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Mechanization of Bridge Construction by Use of Large Prefabricated Blocks

Mécanisation de la construction de pont par utilisation de gros éléments préfabriqués

Mechanisierung der Brückenmontage unter Anwendung grosser Fertigteile

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1. Bridge Construction in Large Prefabricated Blocks in Japan

A conspicuous trend characterizing bridge construction in Japan lately is the use of increasingly larger prefabricated blocks owing to mechanization of erection work. (See Table 1.)

Naturally, the construction of bridges in large blocks is nothing new. However, a distinct conceptual difference lies between the past and the present. In the past, the method of constructing bridges by the use of large blocks had been either an inevitable alternative where other construction methods appeared unfeasible, or had been adopted for very limited applications indeed.

Table 1. Examples of steel bridges constructed by the large block erection method in Japan (1974-75)

Name of bridge	Year of construction	Type	LENGTH OVERALL	Main particulars of erection block	Outline of erection work
Osaka Port Bridge	1974	Cantilever truss bridge	m 980 (235+510+235)	L x B x D— 192.1 m x 23.9 x 26.8 m Weight of max. block 4,500 t	Transshipment onto deck barge by a 3,000-ton+2,500-ton floating crane; hoisted by 8 units of 132 kW double-drum winch
Daikoku Bridge	"	Cable-stayed Bridge	m 265.88 (165.38+100.50)	L x B x D—105 m x 24.2 x 2.78 m Weight of max. block 950 t	Erected by a floating crane with a lifting capacity of 1,500 tons
Katagami Bridge	"	4-span continuous steel box girder	m 475 (95+160+120+100)	L x B x D—131.8 m x 9.3 x 7.1 m Weight of max. block 552 t	Erected by a floating crane with a lifting capacity of 1,300 tons
Suehiro Bridge	"	Cable-stayed bridge	m 470 (110+250+110)	L x B x D—52 m x 18.5 x 2.8 m Weight of max. block 340 t	Floating crane method, 1,000 ton lifting capacity
Ohgishima Bridge	"	3-span continuous steel box girder	m 184 (50+84+50)	L x B x D—184 m x 15.8 x 3.392 m Weight of max. block 1,200 t	Floating crane method; 1,500 ton lifting capacity
Arakawa Coast Bridge	1975	Cantilever truss bridge	m 840 (100+120+125 +150+125+120+100)	L x B x D—197.8 m x 48.5 x 21.57 m Weight of max. block 4,250 t	the largest girder erected by three floating cranes-3,000-ton+2 x 1,500 ton
Oshima Bridge	"	3-span continuous truss bridge	m 725 (200+325+200)	L x B x D—212.5 m x 11.0 x 38.3 m Weight of max. block 1,895 t	Floating crane method, 3,000 ton lifting capacity
No. 2 Maya Bridge	"	3-span continuous steel box girder	m 360 (75+210+75)	L x B x D—127.5 m x 18.0 x 7.5 m Weight of max. block 1,700 t	Floating crane method, 3,000 ton lifting capacity
Kamome Bridge	"	Cable-stayed bridge	m 440 (100+240+100)	L x B x D—75.6 m x 20.5 x 3.1 m Weight of max. block 600 t	Floating crane method 1,300 ton lifting capacity
Hirato Bridge	"	Suspension bridge	m 665 (center span 465.4 m)	L x B x D—63.0 m x 17.5 x 4.0 m Weight of main tower 567.3 t	Floating crane method appolied to the main tower only; 1,300 ton lifting capacity
Rokko Bridge	"	Cable-stayed bridge	m 400 (90+220+90)	L x B x D—93.6 m x 24.1 x 9.348 m Weight of max. block 1,450 t	Floating crane method; 3,000 ton lifting capacity
Kajima Bridge	"	3-span continuous truss bridge	m 340 (69.2+170+99)	L x B x D—180 m x 7.2 x 17.5 m Weight of max. block 634 t	Floating crane method; 3,000 ton lifting capacity

By contrast, today the method is rather a preferred choice which the designer makes on his own initiative from among the many methods available.

In short, the method of constructing bridges in large prefabricated blocks has come back into the picture as a kind of popular prefabricated bridge construction method.

True, even in the past, the structural members of a steel bridge were prepared almost entirely at a shop for simple assembly at site. In this sense, the conventional method may be conceived of essentially comprising a prefab construction method. Only, most conventional methods required a larger proportion of field assembling work to be achieved under stringent working conditions, so the construction period was naturally longer.

The bridge construction method using large prefabricated blocks was developed in Japan in the backdrop of the situation described above as a means to capitalize fully on the prefabricated bridge construction method by improving it as close as possible to perfection.

