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Large Scale Maritime Structures Using Steel Pipe Piles

Masakazu Fukuwaka, Hideo Shinomiya, Hiroaki Furuya

Synopsis :

Since the construction of Philippine Sinter Plant (1974-1977) including the largest jetty structure in the Philippines to facilitate 250 000 D.W.T. ore carrier, Kawasaki Steel has developed various port and harbor projects utilizing high engineering careers obtained through construction of various structures of integrated steel works in Japan. In this report, outline and attractive engineering performances of Kawasaki Steel in major port projects in Southeast Asia, using steel pipe piles, steel pipe sheet piles and other steel products, are introduced.

The body can be viewed from the next page.

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Masakazu Fukuwaka
Staff Manager,
Business Development Sec., Corporate Planning Dept.

· Hideo Shinomiya
Staff Manager, Civil Engineering Dept., Construction Div., Engineering & Construction Div. Gir.

Hiroaki Furuya
Former General Manager, Business Development Sec., Corporate Planning & General Affairs Dept., Kawatetsu Engineering, Ltd. (Deceased)

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1 Introduction

For integrated steel mill with blast furnaces, efficient transport of large quantities of raw materials and products is very important. A great part of this transport involves the use of ships. Kawasaki Steel imports most of its raw materials such as iron ore and coal from various countries and, therefore, large vessels are frequently used due to their cost-effectiveness. It is necessary for integrated steelmaking plants to be developed with port facilities equipped with loading and unloading facilities for receiving these large vessels and conducting cargo handling. Since the initial stage of construction of its steel works, Kawasaki Steel has developed the most appropriate maritime layout and structures as the important part of the total transport system. In the berthing facilities for large vessels, the structures are large because of the great water depths required. Various types of berthing structures are used, such as gravity quaywalls using concrete caissons, bulkheads with anchorage using steel sheet piles, and platform-type wharves using steel pipe piles. In parallel with the planning, design and construction of these berthing facilities for large vessels, Kawasaki Steel has developed not only products, such as steel sheet piles, steel pipe piles and interlocked steel pipe sheet piles, but also techniques for using these products. Such aggressive efforts have resulted in the high potential engineering and contruction of deep-water maritime structures.

From 1974 to 1977 Kawasaki Steel constructed a sintering plant (Philippine Sinter Corp.: PSC) with large berths accomodating 250 000 D.W.T. vessels on Mindanao Island of the Philippines. Since then, Kawasaki Steel has developed engineering and construction services for various kinds of port facilities, especially in East Asia.This paper describes the engineering features of each type of berthing facility for large vessels constructed by Kawasaki Steel.

2 Engineering Study on Large-Scale Berthing Facilities for Large Vessels

2.1 Wharf for 250 000 D.W.T. Vessels

This Philippine sinter plant produces sinter using raw materials (iron ore,etc.) transported from remote countrise such as Australia, South America and Africa by large ore carriers, and exports its products to Japan. Although this wharf was initially intended for berthing 250 000 D.W.T. vessels (required water depth: 23.0 m), its capacity was increased in 1986 by dredging 2 m at the front of the berth to accommodate 300 000 D.W.T. vessels, making it one of the largest port facilities in the Philippines. A typical cross section of the main berth is shown in **Fig. 1** and the required amounts of work are shown in **Table 1**[1]. In constructing such large-scale port facilities, it is necessary to select a site capable of pro-

