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Steel Structure, and Continuous Casting of Steel

Engineering Technologies for Steel Structures Applied to Trans-Tokyo Bay Highway Project

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Synopsis :
The Trans-Tokyo Bay Highway is a 15.1 km toll road which spans Tokyo Bay from Kawasaki City, Kanagawa Pref., to Kisarazu City, Chiba Pref., and consists of a bridge, an undersea shield tunnel and two man-made islands. Many new technologies were introduced in the construction of this road. Kawasaki Steel participated in this project in: (1) development and execution of a jacket type steel revetment, which was the first application of an oil drilling-type jacket to a revetment structure, (2) design and erection of a large-scale bridge with long-span and multi-span continuous girders on the sea, and (3) design and installation of a deck-module structure with facilities for the shield tunnelling.

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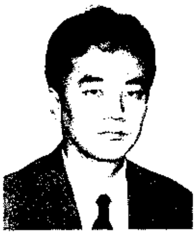
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1 Introduction

The Trans-Tokyo Bay Highway is being constructed on a soft soil and most of its structures are located in deep water. Moreover, since Tokyo Bay is a highly seismicly active region, the highway might be frequently subjected to earthquakes. For this reason, the construction of this road is being carried out using various new technologies and construction processes. Kawasaki Steel is participating in this project played in the fields of offshore steel structures and bridges. This paper describes the essential points of the engineering technologies for steel structures the company used in this project.

2 Outline of Trans-Tokyo Bay Highway

2.1 Background of Project

The Trans-Tokyo Bay Highway is a 15.1 km sea road which spans the east and west sides of Tokyo Bay. It connects Kawasaki City in Kanagawa Pref. and Kisarazu City in Chiba Pref.. The total length of the road is 15.1 km, where 14.3 km are on the sea. This road is a key road since it connects the Tokyo Bay Ring Road, Tokyo outer Ring, etc, and forms a wide-area trunk road network. This is a national project and when completed, it will contribute greatly to the well-balanced development of the metropolitan area and would provide a solution for traffic congestion problems. Investigations for the implementation of the project were started in 1966 by the Ministry of Construction to examine various problems such as technological aspects, social and economic effects, the environmental impact, safety of ship navigation. The investigations were taken over by the Japan Highway Public Corp. in 1976. In 1986, Trans-Tokyo Bay Highway Corp. (TTB) was established to carry out this project by utilizing the capital, management capacity, and technical capabilities of the private sector. In this world-class project, with a total cost of 1 trillion, 438.4 billion yen, approximately 460 000 t of steel products will be used. Construction started in earnest in August 1989, and the man-made islands and the bridge have almost been completed. At present, full scale shield-tunnel excavation work is being carried out.

2.2 Structure and Features of Trans-Tokyo Bay Highway

The construction site of Trans-Tokyo Bay Highway is characterized by thick soft alluvial deposits on the undersea ground, especially on the Kawasaki side. The maximum depth of the water is 28 m at the location near the Kawasaki Man-made Island. Severe natural and social conditions are combined in a complex manner: For example, the site is in an overcrowded sea area

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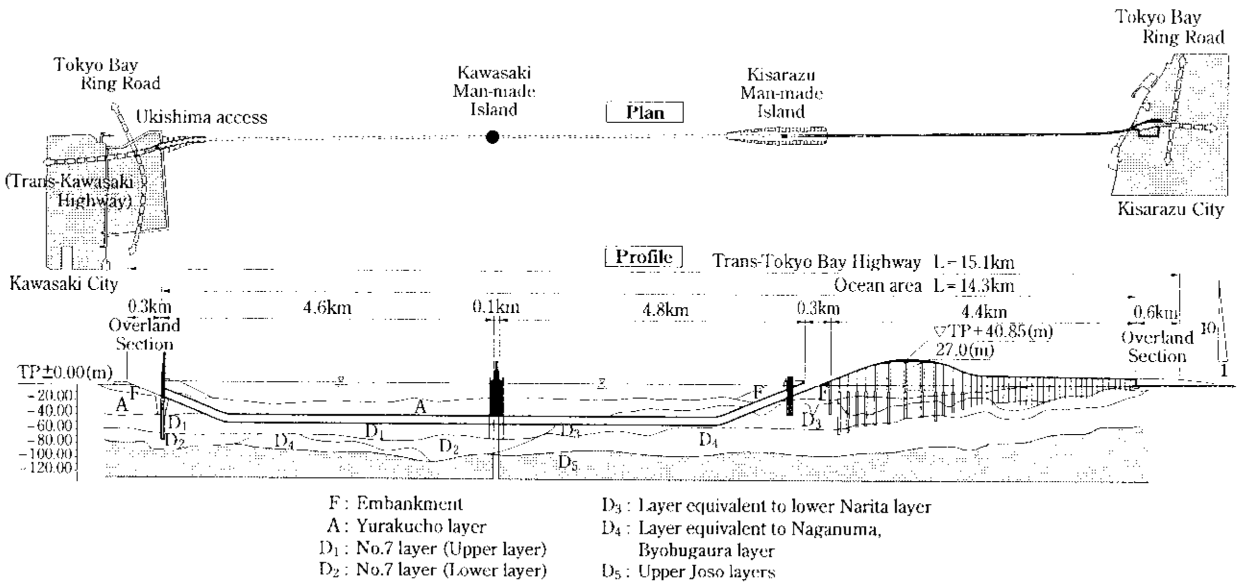


