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Kota Kinabalu Roll-on/Roll-off Facilities

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The body can be viewed from the next page.

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1 Introduction

To establish ferry service between East Malaysia, on Borneo Island, and West Malaysia on the Malaysian Peninsula, the Government of Malaysia undertook a national project in which Kuantan City in West Malaysia would serve as a base. On the East Malaysia side, roll-on/roll-off (RO-RO) facilities were planned for ferry berthings at Kuching City, the capital of Sarawaku State, and at Kota Kinabalu, the capital of Sabah State. Port Authorities at the respective areas were responsible for this government-commissioned construction work, with completion of the project and first actual use scheduled for September 1, 1986, to concide with the National Foundation Day of Malaysia.

Of these facilities, Kawasaki Steel Corp. received a bulk order for construction of the RO-RO facility at Kota Kinabalu (the state capital of East Malaysia; location shown in **Fig. 1**) from the Sabah Port Authorities (SPA) after international bidding. The construction was executed during the period from November 1985 to August 1986. The planned scale of the facility would permit berthing of a passenger-cargo-vehicle ferry 190 m long and 25 m wide with a maximum draft of 5.5 m. The load to be applied to the RO-RO ramp was large, 440 t for dynamic load and 620 t for static load, and sig-

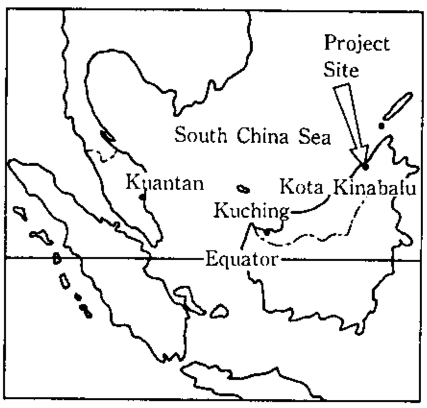

Fig. 1 Project site

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nificantly exceeded the loading of facilities in Japan.

The hydraulic elevating method was adopted for the RO-RO steel ramp structure in consideration of maintenance, safety, and equipment cost rather than the conventional and frequently-used winch elevating method. The latter method uses an electric motor, which makes the drive system unwieldy.

The RO-RO ramp structure was installed at the tip of a new concrete access bridge which was constructed in parallel with the existing jetty, and both the steel ramp and the access bridge were constructed on wave-permeable foundations supported by steel pipe piles. These steel piles are of the polyethylene-coated heavy-duty protective type, and use economical new protective techniques different from those of the conventional cathodic protection method.

This paper describes the design, fabrication, and erection of the RO-RO ramp and marine civil work related to the auxiliary facilities such as the access bridge and dolphins.

2 Outline of Project

This project was a composite one, involving various civil-engineering structures such as the RO-RO steel ramp structure, mechanical and electric facilities for a mobile hydraulic system, a concrete access bridge, and berthing dolphins.

The construction work broadly consisted of the following, as shown in the General Plan (**Fig. 2**):

(1) Dredging of the berthing area
(2) Fabrication and erection of the RO-RO steel ramp
(3) Design, manufacture, and erection of the hydraulic system
(4) Marine pile-driving and concreting work for the new access bridge
(5) Dismantling of the existing jetty, reinforcement and new construction
(6) Construction of berthing dolphins

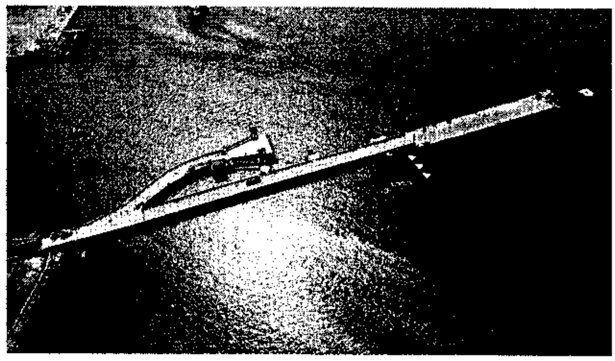


Photo 1 General view

A general view of the project in its near-complete state is shown in **Photo 1**. The RO-RO steel ramp structure was fabricated by the local Sabah Shipyard Sdn. Bhd. on the basis of drawings prepared by Kawasaki Steel using a basic design supplied by a consultant. Mechanical and electrical equipment for the hydraulic system were designed and fabricated in Japan.