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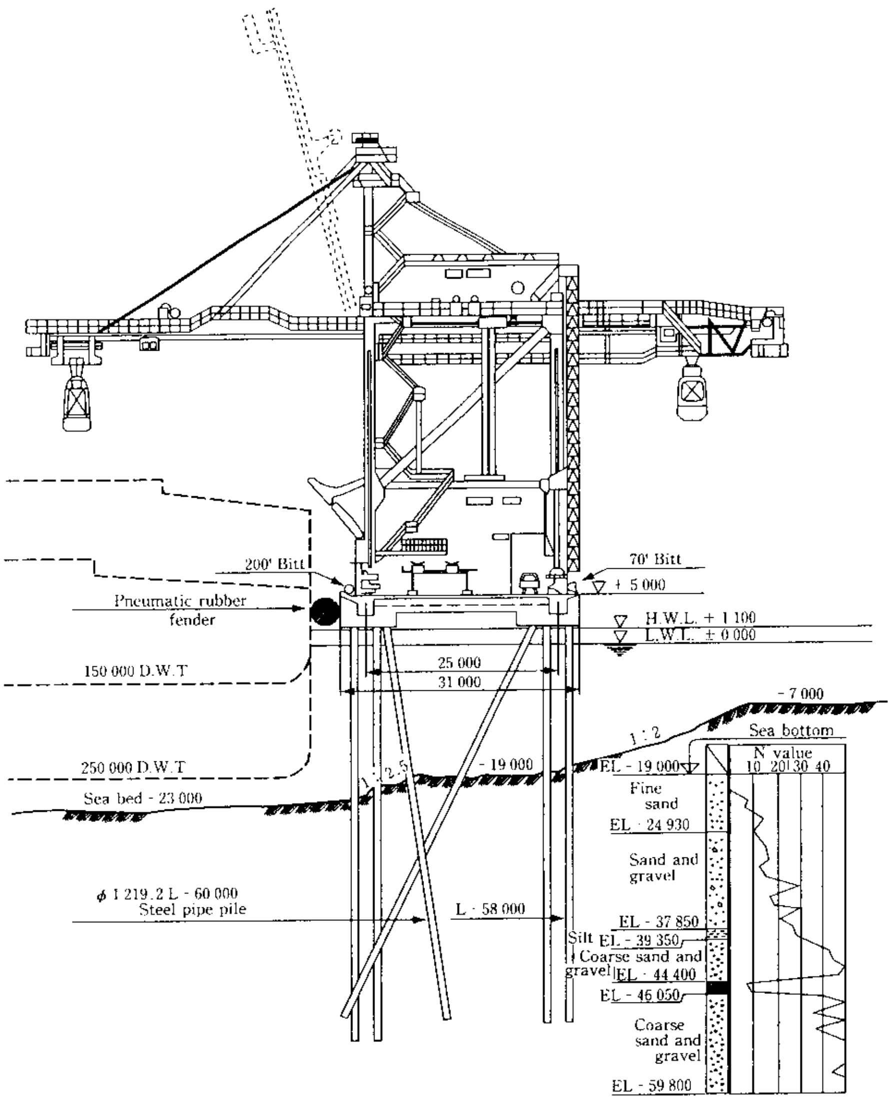


Fig. 1 Typical cross section of main berth

viding a channel, turning basin and required water depth. Meteorological conditions must also be taken into account to inctease the berth occupancy ratio while minimizing the effects of typhoons, seasonal winds, etc. Therefore, Kawasaki Steel conducted wide-ranging surveys of prospective sites in various parts of the Philippines and selected a site near Cagayan de Oro in the northern part of Mindanao Island. The bulk handling berth requires the large scale foundation struture to receive various loads from berthing impact, earthquakes, heavy equipment, and so on. However, it is necessary to meet these requirements in terms of economy and construction period. A plan of the main berth, including the pile arrangement, is shown in **Fig. 2**. In order to withstand berthing force and the strong horizontal force caused by earthquakes, and to reduce the weight of superstructures, each of the seaward and landward piers is connected by concrete beams and steel cross beams to form a rigid frame structure. Two batter piles are arranged, though not uniformly, for each pier at 30 m intervals and structures are laid out in a compact manner to facilitate construction.

In the roughly 20 years that have elapsed since the construction of this facility, this berth has been operating without a problem owing to faithfully conducted maintenance, such as measurement of the cathodic protection potential (aluminum anodes: lifetime of 10 years) of steel pipe pipes, replacement of the anodes at appropriate times, investigation of the degradation of concrete structures, and repair work undertaken when the concrete pavement of apron of steel steet pile bulkhead was broken by wave overtopping during a typhoon in October 1990 and when the rail fishplates were slightly damaged by an earthquake in the northern part of Mindanao in the same year.

