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Technology of Functional Diagnosis and Rehabilitation for Marine Structure at Manila South Harbor

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Technology of Functional Diagnosis and Rehabilitation for Marine Structure at Manila South Harbor*



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1 Introduction

As a member of ASEAN, whose member countries have been undergoing remarkable economic growth in recent years, the Philippines has been enjoying expanded economic activity since the beginning of the 1990s. Accordingly, the volume of physical distribution into and out of the country has been increasing resulting in an urgent need to expand and modernize the functions of the country's port facilities. The ports of Manila are located on the western side of the capital and consist of the North Harbor, a domestic port which serves as the most important base for the flow of material goods in the country, and the South Harbor, an international port with the Manila International Container Terminal (MICT) which is exclusively used for the handling of container traffic (**Fig. 1**).

Both North and South Harbors of Manila have been in operation since the time of the past Spanish reign of the country and were converted to the present type of piers prior to World War II. The harbors were destroyed during the war, and rehabilitation work was carried out by U.S. forces and the Philippine government between 1946 and 1950. More than forty years have passed since then, with damage and deterioration becoming worse these past several years due to damage caused by corrosion

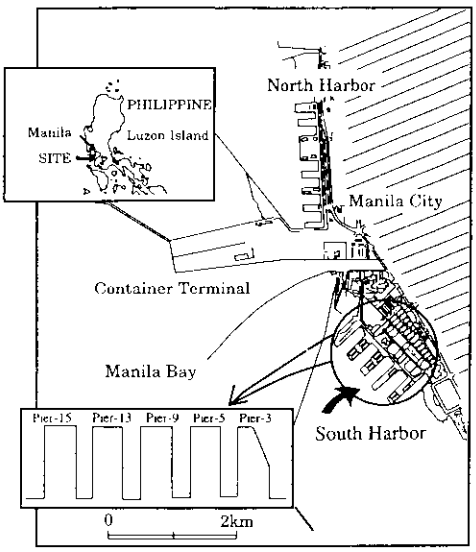

Fig. 1 Ports of Manila

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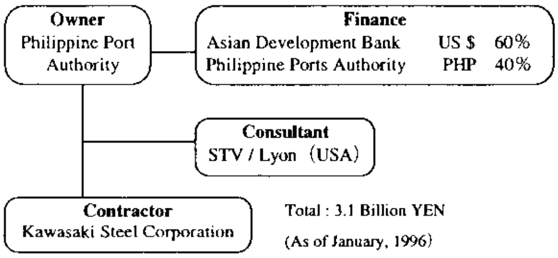

Fig. 2 Organization for construction

and the complexities of port operations. Small scale rehabilitation works have been carried out over the years, but no major rehabilitation has been carried out on the facilities and structures since their being rebuilt at the end of the 1940s.

The port facilities of Manila have been under the control of the Philippine Port Authority since 1975. In order to respond to the increase in cargo volume as well as modernization and ever greater sizes of newer vessels, the Philippine government decided to carry out rehabilitation work on the harbors in its 1978–1987 long-term plan with the aim of modernizing the ports. Accordingly, a feasibility study was carried out by the Japan International Cooperation Agency (JICA) serving as the core agency in this effort, and an outline of the rehabilitation work to be done was thus prepared.[1] Financing by the Asian Development Bank (ADB) was approved in 1987 on the basis of this report and rehabilitation of the Manila South Harbor was realized. The structure of the administrative organization for the implementation of the rehabilitation work is shown in **Fig. 2**. This report outlines the special features of this overseas port construction project which has subsequently come to serve as a foundation for the development of various overseas projects in the period since the conclusion of the Uruguay Round of the GATT.

2 Outline of Work

It was necessary to carry out this rehabilitation work in such a way that it would not disturb the functional operations of the harbor. Consequently, it was decided to complete the work through progressive rehabilitation of the different parts of the harbor after a limited number of berths were released for work by the owner. In managing the construction according to the schedule, it was thus considered necessary to utilize a wider range of techniques and to exercise a higher level of management capability in carrying out the project, including coordination between port operators and the Port Authority, compared with what is usually observed in the construction of a new port and harbor.