3 RO-RO Ramp Construction

3.1 Skeleton Structure

The RO-RO ramp is of the overhanging beam type, and consists of two main I-beams fitted to the landside hinge shoe and a box girder transverse beam, supported by a hydraulic elevating cylinder. The floor system is of a full-welded monolithic construction using trough-rib steel as a bed plate.

The hydraulic cylinder is suspended from the hoist frame of a square pipe truss structure constructed on

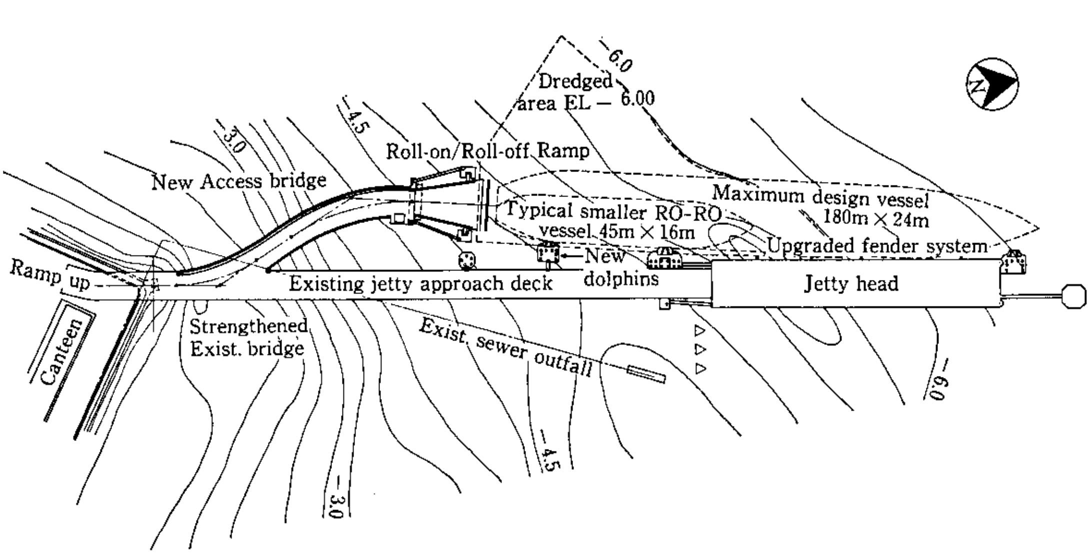


Fig. 2 General layout of roll-on/roll-off facilities

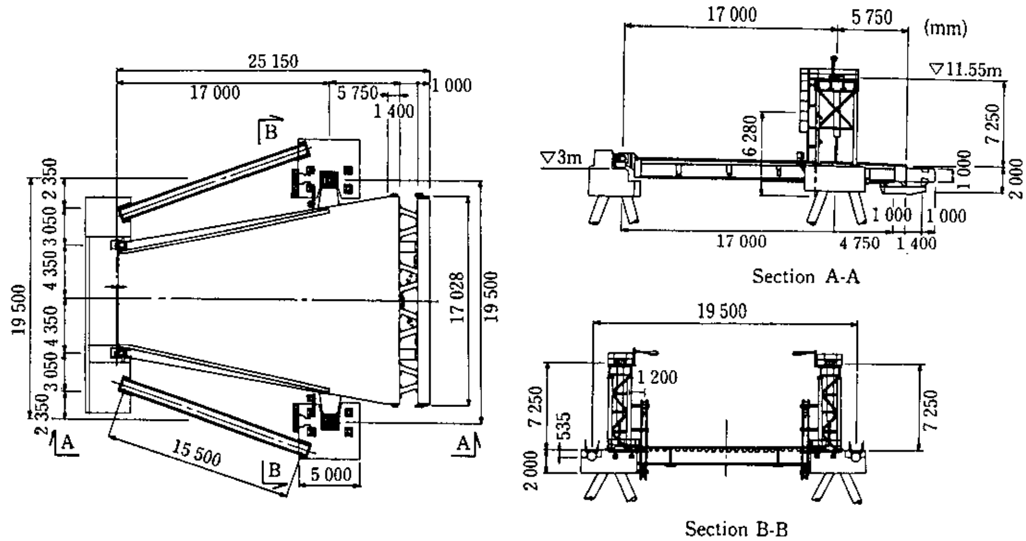


Fig. 3 Roll-on/roll-off ramp structure

the right and left independent dolphins.

3.2 Features of Structure

The RO-RO ramp must be capable of coping with the pitching and rolling of berthed ferries and the ebb and flow of the tide, of supporting vehicle and other load factors, and of maintaining a safe road surface gradient. The plan and cross section of the structure are shown in **Fig. 3**.

The pitching and rolling of ferries are absorbed by a levelling flap located on the ferry end of the ramp. The load of this flap is supported by the bed plate at the head of the ramp. To adjust to rising and falling tide levels, the ramp is elevated by a hydraulic cylinder elevating unit.

To cushion the impact of vessels, both at berthing and due to sea conditions, a π-shaped rubber fender and a steel fender beam are provided at the tip of the ramp. Horizontal forces acting on this fender are held by a land-side hinge shoe.

3.2.1 Ramp construction

To facilitate fabrication of the ramp, welding was carried out in blocks whch were then assembled into a single unit in the factory. As steel material, JIS G 2106 SM41 was used, and for the flange under the main I-girder, steel plates of a maximum 60 mm thickness were used. A 35-mm thick cover plate was welded at the intersection of the main girder with the transverse beam. The height of the web plate for the main girder was 1345 mm. The web plate thickness was 20 mm, and thus no horizontal and vertical stiffeners were needed.

