction project, building of extradosed concrete type of bridge was the first trial in developing countries and the length

Table 5.1 Challenge of Second Mandaue-Mactan Bridge Project

Evaluation and Test for New type of Bridge Structure	
	・3-Dimensional Dyanamic Analysis
	・Creep Test for Concrete
	・2500t Load Test for Concrete Bored Pile
	・Friction Test of Epoxy-Coated Strand and Saddle with Full-Scale Model
	・Single Strand for Stay Cable Tensile Test
	・Full-Scale Fatigue Test of Dywidag C48 type Stay Cable
	・Evaluation of Countermeasure for Rain Vibration
	・Site Vibration Test
Technical Support and Advise by Experts	
	・Client set up Special Technical Assistance Team (S.T.A.T) formed by Japanese Experts.

Table 5.2 Design and Technical Management of Second Mandaue-Mactan Bridge Project

Alternative Proposal for Foundation Design		
	Cast-in-situ Concrete Pile (Steel pipe pile on original tender drawings)	・Cost down ・Time accerаration ・After awarded, client requested changes of the methodology, impacting more local economy due to utilizing local goods.
Alternative Proposal for Girder Design		
	Cast-in-situ balanced cantilever erection method (Precast segment erection method on original tender drawings)	・Cost down ・Difficulty of concurent construction, foundation and segment production ・Difficulty of setting up lager-scale segment production yard ・Incresed shipping trafic volume of Mactan channel

of center span would be the world record. The contractor appointed experienced engineers at the site, and organized the technical support team in Japan, consists of not only Kajima and Sumitomo, but also venders to supply special equipments and material, carrying out a lot of evaluation and tests to verify unique technical assignments, as shown in Table 5.2.

Furthermore the client and the Engineer set up Special Technical Assistance Team (S.T.A.T) formed by Japanese experts, reviewing those challenges.

6. CHIRUNDU BRIDGE CONSTURCTION PROJECT IN ZAMBIA/ZIMBABWE

6.1 Project Outline

The Chirundu Bridge[6)] is a 2-lane bridge with a total length of 400m that connects the international border of the Republic of Zambia and the Republic of Zimbabwe across the Zambezi River (Figure 6.1, Photo 6.1). This area caused heavy traffic everyday mainly because of cargo trucks for trading between the two countries and also for the neighboring South African countries.

The existing 65-year old Otto Beit, steel suspension bridge has only a single lane and is under traffic control, which caused for the delay in

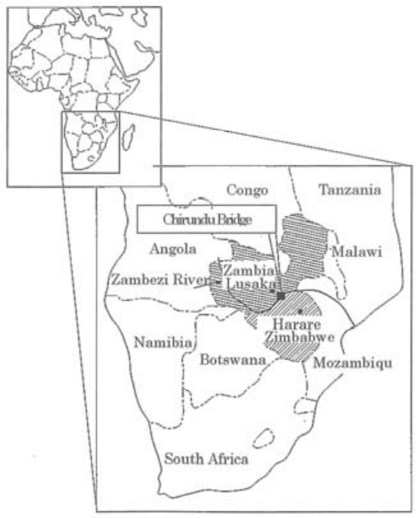

Figure 6.1 Chirundu Bridge Project Location

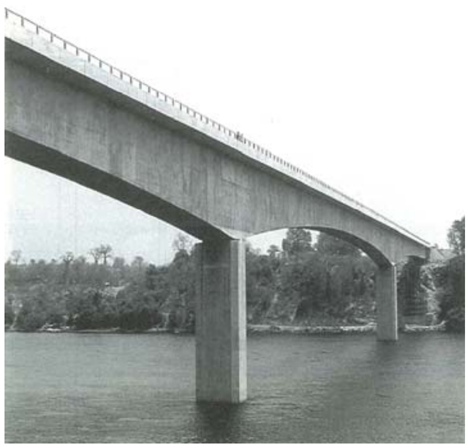

Photo 6.1 Chirundu Bridge

Table 6.1 Stakeholders, Logistics and Technical Management of Chirundu Bridge Project

Stakeholder Management		
	Tri-lateral project	・Japanese government donated a project to two countries, Zambia / Zimbawe. ・Contractor set up an organization of regular monthly tri-lateral meeting in order to involve both countries. ・Contractor employed labor from both countries.
	Project on border	・Project location is on the international border of Zambia / Zimbabwe, managing all necessary immigration issue and customs.
Logistics Management		
	Project in low-income developing countries	・Both countries requested to procure material from local market. For bridge construction with advanced technology, some were difficult, importing goods from neighboring South Africa.
Technical Management		
	Japan's unique steel-pipe-sheet-pile foundation	・Type of foundation was Japan's unique steel-pipe-sheet-pile, required the steel-pipes with unique detailed joint. Contractor imported the steel-pipes from South Africa, dispatched Japanese Supervisor in order to control quality management.
	No availability of Ready-mixed Concrete	・Contractor set up own batching plant for concrete mixing since project location is remote area from city, managing quality control of concrete.
	Camber Control	・Girder was constructed by balanced cantilever erection method using formtravelers.

transporting goods from one country to the other. Hence, the construction of this new Chirundu Bridge was planed with support by Japanese Overseas Development Assistance.