Table 1 Quantity of major material

Item	Description		Quantity	Remarks
Main berth L = 351.25 m	Steel pipe pile (Vertical)	(pcs.)	195	O.D. 1 219 mm, t = 16 mm, l = 55-60 m
	Steel pipe pile (Rake)	(pcs.)	76	O.D. 1 219 mm, t = 16 mm, l = 60 m
	Steel beam	(t)	1 350	
	Reinforcement bar	(t)	2 150	
	Concrete	(m^3)	14 600	
Dolphin one no.	Steel pipe pile (Vertical)	(pcs.)	5	O.D. 1 219 mm, t = 16 mm, l = 60 m
	Steel pipe pile (Rake)	(pcs.)	4	O.D. 1 219 mm, t = 16 mm, l = 60 m
	Reinforcement bar	(t)	27	
	Concrete	(m^3)	320	
Connection bridge L = 47.56 m	Steel pipe pile	(pcs.)	16	O.D. 1 016 mm, t = 14 mm, l = 25-45 m
	H shape pile	(t)	26	H - 400 × 400 × 13 × 21, l = 20 m
	Steel beam	(t)	74	
	Reinforcement bar	(t)	32	
	Concrete	(m^3)	390	
Material berth	Steel sheet pile	(pcs.)	818	KSP IV type, l = 19 m
	Anchor pile	(pcs.)	204	H - 400 × 400 × 13 × 21, l = 10 m
	Reclamation	(m^3)	196 000	
	Dredging	(m^3)	7 800	
Accessories	Anode	(pcs.)	1 184	
	Crane rail	(m)	1 380	
	Rubber fender	(pcs.)	59	
	Capstan	(pcs.)	3	
	Docking sonar	(pc.)	1	

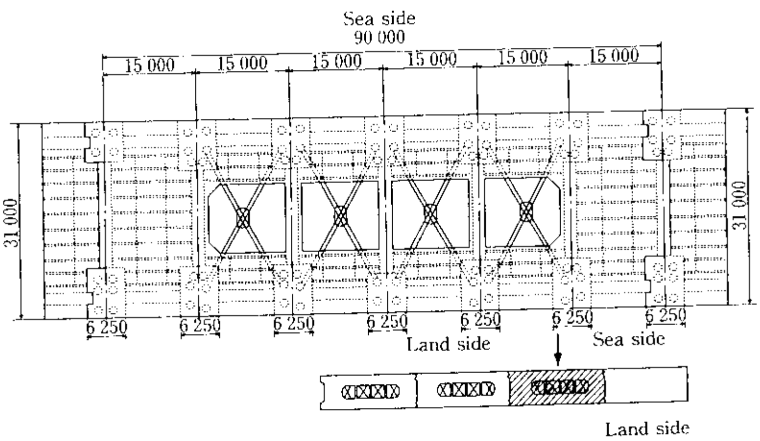


Fig. 2 Detailed plan of main berth

2.2 Taiwan Hsinta Coal Berth (Construction of Steel Pipe piles in the Ocean)

Hsinta Power Corp. planned a coal receiving berth for 10 000 D.W.T. vessels in order to supply coal to a power plant construted in the Hsinta district 30 km north of Kaohsiung. Kawasaki Steel was awarded the construction contract jointly with local companies[2]. At this location,waves are high due to seasonal winds and typhoons that occur 9 months out of the year (one-third significant wave height: 2 to 3 m) and the sea is shallow to a great distance from the shore. Therefore, a platform was constructed about 1 km offshore (**Fig. 3**). The steel pipe piles used are 1 500 mm in outside diameter, 25 and 36 mm in wall thickness, and 33 to 55 m in length (98 piles in all). The engineering focuses of piling works were quality control of welding for thick wall and large diameter steel piles to be fabricated by field circumferential welding and the method for drivig steel pipe piles in the unstable exposed sea. For the field circumferential welding method and quality control, a highly efficient circumferential submerged arc welding method was estab-