The content of this rehabilitation work can be roughly classified into two types, that is, structural rehabilitation and functional rehabilitation. Structural rehabilitation includes:

(1) Demolition of deteriorated concrete and reconcreting
(2) Repair of cracked parts through such techniques as the application of epoxy, etc.
(3) Removal and installation of new fenders

On the other hand, functional rehabilitation consists of such work as:

(1) Leveling of piers to accommodate containerization
(2) Construction of new foundations for container crane rails
(3) New construction of container berths using steel pipe piles

Figure 3 shows the general plan of the rehabilitation project, while the major quantities of materials to be used and the time schedule for the construction project are shown in **Table 1** and **Fig. 4**, respectively.

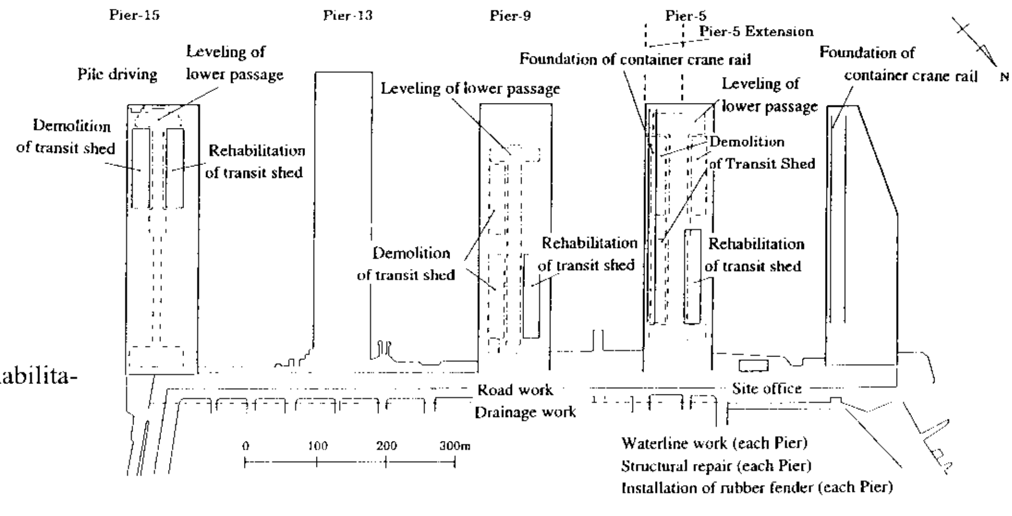

Fig. 3 Plan of the rehabilitation project

Table 1 Major quantities for the construction project

Structural repair		Functional rehabilitation	
Pier-3, 5, 9, 15		Pier-3 CR., Pier-5 CR., Pier-5 EX.	
Pile driving (PC)	17 piles	Pile driving (PC)	544 piles
Concrete	22 136 m^3	(steel pipe)	430 piles
Asphalt paving	166 000 m^2	Concrete	11 321 m^3
Inst. of rubber fender	194 units	Inst. of rubber fender	29 units

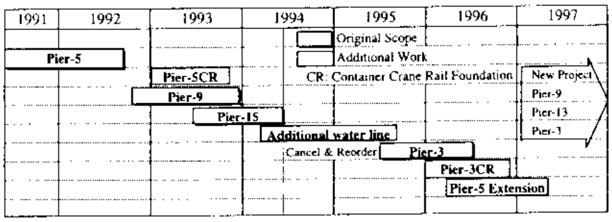

Fig. 4 Construction schedule

3 Structural Rehabilitation Work

3.1 Repair of Cracks with Epoxy Resin

When applying epoxy resin to harbor structures as part of the repair work for these structures, reference was made to the methods of quality control often adopted in the various kinds of repair work carried out at Kawasaki Steel's steel mills in Japan. The quality control work particularly planned for this project was adopted in consultation with the consultant (STV/Lyon).

3.2 Diagnosis of Rehabilitation Methods Prior to Execution of Structural Rehabilitation Work

The rehabilitation work carried out was for existing structures which were widely extended in two-dimensions. As a result, significant variations were present in the type and extent of damage and actual repair work which needed to be done across the range of structures in the harbor. Consequently, it was decided to standardize the manner by which the required work could be diagnosed and various methods of rehabilitation applied, respectively, by preparing a classification table. This table could then be used to accurately and objectively determine the various degrees of damage to each structure and location, and thereby permit the most appropriate method to be selected for rehabilitating a given structure (**Table 2**).