As observed from another angle, the emergence of the Japanese method of constructing bridges in large prefabricated blocks may be construed as having been stimulated by the monumental success achieved by the Japanese shipbuilding industry which adopted the method of building ships in large prefabricated blocks during the postwar years.

The final assemblage work in shipbuilding up to not so long ago used to be achieved by conveying comparatively small, shop-assembled blocks weighing only a few tons onto the building dock where armies of workers where thrown into action to fabricate the ship.

The ever larger vessels came to be built from year to year, the manhours required for assembling increased steadily owing to the inescapable volume of assembling work required on the building docks where working conditions were cruelly restrained; naturally, the ships under construction came to tie down the building docks for longer and longer periods of time. This worked bitterly against shipbuilding efficiency, for the building dock's turnover rate essentially governs the working efficiency of not only the building dock itself but also of the total workshop including steel material stockyard, machining shop, rigging shop, rigging quay and so forth.

To cope with the situation, a large proportion of assembling work on building docks was transferred to the assembling shop by capitalizing on advanced welding techniques as a means to improve shipbuilding productivity, thus heralding in the shipbuilding industry the method of assembling ships in large prefabricated blocks.

Prefabricated blocks conveyed onto building docks have greatly increased in size, currently weighing some 200 – 300 tons each, and working with such massive blocks has inevitably entailed the use of giant hoisting cranes having tremendous capacities.

The successful adoption of large prefabricated blocks for assembling work by the shipbuilding industry has moved bridge constructors to reappraise the advantages accompanying the method to use large prefabricated blocks. But it was only in the early 1960s that the bridge construction method using large prefabricated blocks, practised by Japanese bridge constructors, attracted worldwide attention.

2. Heavy Equipment for Block Handling

Table 1 clearly indicates the overwhelming number of bridges constructed by the aid of floating cranes. Table 2 lists the types of large-size floating cranes now available in Japan.

These heavy equipment were designed not specifically for bridge construction but for use by Japanese coastal industrial complexes in general, for while the country abounds with waters there is a critical scarcity of natural resources. This compels the nation to import raw materials, to convert them into products having high added value, and to export these products. Accordingly, numerous industries proliferate along coastal regions, including ports, harbors and shipyards.

In addition to the large size floating cranes listed in Table 2, they are available in a wide variety of smaller sizes, from which we can freely select the type and size of equipment meeting the specific needs of our bridge construction project.

Table 2. Specifications of large floating cranes (1,000 tons or more in lifting capacity)

Name	Year of construction	Hull dimensions, L x B x D (m)	Hoisting Specifications		
			Rated load (t)	Outreach (m)	Lifting height at rated load(m)
Kiryu	1969	95.0 x 45.0 x 6.67	3,000	29.00	75.00
Musashi	1974	107.0 x 49.0 x 7.70	3,000	41.50	102.00
No. 25 Yoshida	1972	94.0 x 40.0 x 7.80	2,900	28.00	49.00
Shinryu	1971	80.0 x 34.0 x 6.50	1,500	30.00	65.00
Sagami	1972	80.0 x 36.0 x 6.00	1,500	27.88	65.50
Kenryu	1973	80.0 x 30.0 x 5.50	1,300	26.50	60.00
Nagato	1972	80.0 x 36.0 x 6.00	1,300	32.88	80.15
No. 23 Yoshida	1967	74.0 x 31.0 x 6.00	1,200	21.00	49.00
Shokaku	1964	69.0 x 27.0 x 5.80	1,000	19.00	45.00
No. 80 Hoei	1972	72.0 x 30.0 x 5.30	1,000	24.50	42.00
Nisshin	1972	80.0 x 30.0 x 5.50	1,000	26.50	60.00

Shown in Table 3 are the kinds of operations under taken by floating cranes.

Table 3. Working percentage of large floating cranes by kind of work

Kind of work	Frequency of use	Earning ratio
Civil work at ports and harbours	18 per cent	34 per cent
Cargo handling at ports and harbours	44	20
Shipbuilding	21	17
Installation of structure other than bridges	15	17
Bridges	2	12
Total	100 per cent	100 per cent

Note: Based on investigations of 177 cases (1975)

3. Advantages of Construction in Large Prefab Blocks

The sharp rise lately in labor costs has naturally made itself felt at construction sites. The situation has been aggravated by the tendency of young people to prefer working in tertiary or service industries, with the result that the labor force tends to shift towards a higher age bracket and skilled workers are ever harder to mobilize.

Unlike some other countries, Japan does not employ foreign labor, so the need for labor-saving becomes all the more a crucial matter for every business aiming at rationalization of operations.