Fig. 1 General view of the Trans-Tokyo Bay Highway

where 1 400 ships/day navigate 24 hours a day, is affected by the air-area restrictions of Tokyo International Airport, and is adjacent to a good fishery, making it necessary to give adequate consideration to the environment. Thererfore, it is necessary to construct globally unprecedentedly large-scale structures safely, rationally, and in a short period in order to reduce the effect on ships at large and the surrounding environment and improve the profitability of the enterprise.

As shown in **Fig. 1**, the road consists of an undersea shield tunnel over a distance of 9.5 km on the Kawasaki side, where ship navigation is concentrated, and a bridge over a distance of 4.4 km on the Kisarazu side. The Kawasaki Man-made Island is at the middle point of the tunnel, and the Kisarazu Man-made Island is at the junction between the tunnel and the bridge. The Kawasaki Man-made Island is a circular structure with a diameter of 193 m and serves as the departure base of the shield tunnel during the work. After the completion of the work, ventilating equipment, maintenance and control facilities, etc., will be installed at the Kawasaki Man-made Island. The Kisarazu Man-made Island is a filling-type offshore island about 1 400 m in length and 250 m in width (the portion above the sea is 650 m × 100 m). This man-made island is composed of a slope (about 650 m) where the tunnel is excavated and housed and a flat section where such land structures as rest facilities are installed. The depth of the water at the construction site of Kisarazu Man-made Island is about 25 m. A slope similar to that of Kisarazu Man-made Island has also been built at the Ukishima access.

The substructure of the bridge on the Kisarazu side is composed of 12 steel piers in the offshore section and 30 reinforced concrete piers in the shoal area. The superstructure is composed of multi-span continuous box girders with a steel deck in both the offshore and shoal sections. Thus, the Trans-Tokyo Bay Highway has a globally unprecedented scale and structure, and is being constructed using many new technologies and construction processes aiming at completion in fiscal 1997.

Figure 2 shows an outline of the work for which this company received orders in the project. As shown in this figure, the company has participated in the work by constructing the offshore steel structures related to the construction of the Kisarazu and Kawasaki Man-made Islands and Ukishima access as well as the superstructure and substructure of the bridge and various other parts of the work. The technological features of the work are described below.

3 Technologies for Offshore Steel Structures

3.1 Jacket Type Steel Revetment

3.1.1 Outline

The revetment of the high-filling section (filling height: 20–30 m) of the slope at Kisarazu Man-made Island is such that, as shown in **Fig. 3**, the tunnel and surrounding filling are pressed down from both sides and held in a stable manner for a long period of time. The revetment was constructed using jackets of statically indeterminate structure of a high degree, which are especially excellent in earthquake-resistance, because the earth pressure acting on the revetment is high and the collapse of the filling would cause fatal damage to the tunnel construction.[1,2] The total steel weight of the jackets, including steel pipe piles and temporary structures, is 22 000 t. They were fabricated and installed in a total of 22 units, 11 units on each side. The reinforced concrete panels (sheathing panels) that compose the