Intermediate transverse beams were arranged at 4-m intervals, and 250 mm STK 41 pipe was used for the tension-side flange.

The steel bed plate of the floor system was 15 mm thick and fitted trough ribs arranged at a pitch of 600 mm. Near the levelling flap at the head of the ramp, band plates were attached for wear prevention.

The transverse beam supported by the hydraulic cylinder has a box-girder cross-section of 1000 mm × 4000 mm. A cross-shaped solid plate was used to ensure a rigid connection at the intersection of the transverse beam with the main girder. Shear bolts were used at the connection with the cylinder pin for ease of maintenance.

3.2.2 Hinge shoe

The hinge shoe is subject to a constant vertical force of 91 t and a constant tensile force of 46 t, and a horizontal force as high as 470 t at times. To cope with these loads, a 26-mmϕ PC steel rod is used to secure the hinge shoe. The rod ensures a stable connection by extending from the bottom of the footing. In addition, a box anchor about 400 mm square, which is capable of withstanding predicted horizontal forces, is buried at the same horizontal level as the shoe.

4 Hydraulic System for Elevating RO-RO Ramp

4.1 Basic Design

The hydraulic elevating system of the RO-RO ramp consists broadly of a hydraulic pump, hydraulic cylinder, hydraulic piping, and electric control device.

The hydraulic cylinder system includes a high-pressure, high-capacity hydraulic cylinder, used to elevates the RO-RO ramp, and a low-pressure, low-capacity cylinder controlling a spragging beam, which supports the ramp during idle periods. Thus the cylinder system is comprised of two hydraulic systems. The hydraulic installation diagram is shown in **Fig. 4**, and major specifications of the hydraulic equipment are given in **Table 1**.