While conditions may differ from case to case, Fig. 1 demonstrates typical labor-saving effects of the said method of constructing in large prefabricated blocks over conventional methods. True, the said construction method, while permitting rationalization of construction work on one hand, will inevitably lead to higher costs in pre-erection work, in that a large space of the assembling yard in the shop will be occupied for a long period of time at the sacrifice of other assembling work.

The foundation work will also prove costly because of the necessity to bear up against tremendous weight. In addition, transportation of large blocks by water may sometimes prove more costly than handling small blocks, depending on the conditions involved. This would mean that the economics of adopting the construction method using large prefabricated blocks should be discussed by taking into consideration all the factors involved including manufacturing and transportation.

The said large-block method is advantageous in that it shortens the construction time of not only the bridge body itself but also of incidental work to be done after installing the bridge body. Scaffolds and small equipment necessary for advancing remaining construction works such as concrete floor slab laying, for example, can be mounted on the main bridge body at the assembling yard beforehand.

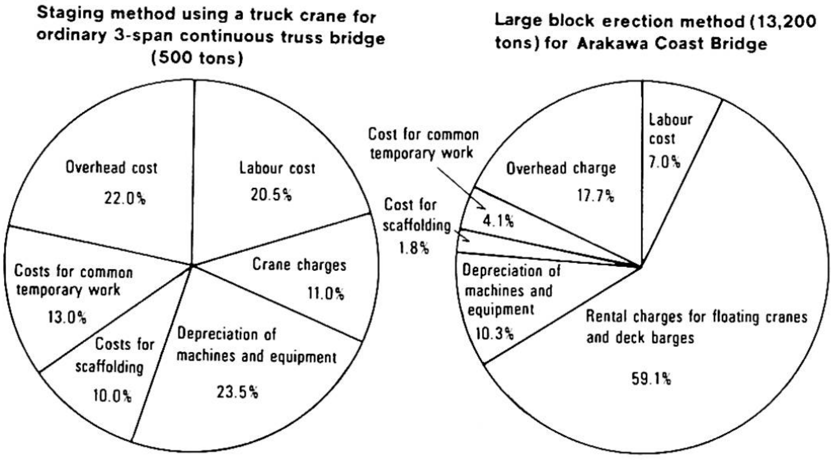

Fig. 1 Cost comparison between large block erection method and conventional erection method

Where the floating crane is concerned, its use in bridge erection will naturally be limited to applications involving waterways. Even in this case, its use may be obstructed by existing bridges. While dismantling its jib for passage under the bridge and subsequent reassembling may be conceivable, the time and costs would in most cases prove prohibitive. In addition, during erection work, the vessel will be completely tied down at the erection site, a cause for additional costs.

In order to cope with these problems, the long practised method of mounting the bridge body on a barge instead of on a floating crane and erecting the bridge body directly on the piers, is adopted. For this, the tidal level difference is utilized and hydraulic jacks are used.

Large floating cranes have deep draught, and as the trim will be changed considerably according to load conditions, they can not be used in shallow waters. Dredging will prove costly in itself, and may conflict with fishing and other local industries.

The lift-up barge shown in Fig. 2, which was used to erect the Keihin Bridge, can be used both for transportation and erection, and can work even in shallow waters as it has an even keel. Since it is not so tall as a floating crane, it can clear bridges having fair clearance.

The lift-up barge transports the bridge block to the construction site while maintaining it at a low position, and lifts the bridge block to the specified position without the aid of any outside equipment.

Fig. 2 Erection of a block of 605 ton by lift-up barge

In Japan, large bridges are mostly built along the coasts or between adjacent islands, and bridge construction projects involving the use of large prefabricated blocks are expected to increase steadily in the years ahead.

Actually, the gross tonnage of steel bridges constructed by the aid of large floating cranes assumes only a small fraction of the total orders for steel bridges, suggesting that bridges which can be constructed by applying the large prefabricated block method are largely limited in terms of structural scale and or geographical conditions.

However, recent bridge construction methods are essentially characterized rather by a wide scope of mechanization and resultant labor saving, a most typical example of which is the construction of bridges by use of large prefabricated blocks with the aid of large floating cranes.

4. Safety Control

The importance of safety control can hardly be over-emphasized. Today, with social responsibility for safety attracting public interest as never before, safety has come to be placed foremost above anything else.

We can never rest assured that the large prefabricated block erection method is intrinsically safer than other methods merely on the fact that no accident occurred in the past. Once it occurs, an accident will prove disastrous not only in terms of direct losses in life and material; the losses sustained by society will be far larger than those invited by conventional construction methods.