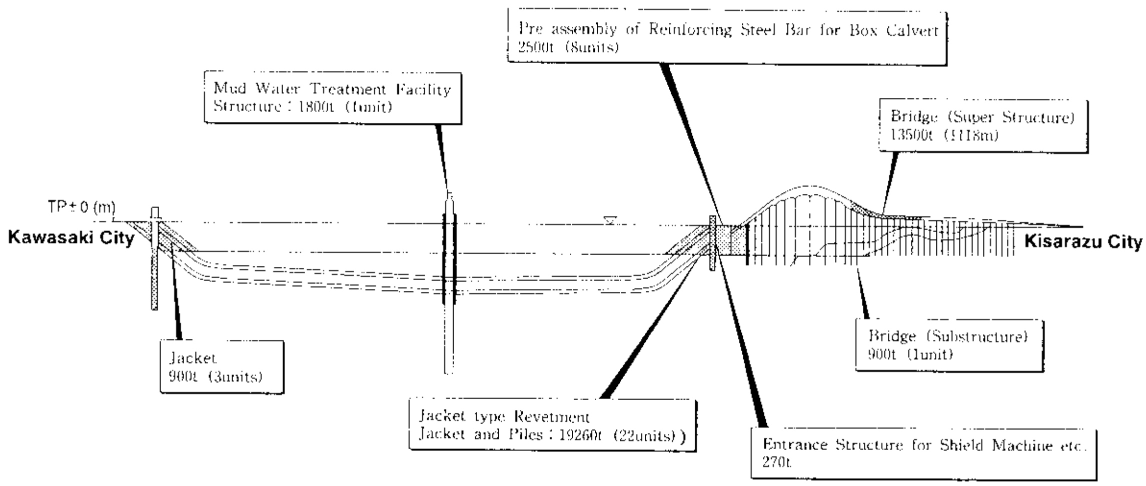


Fig. 2 Major work records for the Trans-Tokyo Bay Highway

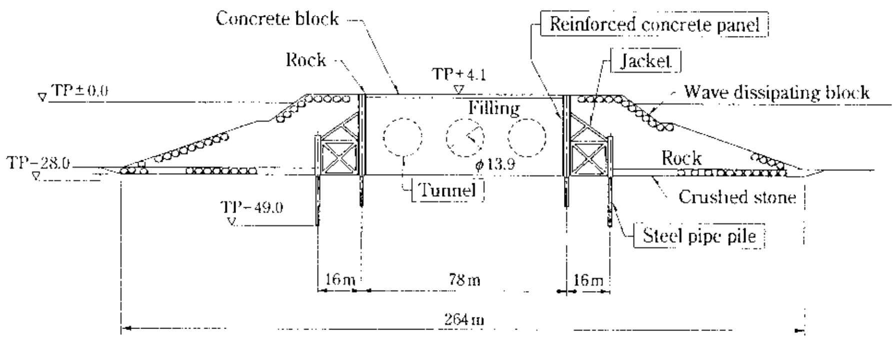


Fig. 3 Cross section of a slope portion of the Kisarazu Man-Made Island

retaining wall of each jacket and the junction guide between the jackets that provides the wall between the adjacent jackets were fabricated separately from the jackets and installed at the site.

3.1.2 Design

The design problem lay in the fact that there was no example in which jackets had been used in a revetment on full scale, although there were many cases of design and construction for use in drilling at offshore oil fields. Because there was no established design standard, a system of jacket design was established by complying with, as a rule, the Japanese Standard Specifications for Highway Bridges, Japanese Standard Specifications for Port and Harbors, etc. and applying API-RP 2A (the American Standard specifications for Jackets for Offshore Oil Fields) to the part peculiar to the jacket structure.

In the analysis of jackets for inplace conditions the two-dimensional framed construction supported by the ground spring was used as the analysis model because the working load is dominant in the directions at right angles to the normal line of the revetment. A three-dimensional model of one jacket was used in the analysis for installing conditions, such as lifting and transportation.

For the corrosion protection of the jackets installed in the sea, 15 mm thick steel plates with a 135 mm concrete covering were used in the splash zone in order to prevent damage by thrown-in rubble-mound blocks, and anodes were used in the seawater.

Steel pipe piles were designed in such a manner that the end bearing effect is not expected, on the basis of the results of loading tests conducted by TTB. A pile driving analysis based on the wave equation theory was conducted beforehand, stresses generated in piles during driving were checked and hammers selected based on the results.

3.1.3 Fabrication

The fabrication of jackets was conducted mainly at the company's Harima and Chiba Works. In order to ship plural units of jacket in a timely manner according to the schedule for installation at the site while minimizing the yard space and manpower, (1) the yard layout was optimized based on a philosophy of line production and examination of the hauling and assembly procedure,

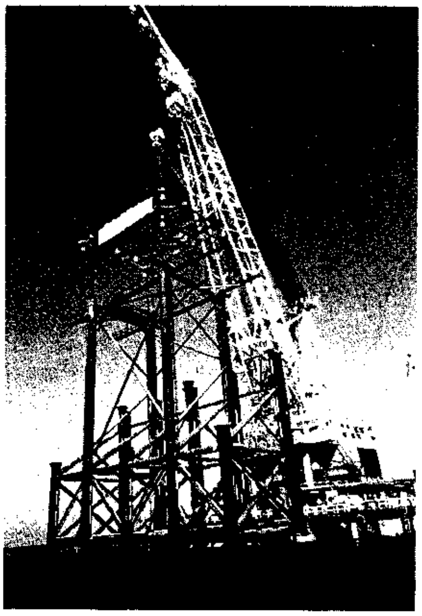


Photo 1 Installation of the jacket for the Kisarazu Man-Made Island

jigs, etc. corresponding to this yard layout, and (2) the efficiency of producing welded joints at the panel points of steel pipe braces was improved, as such joints account for about 40% of the total amount of welds and are produced by outdoor from one side without backing, and the quality of these welded joints was stabilized. For the latter item, self-shielded arc welding (welding wire: Lincoln product) was adopted for high efficiency in the environment where the welded joints at the node members are produced. In order to further improve weldability, TMCP steel plates excellent in weld crack resistance were used in the main pipes at the nodes. Composition design was carried out by conducting several kinds of tests to confirm weldability beforehand and optimum welding conditions were determined. As a result, efficiency was increased by about 10% (compared with planned values) in man-hour terms.