6.2 Project Date

Bridge Length (Span): 400.0m (119.0m＋160.0m＋119.0m)

Total Width: 10.3m

Owner: Ministry of Works & Supply (Republic of Zambia), Ministry of Transport & Energy (Republic of Zimbabwe)

Funding Source: Japan's ODA Grant

The Engineer: Chodai Corporation Ltd.

Contractor: Kajima Corporation

Construction Period: Feb.2000 – Feb.2003

6.3 Design

The bridge is a 3-span continuous prestressed concrete bridge with 400m of total length, 10.3m of road width. The center-span and side-span are 160m, 119m respectively. The main girder is single-box-type prestressed concrete structure with a height at the pier head table section of 9.0m and at the standard section of 4.5m. Bridge design is based on British Standard 5400.

Type of Foundation of main piers is steel-pipe-sheet-pile foundation with 44 pieces of 1000mm diameter large steel pipes. This unique type was developed in Japan, therefore, foundation is designed based on "Specification for highway bridges" (Japan Road Association).

6.4 Construction

Bearing layers of the two piers are sandstone and the average depth of river bed is around 8 meters. 44 pieces of 1000mm diameter, 33 meters long steel pipe sheet piles were driven around the pier using a hydraulic vibration hammer. Underwater concrete was poured in the pier footing and inside the steel pipe piles with a thickness of 5 meters.

Main girder which has 23 blocks at each side of the piers was constructed by the balanced cantilever erection method with 4 formtravellers at the same time. Block length varies from 2.5m to 3.7m. The two cast-in-situ end spans were constructed using a high tension steel shoring. Two end closure blocks and centre block were poured concrete by using formtravellers.

50-ton crane was used at the site for construction of the Temporary Jetty, for driving of steel pipe sheet piles and for lifting materials on the top of the girder which is approximately 25 meters high.

The Chirundu bridge project was jointly constructed by the labor force Zambia and Zimbabwe under supervision of Japanese engineers. With the Japanese advanced methods and techniques in construction, the project has contributed much to the people of the two countries.

6.5 Stakeholders, Logistics and Technical Management

The contractor had several issues concerned with tri-lateral project, to manage those stakeholders. We always needed to treat with both governments, setting up the regular monthly tri-lateral meeting to communicate, to solve issues with timely manner. Since project location was on the international border, the exclusive immigration and customs system were established for the project (Table 6.1).

Regarding logistics and technical management, the contractor had a lot of difficulties in project execution in low-income developing countries, as shown in Table 6.1. Logistics issues had us stumped completely. For manufacturing of steel-pipes with unique detailed joint to suit steel-pipe-sheet-pile foundation by developed in Japan, Japanese engineer was dispatched to the factory in South Africa in order to control quality. Furthermore, it was no available of ready-mixed concrete at the project site, own batching plant was set up.

7. FURTHER CONSIDERATION

7.1 Design and Technical Management for Design and Build Project

7.1.1 Design and Build Construction

With the design-build construction, the project may be completed within a shorter period of time than the traditional design-bid-build construction since the actual construction can be started before the completion of a detailed design. This requires a closer working relationship between the design team and construction team. The design team needs to be actively involved in the construction phase by providing information and answering questions to the construction team in a timely manner. If the design team spends too much time on looking for the cost-effective design and more effective transformation of design concepts into construction reality, it will waste the overall construction duration that could have been used by the construction team. The design team must be well-balanced in finding not the best but an appropriate solution within a limited amount of time/money.

7.5.2 Technical Study and Engineering

In huge-scale Design and Build project, a main contractor organizes subconsultants, a number of subcontractors and venders. The known detailed design is carried out by consultants, however, a lot of technical study and engineering are studied by subcontractors. Such a technical management is the key to success for achieving the goal.

8. CONCLUSIONS

Historically in-house engineers of owner side have been leading the project based on mutual understanding in Japan’s construction industry. And also projects have been executed with Design and Construction separation principle for a long time. Hence contractors are unfamiliar with the project management for Design and Build contract, not having culture to tackle.

In the meantime, Japanese contractors have been experiencing overseas bridge construction projects with Japan’s ODA and nowadays are trying to work the large-scale Design and Build project.

As discussing in this paper, it goes without saying that design and technical management is essential. Lastly, the viewpoints, which Japanese contractors will have to experience and learn, are as the below.

1) Fast tracking
2) Concurrent engineering
3) Project-based organizations
4) Scope management
5) Risk management
6) Integration management

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