3.3 Flow of Rehabilitation Work and Its Cost Management

Rehabilitation work was performed by taking the following steps.

(1) An investigation was made on the extent of damage and its condition by visual inspection.
(2) Types of rehabilitation methods were classified and an assessment survey report was prepared.
(3) Shop drawings were prepared.
(4) Preparatory work was carried out upon obtaining approval from the consultant.
(5) The amount and details of work to be done together with the quantity of damage were confirmed with the consultant in attendance, and based on these results, revised shop drawings were prepared.
(6) Rehabilitation work was then carried out.
(7) The quality of rehabilitation work done as well as the quantity and quality of the repair were checked by the consultant.

The flow outlined above was followed consistently throughout the course of the work. In this manner, increases and decreases in the amount of work, materials, as well as actual costs could thus be easily made clear. This procedure of control contributed greatly to improving the rate of return in systematic quantity survey work.

4 Functional Rehabilitation Work

4.1 Leveling of Piers to Accommodate Containerization

The South Harbor had originally been designed such that lower passages were built on the center line of the piers so as to facilitate transportation of cargo by truck. However, containerization of cargo has since advanced and cargo handling is mostly done by forklifts at present. As a result, these lower passages have instead become obstacles to cargo handling. Plans were thus made to flatten the piers by leveling the lower passages in order to facilitate smoother container cargo handling. One significant technological challenge in carrying out this work was that the accuracy of pile driving in the existing piers was very poor. The actual position of the piles found after demolition of the slabs of the lower passages differed from that shown in the original drawings to a large extent. If the new beams were to be constructed by adjusting the position according to the existing piles, almost all of the approximately 500 blocks of precast concrete slabs which were to be placed on the new beams would have had to be made into different shapes with the result that the advantages of factory production could not be effectively realized. Consequently, structural ideas were applied in constructing new beams so that the precast slabs could be made in several type of fixed form. These fixed form slabs were then used under the acceptance of the consultant.

4.2 Construction of Container Crane Rail Foundation Beams

A recent trend in marine transportation in the flow of material goods is that container transport, which began during the later half of the 1960s, has since advanced to

Table 2 Classification table for selection of rehabilitation methods

		Type - A	Type - B	Type - C	Type - D	Type - E
Slab	Damaged condition	Need to change reinforcing more than 10%	Reinforcing bar more than 90% Flaked area is more than 50%	Flaked area is 25 - 50%	Flaked area is less than 25%	Crack width is 1 - 3 mm Total length is less than 30 m
	Repair method	Demolish damaged portion and concreting with reinforcing bar	Demolish damaged portion and repair by shotcreting	Demolish damaged area and repair by shotcreting	Apply cement mortar	Apply epoxy mortar
Beam	Damaged condition	Flaked area is more than 50% Both slabs are type - A	Flaked area is more than 50% One side or both side slab is not Type - A	Flaked area at bottom is more than 50% Flaked area at side is more than 50%	Flaked are is less than 50%	Crack width is 1 - 3 mm Total length is less than 10 m
	Repair method	Concreting with reinforcing bar	Demolish damaged portion and repair by shotcreting	Demolish damaged area and repair by shotcreting	Patching by cement mortar	Apply epoxy mortar
Pile	Damaged condition	For batter pile only Pile is separated from pile cap	For vertical & batter pile Need to change reinforcing bar Flaked area is above MLLW*	For vertical & batter pile Need to change reinforcing bar Flaked area is below MLLW*	For vertical & batter pile No need to change reinforcing bar Flaked area is observed	For vertical & batter pile Crack is observed
	Repair method	To be connected by concrete	Demolish from pile cap to MLLW - 30 cm at least After jacking up, concreting with reinforcing bar	Demolish damaged portion and concreting with reinforcing bar	Above water, patching cement mortar Below water, patching epoxy mortar	Applying epoxy mortar
Pile cap	Damaged condition	Flaked area is observed No need to change reinforcing bar	Flaked area is observed Need to change reinforcing bar			
	Repair method	Demolish damaged portion and repair by shotcreting	Demolish damaged portion and repair by shotcreting			