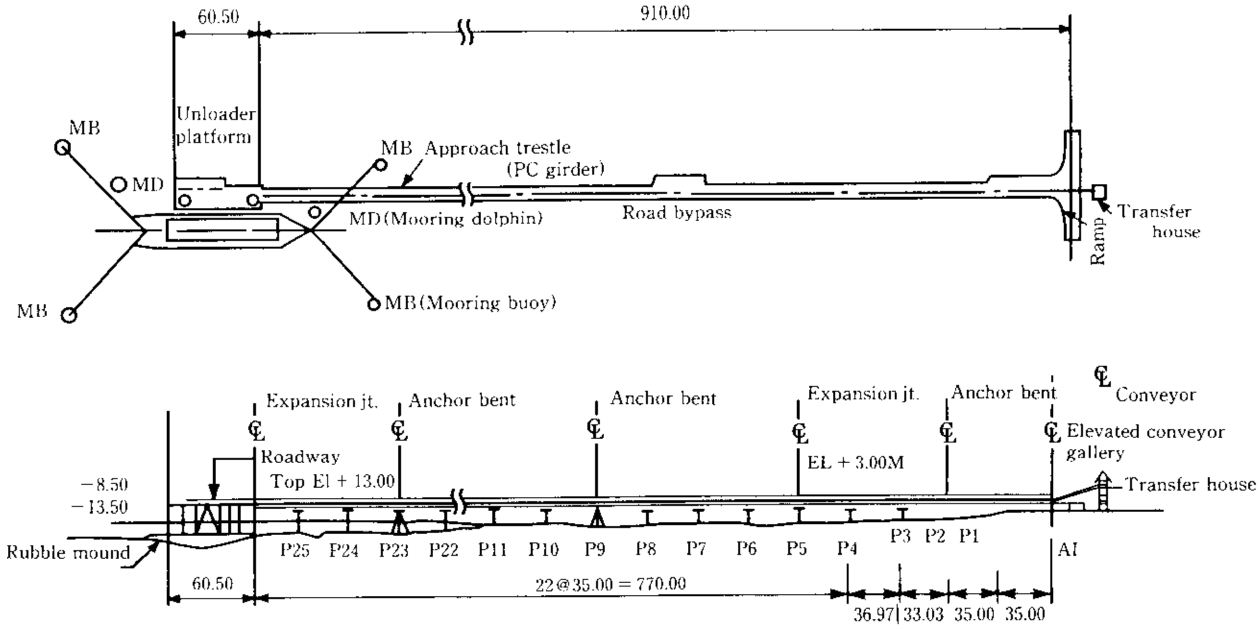


Fig. 3 Layout plan of offshore facility

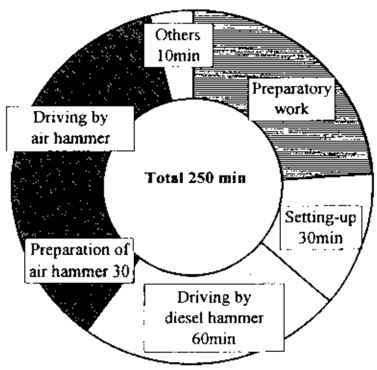


Fig. 4 Standard time cycle of piling work

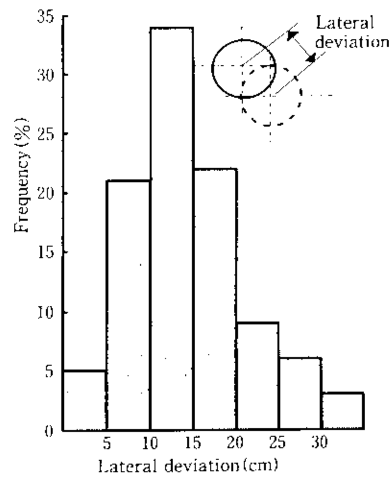


Fig. 5 Deviation after driving

lished by conducting prior experiments. Good results were obtained with an acceptance rate of 93.5% for JIS Grade 1[3].