No failure being permissible, the large prefabricated block erection method is naturally undertaken under the strictest safety control setup. Namely, not only bridge construction experts but also engineers related to marine vessels, oceanography, transportation and many other fields rally their efforts to establish a foolproof safety control system with their advanced technology and scrupulous care.

Whereas construction by the ordinary method is carried out discretely in veiw of time and space, work by the large prefabricated block erection method is advanced in concentrated time and space, which enables safety control to be achieved more thoroughly.

A sharp reduction in the number of workers through labor-saving measures conduces to reducing the possibilities of human hazards. Also, since mechanization reduces the amount of work done at high places, the degree of human safety is even more amplified.

The fact that construction is concentrated in a short span of time, or as the time required for erection under hazardous conditions will be quite limited, the relative safety of the said construction method against unpredictable natural elements such as wind, wave and earthquake can be increased, with the result that a wider freedom of choice will be in store for meteorological as well as sea conditions.

5. Examples of Bridge Erection Work

Figs 3 the erection work of the Arakawa Coast Bridge. (Constructed jointly by IHI, Mitsubishi Heavy Industries and Yokogawa Bridge Works on order by the Metropolitan Expressway Public Corporation.)

The steel structure of Arakawa Coast Bridge, weighing 13,200 tons, was erected as divided into seven (7) blocks. These blocks were assembled at three coastal assembling yards in Tokyo Bay, then loaded on a large deck barge (DW = 12,000 t) by floating cranes for transportation to the erection site by sea.

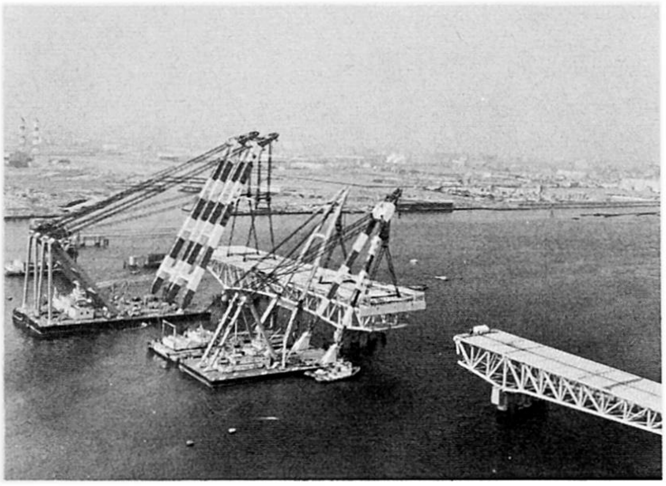

Fig. 3 Erection of the largest block (4,250 ton)

It was on February 11, 1975 that the first block was swung out of the shop onto a deck barge, and the seventh block was erected in the final position on April 23, the same year.

Although the erection work was partly interrupted during that period owing to strong winds, the entire project was executed strictly as scheduled.

When hoisting with three floating cranes the bridge's largest block of 4,250 tons, the load distribution was controlled by means of load meters. By action of the self-regulatory effect based on changes in the draughts, the hoisting loads of the respective floating cranes were successfully contained within their prescribed tolerance ranges as initially planned without any difficulties.

Prospects are now bright for the economical and safe erection of large prefabricated blocks, which may be even larger than those used in the construction of the Arakawa Coast Bridge, through combined use of several floating cranes.

SUMMARY

Examples of bridges constructed by the method of using large prefabricated blocks are given, together with the reasons which have made this method popular lately in Japan. Also given is a list of floating cranes which serve as a key to this method, and their functions. In addition, the large prefabricated block erection method is discussed from the viewpoint of working safety. Finally, the erection of the Arakawa Coast Bridge is introduced as a typical example.

RESUME

Des examples de ponts construits avec la méthode de montage de grands éléments sont donnés, ainsi que la raison de sa large diffusion au Japon. On donne une liste de grues flottantes, comme équipement principal pour cette méthode et de leur fonctionnement. Les problèmes de sécurité sont évoqués en cas d'utilisation de la méthode en question. La construction du pont de Arakawa est présentée comme exemple.

ZUSAMMENFASSUNG

Es wird über Brücken berichtet, die in Grossfertigteil-Bauweise ausgeführt wurden, und zugleich der Grund erörtert, weshalb diese Bauweise zur Zeit in Japan so oft zur Anwendung gelangt. Es wird auch eine Uebersicht über die verfügbaren Schwimmkräne, die die Grundlage zu diesem Verfahren bilden, angegeben sowie deren Wirkungsweise erläutert. Die Grossfertigteil-Bauweise wird vom Standpunkt der Sicherheit aus diskutiert, und zum Schluss wird die Montage der Arakawa-Küste Brücke als ein typisches Beispiel dieser Bauweise beschrieben.