3.1.4 Field work

The jackets transported by ship from the work shop were installed, as shown in **Photo 1**, in the prescribed places at the sea bottom using a 1 800 t floating crane. Jackets for the drilling of offshore oil wells are installed as individual units in sea areas, while those for revetments are continuously installed as plural units and connected with each other. For this reason, very high installation accuracy (horizontal displacement, height, and inclination) is required, and it has to date been impossible to install them by the conventional process.

The installed support pipe process[3] was developed as a method for high-accuracy installation in deep water. In this process, steel pipe piles for temporary support are installed beforehand at the height of the ground of

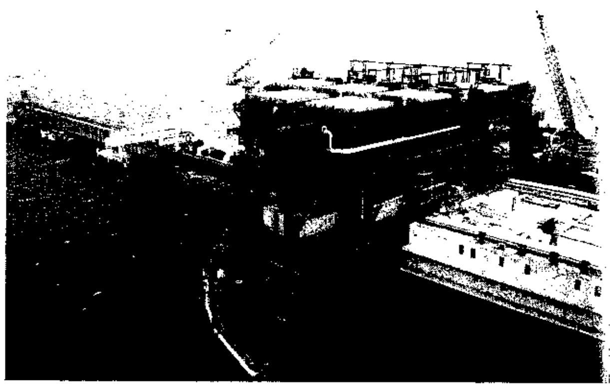


Photo 2 Mud water treatment facility completed at the Kawasaki Man-Made Island

seabed and the jacket is placed on the pile head and temporarily supported to meet the severe tolerances for installation accuracy of the jacket. The adoption of this process improved the installation accuracy of the 22 jackets to such a degree that the horizontal displacement was 5 cm on average, height was 3 cm, and inclination was not more than 1/500. The above mentioned figures satisfied the allowance of standard specification.

3.1.5 Others

A jacket type steel revetment was also constructed in the slope section of the Ukishima access. The company carried out the shop fabrication of 3 jackets (970 t) out of 10 by further increasing efficiency using the know-how accumulated in the jacket work for the Kisarazu Man-made Island.

3.2 Structural Bases of Mud Water Treatment Facility

3.2.1 Outline

In the pressed mud water shield tunneling, dehydration of large volumes of excavated earth is a very important process for the stable excavation of a tunnel. The Kawasaki Man-made Island, which serves as the launching base for four shield machines, has a very limited area, and it was impossible to secure the installation space for the mud water treatment facility, which requires about 10 000 m^2. Therefore, the two structural base units (steel weight: 1 800 t/unit) on which the mud water treatment facility shown in **Photo 2** is mounted were installed on a dolphin type shock-absorber work for the prevention ship collision built adjacent to the man-made island.

3.2.2 Design

The structural bases were designed in accordance with the design standard for the jacket type steel revetment constructed earlier. In the basic structural plan, the structural bases were planned as a three-level structure composed of columns, trusses, girders, and floor framing in consideration of the layout of the mud water treatment facility, including the filter press, and the interface with the shock-absorber work.

The structural analysis of the whole structure was conducted using a three-dimensional frame model in consideration of the working load, shape of the base proper, and asymmetry of the layout of the equipment. A circular steel pipe section that has high resistance to local buckling and torsion and is free of directionality in cross sectional performance was selected as the sectional shape of each member as a result of trial calculation for comparison. An H-shape section, in which the design load is dominant in the vertical direction and which is favorable for interface with the treatment facility to be mounted, was adopted for the girder members. The through-diaphragm type that has good workability in member working and solid assembling was adopted as the panel-point structure of columns and girders. The sectional dimensions at panel points were determined based on the stress calculation method for the rigid frame, and safety was confirmed by the finite element method.

The completed structural base, including the equipment mounted on it, weighed about 5 100 t/unit, and could not be transported even with the largest floating crane in Japan. For this reason, the structural base was fabricated in two equal parts, obtained by dividing the whole structure horizontally, which were transported to the installation field during lifting and erected there. In the design stage, the strength of the structural base relative to the load during lifted transportation was checked and lifting plans (lifting position, cable procedure, etc.) were prepared. In a lifting analysis, consideration was given to the fact that the tension of the lifting cable is constant for each hook of the floating crane because egualizers are used.

3.2.3 Fabrication

The full assembly of the structural bases and the mounting of the mud water treatment facility were carried out in the Oihama yard at Chiba Works. The full assembly of the bases divided into two blocks and the mounting of the treatment facility were conducted alternately for each level from first floor (1F). In the fabrication of large steel structures, it is important to ensure accuracy during full assembly. In this work, special consideration was given to the level of the bottom surface at the panel joints of the columns of 1F which provide an interface with the shock-absorber work, the horizontal position, and the inclination of columns, and the inspection results fully satisfied the allowance of specification. Because the structural bases are temporary structures and their expected service life is only about three years, the quality standard of the welded joints was properly set according to the degree of structural importance of each joint.