In the offshore pile driving work, it was necessary to speed up the progress of work while maintaining the accuracy of piling (allowable horizontal deviaticn = 10 to 20 cm) even under the severe maritime and meteorological conditions. Because piles should be driven in the period when piling is affected by the north-northeast seasonal winds (October to March) and swells become large in the afternoon, pile installation was conducted using MH-80B diesel hammers and the process was completed using an MRB-200 air hammer, which is relatively unaffected by the seveve maritime and meteorological conditions. Piling was started on October 1, 1981 and was completed on January 23, 1982, requiring a total of 115 days (0.85 pile/day). The standard time cycle of piling work is shown in **Fig. 4** and the deviation after piling is shown in **Fig. 5**. Satisfactory results were obtained in terms of construction period and accuracy of piling in spite of the very severe maritime and meteorological conditions. This is the fruit of the prior careful investigations of the maritime, meteorological and soil conditions and the integrated engineering from pile fabrication to piling based on the results of these investigations.

2.3 Steel Sheet Pile Bulkhead in Leyte Island of the Philippines (Construction Cost Reduction by Alternative Design)

This work involved constructing port facilities in a

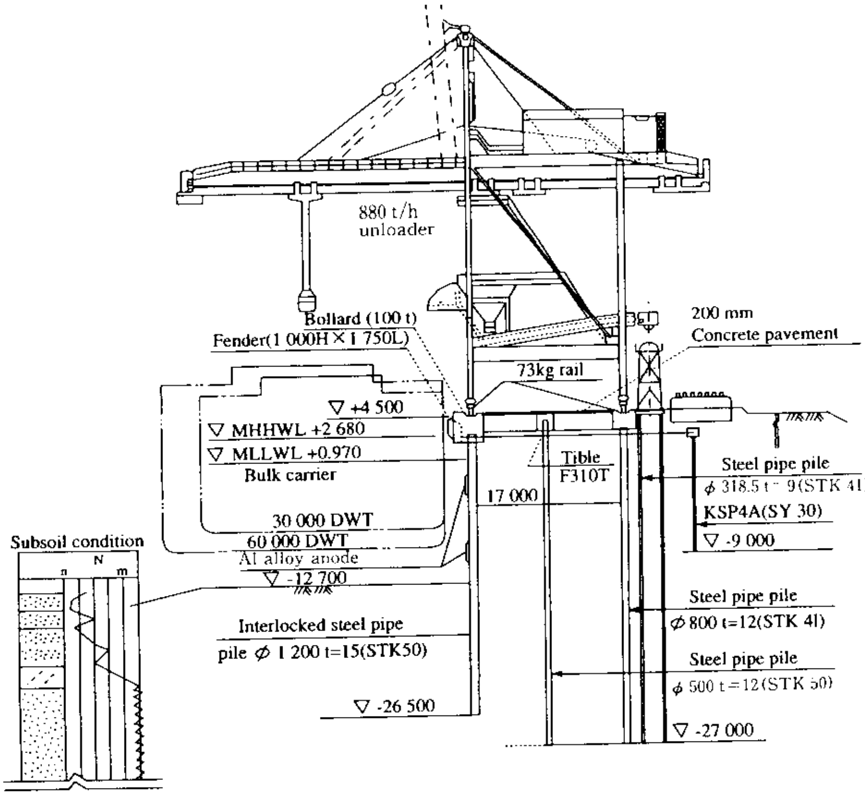


Fig. 6 Typical cross section of wharf structure supported on interlocked steel pipe piles

coastal industrial zone situated on the west coast of Leyte Island. Kawasaki Steel was awarded the contract for investigation, design and construction of port facilities as well as engineering services for the operations of the facilities[4]. National Development Company (NDC) the owner of these facilities planned for a gravity quaywall using reinforced concrete caissons as the quaywall structure based on their judgment that the pile-type structure could be adopted because of the high N-value (over 100) in the standard penetration test of the sea bed. However, because it was difficult for Kawasaki Steel to consider that such hard soil was present based on its experience with soil investigations and its analyses, Kawasaki Steel conducted its own soil survey and found that the soil was mainly composed of sandy soil with N-value of 20 to 40. It was judged that the piling method using steel pipe piles would be advantageous to the concrete caisson-type structure. Kawasaki Steel devised the structure using the interlocked steel pipe sheet piles and steel sheet piles shown in **Fig. 6** and proposed an alternative plan ensuring a balance of soil between dredging and backfilling by shifting the face line of the wharf about 20 m landward from its original position. This would secure the good soil at the back of the wharf. The client finally decided to abopt this modified plan after careful evaluation in terms of cost, time and quality. In driving the steel pipe and interlocked steel pipe piles that are the main structural members of the wharf, MB-40 and MB-70 diesel hammers were used according to soil conditions and the size of steel pipe piles (interlocked steel pipe sheet piles). The project was efficiently executed, as shown in **Table 2**.