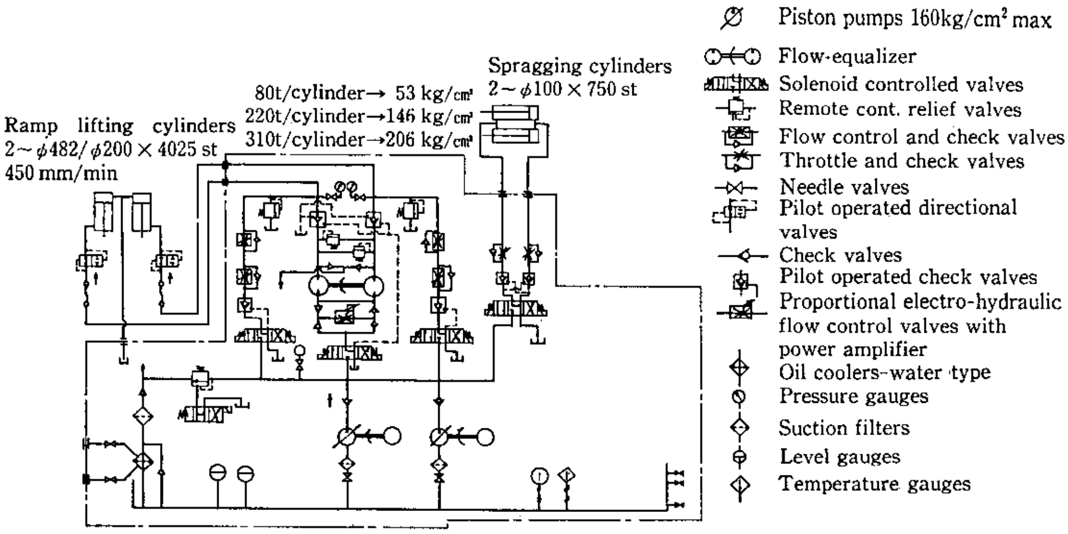


Fig. 4 Hydraulic installation diagram

Table 1 Specification of hydraulic equipment

Oil pressure equipment	
Max. pressure	160 kg/cm²
Discharge capacity of pump	150 *l*/min (Pressure 80 kg/cm²)
Pump type	Variable displacent pump
Electrical capacity of motor	AC 22 kW
Nos. of pump	2 units
Volumetric capacity of tank	1 000 *l*
Lifting cylinder	
Internal diameter of cylinder	482 mmφ
Out-side diameter of rod	200 mmφ
Stroke	4 000 mm
Surface treatment for rod	Chromate coating
Lifting load (per one unit)	
Usual	80 t
Maximum	220 t
Max. supporting road (per one unit)	310 t (Pressure 206 kg/cm²)
Nos. of cylinder	2 units
Lifting speed	450 mm/min
Spragging beam cylinder	
Internal diameter of cylinder	100 mmφ
Out-side diameter of rod	56 mmφ
Stroke	750 mm
Running pressure	140 kg/cm²
Nos. of cylinder	2 units

4.2 Characteristics of Hydraulic System

4.2.1 Adoption of flow equalizer

When a hydraulic cylinder method is used, the system must ensure reliable synchronized operation of the right and left cylinders. For this reason, a two-throw-type flow equalizer, which shunts constant quantities to the right and left, was installed as the hydraulic synchro circuit. Use of this type of synchro circuit in RO-RO ramp hydraulic systems is rare, so it may be said that a conventional technique was, in this case, applied to a new field.

This shunt equipment has a shunting difference of within 3% and shows better synchro accuracy than the 5% of other types of shunt equipment, giving it an excellent capacity to cope with fluctuations of lateral load balance. Thus, differences in elevation between cylinders are minimal, ensuring the horizontality of the ramp and significantly contributing to its safety.

4.2.2 Electrical synchro devices

The RO-RO ramp is elevated by two cylinders. To prevent damage to the mechanical system due to level differences which may occur during operation, electrical synchro devices are provided. When the difference in level between the two cylinders exceeds 15 mm, the leading cylinder is automatically stopped, while the action of the lagging cylinder continues until the difference in levels is again within 15 mm. When the level difference has been eliminated, the stopped cylinder resumes movement, and the difference in levels is then automatically controlled to within 15 mm.