From the standpoint of safety and construction schedule control, accidents were prevented and work efficiency was improved by avoiding the simultaneous execution of fully assembly and mounting of the treatment facility. In construction schedule control, all work in each level for each block is the critical path, and strict individual coutrol was therefore applied to the progress of each work.

4 Bridge Technologies

4.1 Outline

As shown in **Fig. 4**, the portion of the bridge of the Trans-Tokyo Bay Highway from the Kisarazu Man-made Island to a 2.0 km distance from Abutment A1 through Pier (P13) is referred to as the offshore part, and the 2.4 km portion on the Kisarazu side from Pier (P14) to Abutment (A2) is referred to as the shoal part. In the offshore part, an channel that permits the passage of ships with a gross tonnage of the 2 000 t class (about 28 m in height and 164 m + 212 m + 212 m + 164 m in breadth) is secured by 4 bridge spans. The spans in the offshore part are determined by this channel breadth, and the maximum span is 240 m. In the shoal part, the span is 80 m, which is a standard figure for a box girder bridge with a steel deck.

The box girder type with steel deck, which is excel-

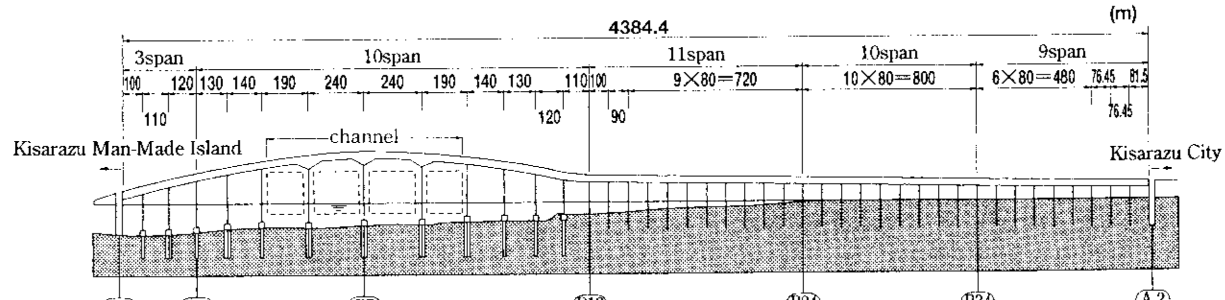


Fig. 4 Plan of bridge

lent in economy and functionality, was adopted as the superstructure of the bridge. In the offshore part, the superstructure is characterized by 3 continuous spans (330 m) from the man-made island side and 10 continuous spans (1 630 m). The shoal part is composed of 11 continuous spans (910 m), 10 continuous spans (800 m) and 9 continuous spans (714 m), which is an unprecedented number of continuous spans in Japan. In the offshore part, the horizontal reaction force and horizontal displacement from the superstructure are absorbed by flexible high steel piers. In the shoal part, the load and displacement from the superstructure are received by large rubber bearing supports because the concrete piers are low and have high rigidity.

In both the offshore part and the shoal part, the horizontal force from the superstructure is distributed to many middle piers. Improved aseismicity by an increase number of spans, improved driving performance by a decreased number of expansion joints, and a reduction of maintenance were possible.

Kawasaki Steel fabricated and erected 2 blocks (about 2 400 t) out of total steel weight of 13 000 t in the offshore part of P11 to P13 and shoal part of P13 to P24 as part of the superstructure work IV of the bridge. The company also fabricated the steel pier P12 (about 900 t) as part of the substructure work II of the bridge.

4.2 Superstructure Work

4.2.1 Design

As is apparent from the framework model shown in **Fig. 5** in which one girder of 1 box and 3 cells is replaced with one bar, a space frame analysis was conducted using microdeformation theory. For continuous girders of 10 spans, the main-girder axis is set at 1/2 of the web height, and the arch action due to changes in girder height and in the longitudinal slope are taken into consideration. The live load is TL-20 and TT-43, and safety was confirmed by examination by TL-25 after completion of the design.

The central cell is used exclusively for the accessory of Tokyo Electric Power Co., Inc. Because the cable racks, inspection passages, etc. of NTT and TTB are also installed in the right and left cells, the middle diaphragm has a large opening. Therefore, designs were prepared by assuming that the structure is a rigid frame loaded with live loads. In the diaphragm at the middle supporting point, the supporting point is not at the center of the box section and, therefore, designs were prepared considering the effect of eccentricity. HTB joints are used in the edge girders in the bracket, because the number of traffic lanes is to be increased to 6 in the future.

4.2.2 Fabrication and Transportation

As shown in **Fig. 6**, the superstructure of the box girder bridge with a steel deck has a maximum girder height of 10.5 m and a large section of 22.9 m in width. The weight per block is also large. To assemble small blocks (to form a large block), yard welding was adopted for the external surface of the girders, and HTB joints were used for the internal surface. Therefore, quality control of higher level than in the past was possible in fabrication. Shop fabrication was carried out in both the Harima Works and the Chiba Works, each for one block in consideration of the manufacturing period. In both Works, small blocks of about 100 t were fabricated and shop-painted in consideration of the crane capacity within the shops. The small blocks were then assembled into large blocks on the ground in the yards near the wharf.