It should be noted that in this project, the discrepancies between data on soil conditions enabled a gravity quaywall of reinforced concrete caisson to be replaced with a wharf using interlocked steel pipe sheet piles and steel sheet piles.

2.4 Kota Kinabalu Port Expansion Work (Alternative by Heavy-Duty Corrosion Protection Steel Pipe Piles)

Kota Kinabalu Port is one of the major commercial ports controlled by the Sabah Ports Authority in Malasia. It ships out mainly timber products, which is a source of revenue for Sabah State, and handles general consumer goods and industrial products and provides a base for Sabah State's economy. Since the start of service in 1968, the scale of this port has been increased through several expansion projects. This time, large-scale expansion work was carried out in order to ameliorate the lack of harbor capacity relative to the amount of cargo that increases year by year, the superannuation of existing facilities, and the growing trend toward the use of containers in cargo handling. The expansion work comprised an L-shaped new south jetty replaced the old wooden pile berth of and a north extension that involved

Table 2 Operation records of floating pile driving equipment

Description		Interlocked steel pipe pile	Steel pipe pile	Steel sheet pile
Dimension	(mm) (mm)	O.D. 1 200 × 15 t O.D. 800 × 13 t	O.D. 500 × 12 t O.D. 600 × 12 t O.D. 800 × 12 t	KSP VL
Length	(m)	21.0-33.0	22.0-40.5	21.5 23.5
Quantity	(pcs.)	380	145	897
Calender days	(d)	71	21	63
Operational days	(d)	45	14	33
Non-operational days	(d)	26	7	30
(due to bad weather)	(d)	21	4	11
(due to other causes)	(d)	5	3	19
Rate vs. calender day	(pcs./d)	5.4	6.9	14.2
Rate vs. operational day	(pcs./d)	8.4	10.4	27.2

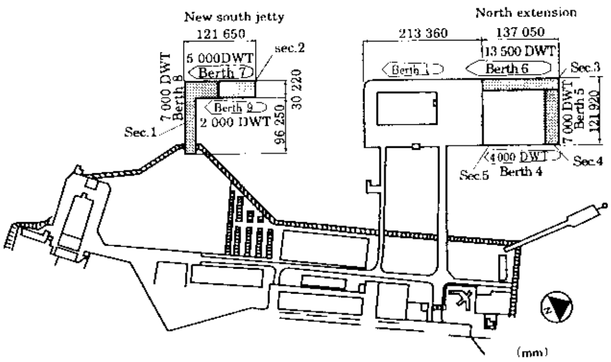


Fig. 7 General plan

Table 3 Comparison of steel pipe pile foundation system

Item		Original design	Final design by KPP pile
Outer diameter	(mm)	660	660
Wall thickness			
Upper pile	(mm)	19	17
Lower pile	(mm)	14.2	13
Weight	(t)	12 035	10 929
Corrosion Protection			
Material		Coal tar-epoxy	Polyethylene
Coating thickness	(mm)	0.45	2.5

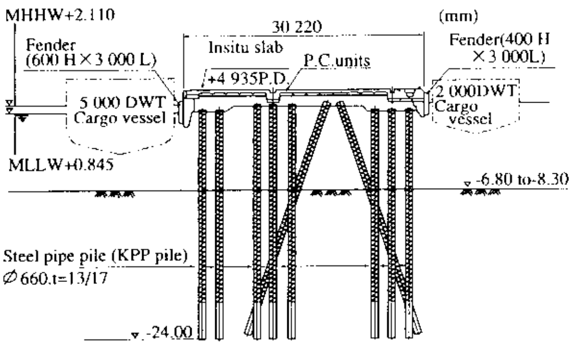
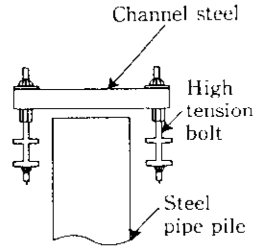
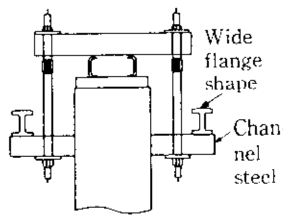
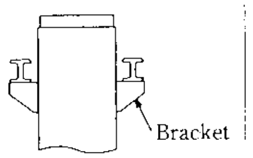
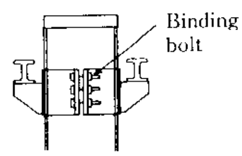