A diagram of the electrical synchro device is shown in **Fig. 5**. The system for monitoring differences in cylinder levels is comprised of two synchro receivers, a micro-switch actuated by a cam connected to the output shaft of the receiver, and a level difference indicator. The respective levels of the two cylinders are detected as two electric signals from the corresponding synchro transmitters and input to the differential synchro receiver. The receiver then converts the difference in levels into a rotation amount and actuates the micro-switch and level difference indicator.

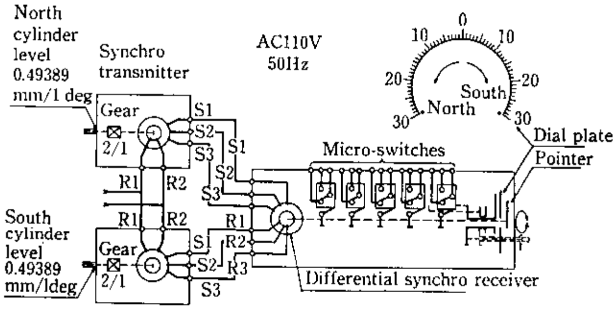


Fig. 5 Electrical synchro devices

4.2.3 Other features

Other features of the hydraulic system include:

(1) When damage to the hydraulic piping leading to the elevating cylinder, valves, etc., occurs and results in leakage of the hydraulic fluid, an emergency shut-off circuit stops cylinder operation instantly at the position where the damage occurred, even during operation.

(2) Two hydraulic pump are used in consideration of the importance of the facility. If one pump fails, operation remains possible, though operation speed is reduced by half.

(3) When the facility is idle, the ramp structure is supported by a spragging beam operated by a secondary hydraulic cylinder to avoid unnecessary loading of the main hydraulic unit and elevating cylinders.

5 Construction Work

5.1 Construction Schedule

The construction schedule of the project is shown in **Fig. 6.** Construction work began on November 28, 1985, and was completed on August 7, 1986. The construction period was short at eight months, in spite of the variety of tasks involved, which ranged from dredging, pile-driving, and concreting to the design, fabrication, and installation of the hydraulic equipment and ramp, as well as the electrical system.

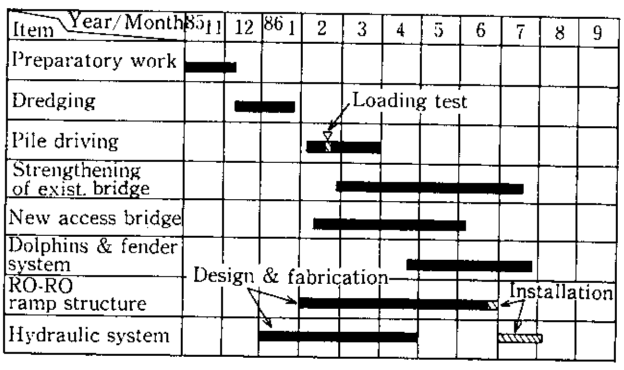


Fig. 6 Construction schedule

5.2 Local Construction Work

5.2.1 Scale of construction work

Several local contractors were engaged to execute work under the supervision of Kawasaki Steel. Figures for various types of construction work are given below.

- Dredging 2000 m^3
- KPP pile driving 91 piles (600 t)
- Concreting 1800 m^3
- RO-RO steel ramp (incl. ancillary works) 220 t
- Hydraulic and electrical equipment installation

5.2.2 Marine pile-driving

Polyethylene-coated heavy-duty protective steel pipe piles–KPP pile (Kawasaki plastic-coated pipe pile)–were used as marine piles. Specifications of these piles are shown in **Table 2.**

For several reasons the pace of pile driving was slow at 3.73 pcs per actual working day: Most piles were driven obliquely, and a number of piling-driving barge capsizings occurred due to the curved shape of the pile structure. In addition, pile-driving was scheduled for February and March, which fell in the local monsoon season. Days when swells made pile driving impossible reduced the pile driving rate per calendar day to 1.98 pcs/day.

As Diesel hammers, KOBELCO KB45 or KB35 were used, depending on the diameters of piles being driven.