*Mean lower low water

become one of the most efficient and rationalized means of transporting cargo available. As domestic politics in the Philippines have become more stable, economic policies have also changed to become more positive, and the volume of container traffic is expected to expand to a large extent in the Philippines, as well. As a result, it has become essential that ports be upgraded with facilities capable of handling and responding to the growing volume of containers being transported. An examination of the matter in terms of cost as well as scheduling by the Port Authority concluded that it would be more advantageous to construct a new container crane rail foundation on existing Piers 3 and 5 rather than to build new container berths. Plans were then drawn up accordingly to reflect the results of this examination. The following two plans were proposed for Pier 3 only (**Fig. 5**), since Pier 5 has been designed already by STV/Lyon.

(1) Container crane foundation beams would be constructed over existing piles.

(2) New piles would be driven in without using the existing piles. The rail foundation beams would then be constructed using these new piles as the foundation.

Since no design data existed concerning the existing piles at Pier 3, Kawasaki Steel pointed out that there would be a problem with the reliability of the existing piles and proposed forming a conclusion on the matter after diagnostic and strength tests of the structures were first completed. Since the Engineering & Construction Div. Gr. of Kawasaki Steel had experience in using one particular suitable type of pile driving analyzer (PDA), it was decided to use this analyzer for the tests and to determine the condition of the existing structures objectively by judging the bearing capacity of the existing piles and estimating the length of these piles.[2] Consultations were then held with the Port Authority and the consultant on the basis of the results of the PDA analyses thus obtained. These results are summarized in **Table 3.** It was subsequently decided to adopt plan 2 mentioned above, that is, to drive in new piles in order to construct the foundation for the container crane rails for the following reasons.

(a) Eighty percent of the existing piles were found to be insufficient in their capability to accommodate the ultimate design bearing capacity.

(b) The existing piles were found to have reached only to the intermediate bearing stratum but to have excellent skin friction. While these piles were capa-

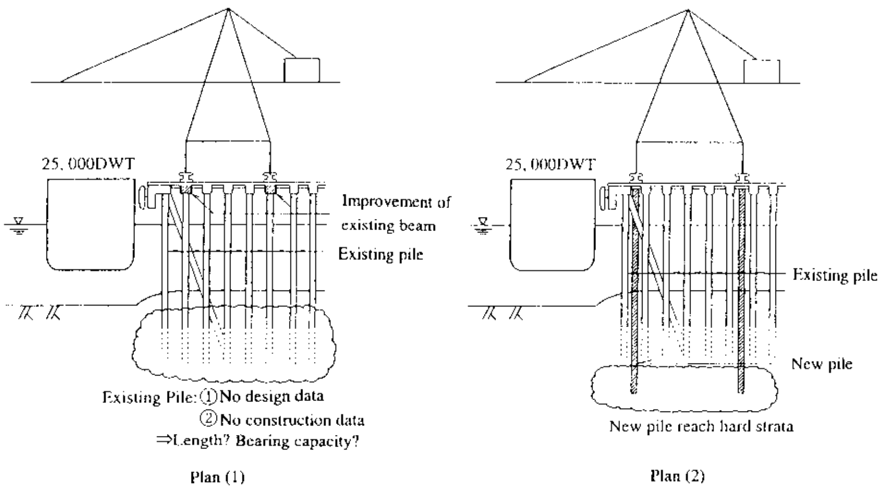

Fig. 5 Two plans of design and construction for foundation container crane rail

Table 3 Result of PDA analysis

Pile No.	Driving number (times)	Dropped height (m)	Assumed pile length by analysis(m)	Ultimate bearing capacity(kN)	Skin friction(kN)	End bearing capacity(kN)
A - 110	4	3.0	28	2 840	2 010(70.7%)	830
H - 100	5	4.0	30	2 000	1 600(79.9%)	400
I - 83	2	3.0	24	1 820	1 180(64.5%)	650
H - 67	3	4.5	20	1 520	820(54.2%)	700
H - 63	3	4.5	20	1 960	1 280(65.5%)	680
H - 20	—	—	18		—	—

ble of supporting the existing piers, the bearing capacity of these piles was judged to be inadequate for the task of supporting the loads of the heavy container cranes.