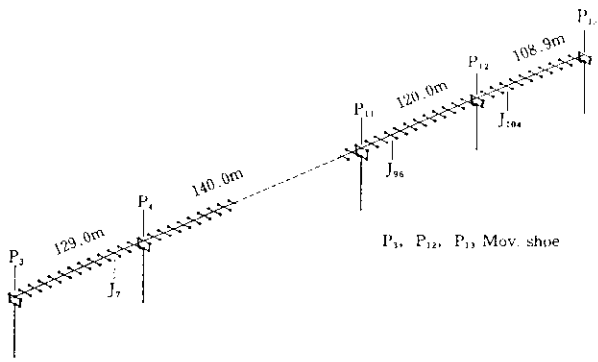


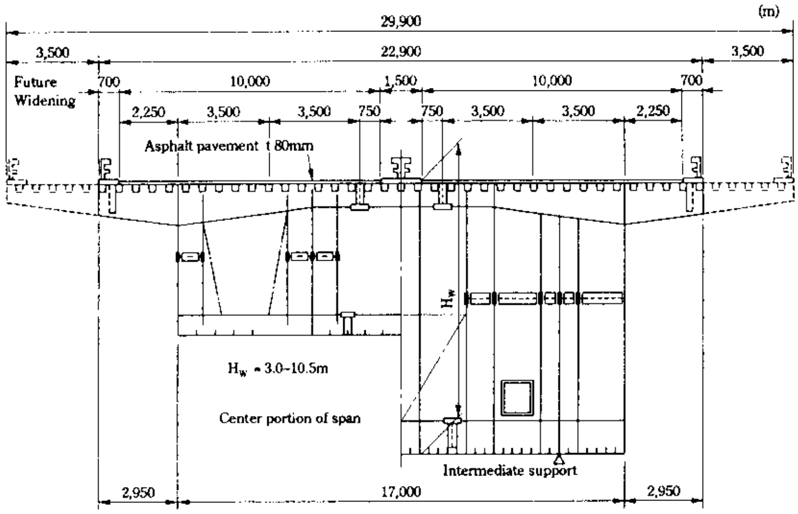
Fig. 5 Analysis model

Because the block fabricated in the Harima Plant required long-distance marine transportation to the erection site, the safety of the block during transportation was checked by conducting an analysis of the pitching and rolling of the transport deck barge waves.

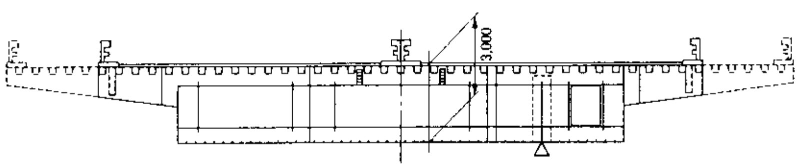
In the Chiba Works, a yard for the ground assembly could not be near the wharf because of the relation to the preceding work. Therefore, ground assembly was conducted near a temporary assembly yard, and the large block was moved by a self-propelled transportation truck and rolled onto a transport deck barge. Effective utilization of yards will be ensured in the future by applying this shipping method to the fabrication of large structures and simultaneous fabrication of plural structures.

4.2.3 Erection

In erecting the girders, collective erection of large blocks by a floating crane was adopted for the offshore part water and some shoal area, and erection of large blocks by a deck barge was adopted for the remaining shoal area. In the collective erection of large blocks, the hinge connection method was adopted. This method involves setting beams to adjust the connection of the joints of girders and to make the erection hinge by shifting the load onto the existing girders during erection. Therefore, analysis of the superstructure during the erection at each step were conducted and safety was



Typical cross-section of bridge in offshore area



Typical cross-section of bridge in shallow sea area

Fig. 6 Typical cross section of the bridge

checked. Furthermore, the interface between the joint angle of the existing blocks during erection and the joint angle during the lifting of the erection blocks by the crane ship was examined beforehand. The situation of construction of the superstructure is shown in **Photo 3**.

A special deck barge equipped with a deck mounted with four jacks was used in the shoal area which the floating crane could not enter easily. In erection, the deck barge was moved longitudinally and laterally using winches because entry by a tow boat was difficult. In this connection, the draft of the deck barge was strictly controlled in consideration of changes in the tide level and load, because of the extremely shallow depth of the water at the erection site.