Table 2 Pile specifications

Structure \ Dimension	Polyester coated pile				Quantity (pcs)
	Dia. (mm)	Thickness (mm)	Pile length (m)	Coated length (m)	
Strengthening of exist bridge	ϕ 610	13	24	12.0~13.0	8
New access bridge	ϕ 762	13	23~31.5	12.5~14.5	35
Dolphins	ϕ 762	13	27~30	14.5~16.0	40
Fender pile (Tar epoxy painted)	ϕ 762	13	12~13.5	12.0~13.5	5
	ϕ 914.4	30	11~13.5	11.0~13.5	3

5.2.3 Pile loading test

The design bearing capacity of the piles was $_cR_a=$ 200 t; design tension capacity was $_tR_a=100$ t. Geologically, as shown in **Fig. 7**, the site was soft silty clay of N-value $=0$ extending from the sea-bottom surface to about 18 m (60 ft), below which was a rock mass of N-value >50, which formed the bearing layer.

To confirm the bearing capacity of driven piles, a compression test at a maximum load of 400 t, and a tension test at a maximum load of 150 t, were conducted using the initially-driven vertical pile (762 mmϕ). The dynamic bearing capacity (ultimate bearing capacity) of

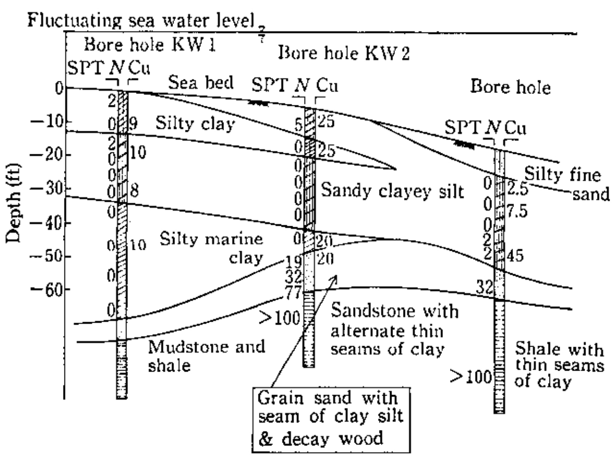


Fig. 7 Boring log

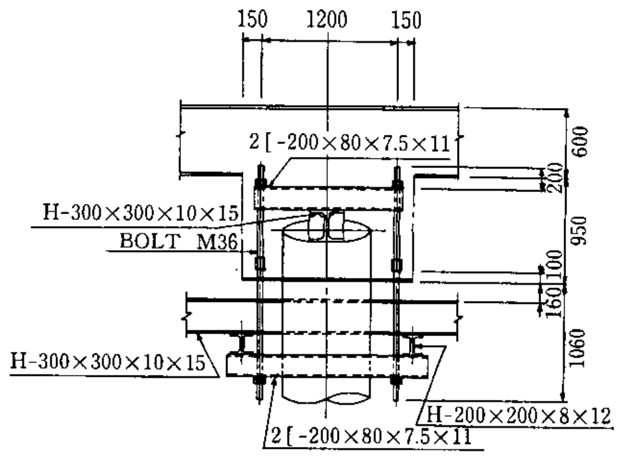


Fig. 10 Staging for concrete work

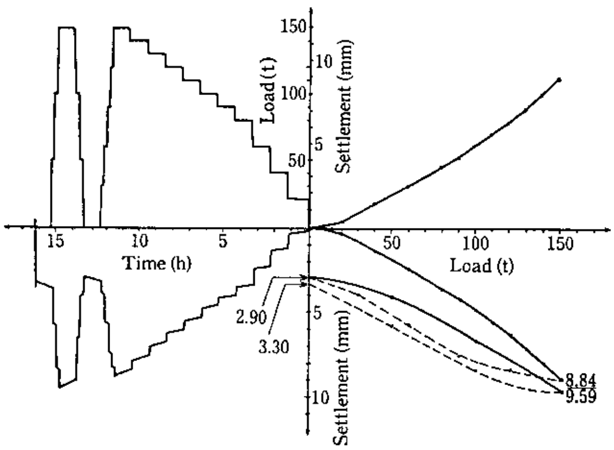


Fig. 8 Pile tension test results

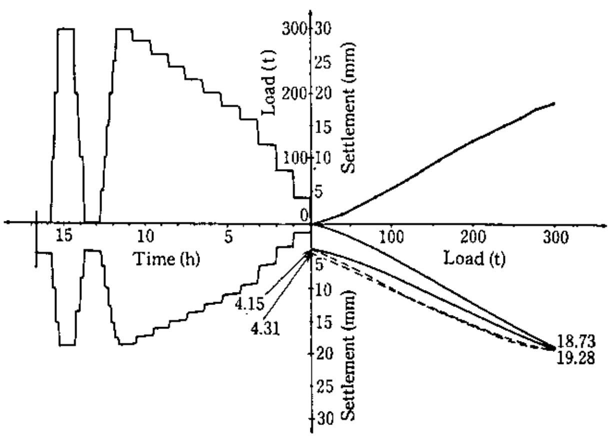


Fig. 9 Pile compression test results

this test pile was $R_u = 788$ t.