Fig. 8 Typical section

nearly doubling the length of the existing berth (**Fig. 7** and **8**). Phased hand-over was conducted five times because the work had to be executed while the harbor was in service[5]. The selection of piles was the most important concern because there were, 1 429 piles in all and material costs accounted for a large proportion of the work cost. Although the use of both concrete piles and steel pipe piles was acceptable in the bidding stage, there was no plant manufacturing conventional concrete piles in the local area so it would have been necessary to transport concrete piles from Peninsular Malaysia by sea. Concrete piles were also unfavorable in terms of construction period. Furthermore, eventually, it was decided to use the steel pipe piles, and to protect them from corrosion by coaltar epoxy coating and sacrificial wall thickness, a design which provided a considerable margin in terms of stress. Therefore, Kawasaki Steel proposed a plan to use polyethylene coated steel pipe piles (KPP piles) as the corrosion protection method for steel pipe piles, thereby reducing the total steel weight by 1 100 t as shown in **Table 3**. The major technical concern about using heavy-duty corrosion protection steel pipe piles was how to complete the structures without damaging the corrosion-protection layer coated in the shop. A temporary supporting system for formwork is important, especially in offshore concrete work. **Table 4** shows a comparison of various supporting systems. Examinations were conducted and the hanger type (2), in which the tolerance to the eccentricity of piles is large and the damage to the coating layer is slight, was even-

Table 4 Comparison of supporting system

Hanger type(1)	Hanger type(2)	Bracket type	Prefabricated bracket
			
* Easy installation * Small allowance for pile deviation	* Take time for installation * Large allowance for pile deviation	* No embedded steel * Damage to coating	* No embedded steel * Small bearing capacity

tually adopted. The bracket type may be effective in cases where the top concrete is small and the load to timbering during concrete is small and the load to timbering during concrete casting is low. However, this type was not adopted because the concrete load here was heavy and the under water tidal work was difficult due to the conditions at this site.

Although about ten years have elapsed since the construction of this wharf, the results of subsequent investigations have shown that the KPP piles have adequate soundness, and have been highly acclaimed by the owner for being maintenance-free.

3 Conclusions

The features of large vessel berthing facilities engineered by Kawasaki Steel are summarized as follows:

(1) Kawasaki Steel conducts integrated engineering studies covering the whole process from site selection to various investigations, planning, design and execution of the project.

(2) Utilizing characteristics of steel pipe piles, which are lighter and more rigid than concrete piles, economical design and reduced construction time are realized based on the high potential and Kawasaki Steel's vast knowledge of steel products.

(3) Kawasaki Steel can provide advantageous alternative planning in terms of cost and time through effective VE (value engineering), which entails not only berth facilities but also the total function of the port.

In the planning and design of port facilities, especially when they are planned by private companies, there are many cases where too much importance is attached to economy and the long-term consideration is given inadequate. It is difficult to modify or reinforce the wharf structure itself although it is relatively easy to take measures for the loading and unloading facilities when their lifetime is over or when the cargo handling method is changed. In port and harbor planning, therefore, it is important to conduct flexible design and planning in which the main causes of future changes are considered. Furthermore, port facilities, which are structures serving as the interface between marine and land transport, should be planned and designed as part of the whole material-handling system. Port facilities is one of the fields where Kawasaki Steel's know-how on handling large-scale material distribution can be utilized widely.

Kawasaki Steel is conducting the planning, design and construction of many port facilities especially in East Asia. The arthors wish to contribute to the economic development of these countries through the engineering of port facilities as important elements of their respective infrastructures.

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