(c) There was some uncertainty as to whether all of the other existing piles were still in a sound condition considering that they had been supporting the existing structures for more than thirty years after being originally driven in.

As explained above, using reliable data obtained from the PDA analysis carried out on those existing piles for which no design or construction data had been available, Kawasaki Steel conducted technical examinations into the matter and finally received the notice to proceed with construction of the container crane rail foundation project, and which has been completed.

4.3 Construction of New Container Crane Berth According to an Alternative Plan to Use Steel Pipe Piles

The following construction related tasks were performed in response to the needs of containerization in handling the flow of cargo in the Manila South Harbor.

(1) Piers 3 and 5 were modified into container crane berths.

(2) The foundation of the container crane rails for Pier 3 were strengthened.

In addition, the Port Authority decided to carry out the following construction work in its year 2005 Harbor Plan:

(1) Extension of the Pier 5 container crane berth (70 000 DWT, design water depth: 15 m)

(2) Rehabilitation of Pier 13

(3) Expansion of the back side yard of Pier 3 through reclamation

(4) Extension of Pier 9

Of the above items, the Port Authority accepted the proposal of the port operation company to invite tenderers on item 1 above.

The original plan for the tender was of a common design in Southeast Asia to use precast (PC) concrete spun piles having a diameter of 900 mm which was prepared by an Australian consultant. However, Kawasaki Steel had full knowledge of the deep and complicated composition of the foundation ground of the Manila South Port through previous rehabilitation projects and could easily note several problems in the original plan. Design problems in the original plan included the following.

(1) Load conditions: The design load for sustaining

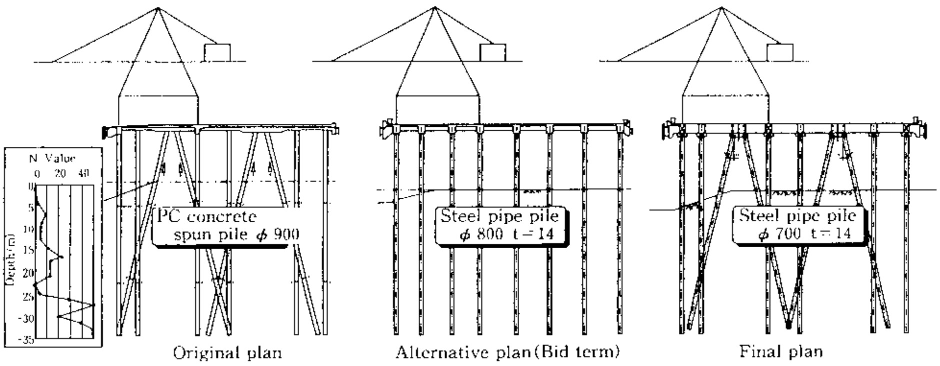

Fig. 6 Plans of new container berth

Table 4 Comparison among original design, alternative design, and final design

	Original design (PC Concrete spun pile)	Alternative design (Bid term) (Steel pipe pile)	Final design (Steel pipe pile)
Pile (pile)	430(ϕ 900)	344(ϕ 800, t=14)	430(ϕ 700, t=14)
Concrete (m^3)	9 884	9 880	9 690 (Pre-cast)
Slab thickness (mm)	450	300	300 (Pre-cast)
Load condition : Crane zone (t/m^2) Container yard (t/m^2)	 5.0 5.0	 1.0 5.0	 3.0 5.0
Construction schedule (month)	20	14	12
Construction amount (billion yen)	1.7	1.1	1.23

container loads was 5 t/m^2 for the entire area of the pier, but this value was considered to be excessive.

(2) Slabs: The slab thickness of 450 mm was considered to be excessive compared with the 250 mm thickness of existing slabs.

(3) Piles:
- (a) It was considered inadequate to use PC concrete spun piles which are not strong against bending for the deep ground with a thick and weak stratum.
- (b) PC concrete spun piles have to be made by splicing three lengths of 18 m line sections (12.7 t each) at offshore which is a very difficult task.