Test results are shown in **Fig. 8** and **9**. In both the compression and tension tests, the load-displacement curve was an approximately straight line, indicating that the maximum load applied was within the yield load limit. These results confirmed the adequacy of the initial design bearing capacity and tension capacity.

5.2.4 Concreting work

Because the pile used in this work was polyethylene coated, it was impossible to weld the staging work for the concrete formwork directly to the pile as is normally done with conventional steel pipe pile. Therefore, concrete was poured using the suspended formwork method, in which a bracket is attached to the pile head. Long bolts are suspended from the bracket to support the formwork, as shown in **Fig. 10**.

Since suspended formwork is less stable than supported formwork, more staging material tends to be used. Therefore, efforts were made in the design work both to ensure the safety of the staging material, and to decrease the amount of staging material used.

5.2.5 RO-RO ramp erection work

One of the most difficult problems in the local construction work was how to install a ramp weighing

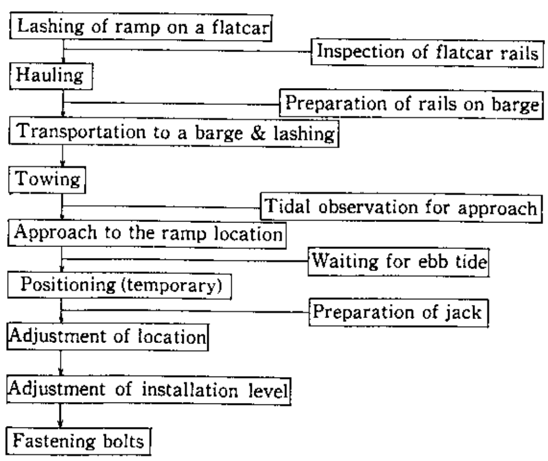


Fig. 11 Work flow for ramp installation

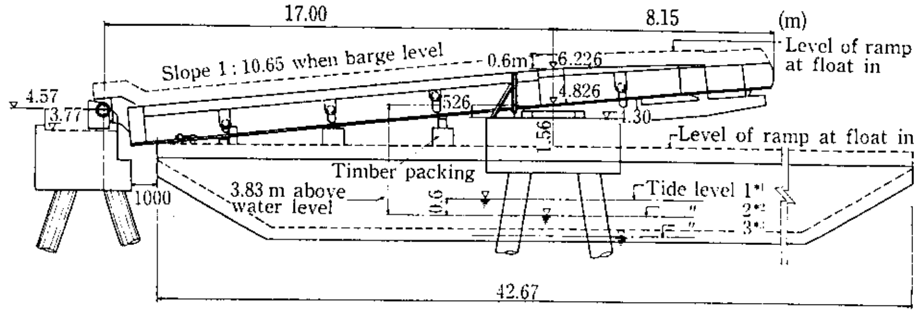


Fig. 12 Installation scheme

*1 Tide level 1……High tide+1.6 m at float in
*2 Tide level 2……Tide+1.0 m at ramp seatings
*3 Tide level 3……Low tide+0.2 m

183 t. Considering the local availability of heavy-duty machinery such as the marine cranes, as well as marine meteorology, the ramp was erected using tidal ebb and flow differences.