4.3 Substructure Work

4.3.1 Outline of steel piers

The construction period of the piers P1 to P12 of the offshore part in the field work was short, and underwater steel piers excellent in economy and ease of construction were adopted. A steel pipe pile foundation was used as the pier footing. This foundation is constructed as follows. Steel piers in which the pier studs and footings are integrated are fabricated on land and installed, using the floating crane, on steel pipe piles driven beforehand with high accuracy using underwater tem-

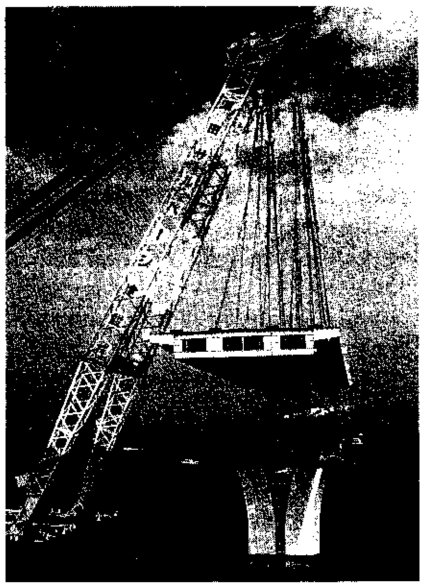


Photo 3 Installation of a super structure

plates, and underwater concrete is cast into the footings to connect the piles and footings. As shown in **Fig. 7**, the pier P12 fabricated by the company is 29 m in height, has a footing which is a square with sides of 20

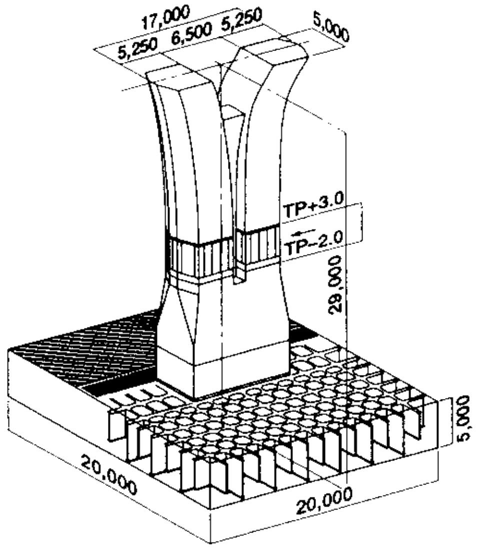


Fig. 7 General structural diagram of steel pier

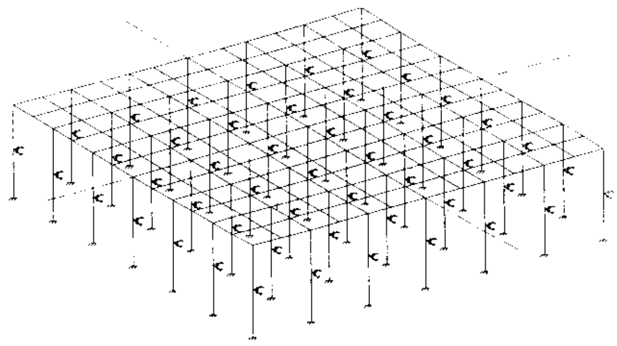


Fig. 8 Structural modeling of footing

m, and weighs approximately 900 t.

4.3.2 Design and fabrication

A space frame model in which the piers and footings including the superstructure are integrated was used for a structural analysis. The footing was analyzed using a space frame model in which the concrete in the footing is neglected and steel I-girders (girders and beams) are the basic components (**Fig. 8**).

Since the Trans-Tokyo Bay Highway is located at the gateway to the capital, due consideration was given to the landscape aspect of the structure. As a result, curved Y-shape piers were adopted as the design of the piers and a deformed pentagonal section was adopted as the section of pier stud. The web on the side is three-dimensionally twisted and its weld to the flange is produced by welding with complete penetration, making this the most difficult fabrication job the company has undertaken to date.

Pier studs and footings were shop-fabricated as small blocks of less than 100 t and assembled and yard-welded in the assembly yard with the pier studs horizontal and the footings upright. The pier studs were then brought into the upright position by the 2 200 t floating crane and connected to the footings.

4.3.3 Corrosion Protection of Steel Piers

It was necessary to give special consideration to the corrosion protection of the steel piers because they are directly exposed to the severe corrosive environment of the sea. Fluoroplastic coating was used as the coating for the outer surface of the pier above the splash zone and tar epoxy resin coating and cathodic protection were used in combination for the outer surface below the sea level. Clad steel (1 mm thick titanium layer plus 4 mm thick steel layer) was used in the range in the severest corrosion environment, comprising the splash zone and tidal zone (TP + 3.0 ~ TP − 2.0). Because titanium itself cannot be welded to steel plates, clad steel and the steel plate of the stud proper were welded, and TIG welding was conducted by applying titanium (2 mm) to the weldment.

5 Prefabricated Reinforcement Block Method for Culvert-Boxes

Culvert-box type road structures 51 m in width and 11 m in height were planned in the 240 m section of the flat land portion of Kisarazu Man-made Island. Because the role of this section was to provide the material supply path in tunnel excavation during the work, the construction of the road structures was a critical path for the shield commencement of tunnel excavation process. In order to shorten the construction period, a new prefabricated reinforcement block method was adopted in which the whole division was divided into 20 parts and the corresponding reinforcements were prefabricated in the shop, lifted and transported to the construction site, and installed.