In view of the above, Kawasaki Steel examined an alternative plan which called for the use of steel pipe piles based on the following principles.

(1) Application of steel pipe piles
- (a) Because the weight of steel pipe piles is about 40% less than that of PC concrete spun piles, it is possible to drive in steel pipe piles from a pile driving barge of a smaller capacity.
- (b) Since the piles can be spliced on shore, it is possible to shorten the pile driving cycle time.

In the case of designing long piles, steel pipe piles are more advantageous than PC concrete spun piles. In particular, steel pipe piles can be produced more economically by procuring hot coils from a third country, fabricating the coils into pipes and then applying polyurethane corrosion proof paint to the pipes.

(2) Application of PC concrete beams and slabs
- (a) It is possible to reduce the thickness of concrete slabs from 450 mm to 300 mm.
- (b) By precasting beams and slabs, concreting can be completed quickly on shore in advance. In addition, it is possible to equalize the amount of concrete required over the period of construction.
- (c) PC concrete slabs serve a function as bottom forms, and concreting of slabs should become easier like the construction work being done on shore.

(3) Adoption of the design carrying load used for the average container crane berth in Japan
- (a) The design carrying load of 5 t/m^2 in the original plan is excessive compared with the case of similar berths in Japan.
- (b) By reducing the carrying load, it is possible to reduce the total load on the structure as a whole.

Technical investigation of the above items thus resulted in reducing the amount of construction work by about 20% (**Fig. 6**, **Table 4**). Costs could thus also be reduced significantly and a competitive plan could be prepared. Kawasaki Steel is continuing with construction work on this project at present.

5 Conclusion

Building on the technical capabilities of engineering and construction work initially gained through the construction of the Chiba Works since 1951 and of the Mizushima Works since 1961, the Engineering & Construction Div. Gr. of Kawasaki Steel has been developing the concept of total engineering from design through construction both in Japan and overseas. The company's steel works have been developing various peripheral techniques, with reclamation bulkhead, port and harbor construction techniques using steel sheet piles and steel pipe piles as a core. Among these techniques, the corrosion protection technique (polyethylene coated steel pipes, electrical corrosion proofing, painting) and the repair technique (corrosion protection of steel reinforcing bars, changing and replenishing of steel reinforcing bars, painting, rehabilitation of sections, application of epoxy to cracks) have been given greater importance in recent years as suitable methods for performing maintenance on age-deteriorated water front structures. Kawasaki Steel is currently making greater efforts to develop these techniques further. The company has been aiming at improving the quality and level of service of rehabilitation techniques in this project.

In summary, this report described the efforts being made by Kawasaki Steel to rehabilitate the port structures in the Manila South Harbor. These efforts are briefly summarized as follows.

(1) The company planned to reduce the cost and shorten the construction period for rehabilitating the harbor structures by establishing a method of classifying the rehabilitation methods and by promoting the systematic flow of the construction procedure.

(2) In carrying out rehabilitation work, the company rehabilitated the piers without interrupting the functional operation of the port through a careful display of its project management capability including schedule management, coordination, and the like.

(3) In constructing the Pier 3 container crane foundation, the company verified the length and load bearing capacity of the existing piles of the old container crane berth through PDA analysis and rehabilitated the foundation through the use of a reliable method.

(4) In expanding the Pier 5 container crane berth, the company conducted a technical examination within a short period of time of the original plan proposed by the consultant to use PC concrete spun piles. As a result of this study, Kawasaki Steel received the order to carry out the work by acquiring the final negotiating rights with an alternative plan to use steel pipe piles, work which the company is currently in the process of carrying out.

As explained above, various techniques fostered through the construction of Kawasaki Steel's steel mills over many years of experience were applied to the rehabilitation project in the Philippines. Highly challenging engineering and construction projects of this kind are expected to increase in the Southeast Asian region, and Kawasaki Steel is planning to take on the callenges of these new projects with the experience gained through this project in the Philippines as a foundation.

In closing, the authors wish to express their sincere gratitude to those concerned for their guidance and cooperation.

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