The flow chart of transportation and erection of the completed ramp is shown in **Fig. 11**.

The ramp was secured to a flat barge in the tilted position shown in **Fig. 12** so the hinge and the dolphins could be erected simultaneously. When the ramp arrived at the erection site, it was brought into position for erection at a high tide level of +1.6 m. When the tidal level fell to +1.0 m, the ramp came to rest on the concrete structure. The barge ballast was then increased so the barge could be pulled from under the ramp, completing provisional erection. Subsequent adjustments of flat surface position and level were carried out using three jacks. Scenes of the erection work are shown in **Photo 2**.

6 Conclusions

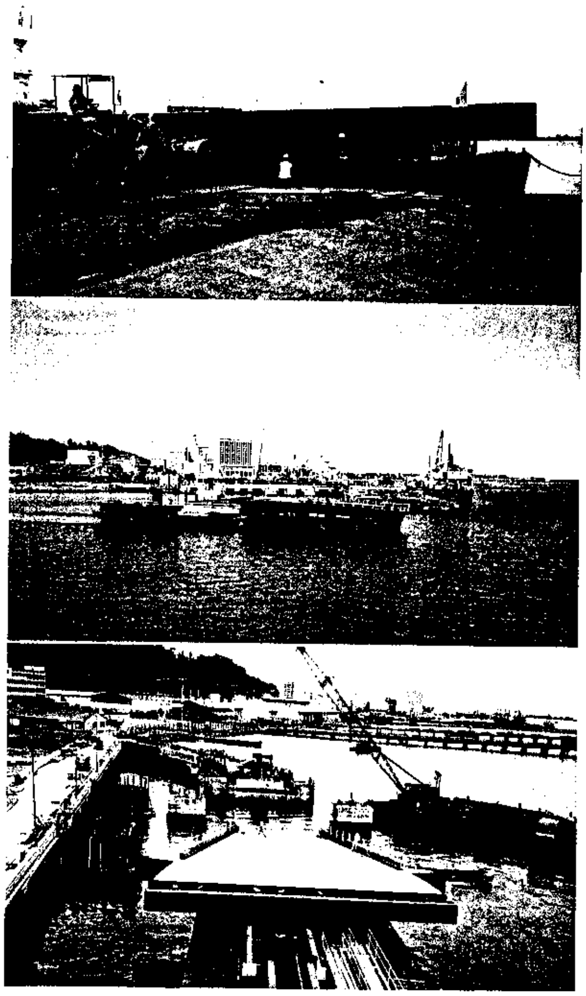
An roll-on/roll-off ramp for the ferry connecting East and West Malaysia was installed in Kota Kinabalu, the capital of Sabah State, East Malaysia. The project was completed in August 1986. Main features of the project were:

(1) A hydraulic elevating method was adopted to cope with the loads affecting the RO-RO steel ramp structure (dynamic load, 440 t; static load, 620 t). The hydraulic system included a high-accuracy 2-throw-type flow equalizer and electric synchro devices, ensuring reliable synchronized operation of the right and left cylinders.

(2) Polyethylene-coated heavy-duty-protective steel pipe piles (KPP piles) were used as foundation piles in the access bridge site construction.

(3) Because the RO-RO ramp was a heavy structure and erection equipment was limited, the ebb and flow of tides was used to advantage in the actual erection work.

The present composite project is an excellent example of the successful synergy of three technologies: harbour civil engineering, hydraulic systems, and steel structures.



Upper: Loading ramp on barge
Middle: Towing ramp to the site
Lower: Approach to the ramp location

Photo 2 Work flow for ramp installation

The authors would like to express their deep appreciation to those concerned who have given valuable cooperation in the course of executing this project.