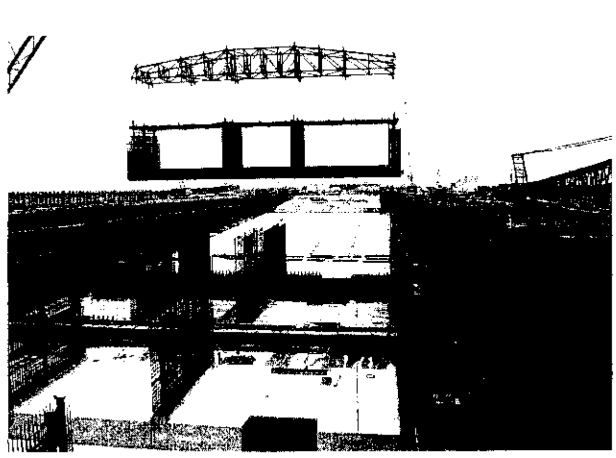


Photo 4 Installation of a culvert-box prefabrication block

As shown in **Photo 4**, each reinforcement block was divided into two portions of upper and lower floors, which were transported by ship and joined at the site. Each block weighed approximately 300 to 350 t. The company fabricated eight blocks, weighing about 2 500 t in total.

Because there was no example of construction of this type of structure, in fabricating the prefabricated reinforcement blocks, a preliminary examination of the procedure for assembly was thoroughly conducted in order to increase the work efficiency, shorten the construction period, and improve safety by reducing the amount of overhead work. Special attention was paid to the accuracy of the connections between the upper and lower floors obtained by field joining, and the detail structure was examined. As a result, the ease of insertion was ensured by installing insertion guides in the upper part of the lower floor and shear connectors and stoppers in the lower part of the upper floor. Furthermore, a structural examination was conducted as to the stability and shape-keeping during lifted transportation of large reinforcement blocks by sea, and a method was adopted which involves building a temporary shape-keeping frame of steel pipes in the interior of the reinforcement block and connecting the two by fixing jigs.

6 Conclusion

Kawasaki Steel has solved many technological problems in the Trans-Tokyo Bay Highway project, obtaining the valuable results summarized below:

(1) In the field of offshore structures, jackets were used on a full scale as revetments in deep water for the first time in the world. A new jacket application was developed by applying jackets developed for offshore oil drilling structures in deep-water revetment structures. This process established systematization of structural plan and design methods of jacket type revetments, efficient fabrication procedures and welding techniques for large steel structures, analysis techniques for transportation of three-dimensional numbers, in which the pitching and rolling of ships are considered, a high-accuracy construction method for jacket structures in deep water, techniques for measuring the bearing capacity by the dynamic method for large-diameter steel pipe piles, etc.

(2) In the field of bridges, the design and engineering technologies for large-span bridges above the sea were accumulated. In this process, the company acquired techniques for fabricating multi-span continuous girders with a steel deck of the largest scale in Japan, high fabrication control capability, and techniques for installing large base-isolation rubber shoes suitable for continuous girders. Furthermore, the company established the application of a long-term corrosion protection method using titanium clad steel for the first time in the world, selection of an optimum erection method suited to erection conditions, such as shoal and sea areas with heavy traffic, and construction control, and techniques for erection analysis in which erection systems are considered. The company contributed greatly to the improvement of its basic techniques as a total bridge constructor by executing a series of jobs.

(3) In this project, the company as a member of a joint venture received orders for the principal part (Kisarazu Man-made Island work and superstructure work No. IV of the bridge) as a prime contractor. By carrying out this work, the company was able to improve its overall project management techniques, such as general coordination of large-scale work and techniques for work process control, quality control, and safety control, and achieved outstanding results in construction and excellent safety performance.

With both the scale of projects for the construction of marine bridges and the depth of water at the construction site increasing, many plans to construct marine bridges under severe natural and social conditions have been formed. To carry out these plans, it is essential to develop types of structures for constructing safe and economical infrastructure in a short period by overcoming difficult design and construction conditions. In the Trans-Tokyo Bay Highway project, steel structures used in offshore work were positively adopted and their effectiveness was verified. The authors consider that it is important to have an accurate grasp of the trend toward prefabrication of more structures and blocks of larger size, which will increasingly predominate, and to develop and accumulate further steel structure technologies.

References

1) K. Koga, T. Hiramoto, and K. Furumuro: *Kawasaki Steel Technical Report*, **31** (1994), 61
2) K. Kanda: "Fabrication for Jacket Type Revetment for Kisarazu Man-Made Island, Trans-Tokyo Bay Highway", Proceedings of the 6th Seminar on Engineering for Coastal Development, (1991), 77–87
3) H. Shinohara, K. Furumuro, S. Kawase, and T. Nishi: 47th Conference of the Japan Society of Civil Engineers, (1993)