ASEAN-Japan Transport Partnership

Guidelines
on
Strategic Maintenance for Port Structures

Port Technology Group
ASEAN –Japan Transport Partnership

Port and Airport Research Institute(PARI),Japan

Ocean Policy Research Foundation(OPRF), Japan

Ports and Harbours Bureau, Ministry of Land, Infrastructure, Transport and Tourism(MLIT), Japan

Foreword

This guideline entitled "Guidelines on Strategic Maintenance for Port Structures" aims at providing developing countries, particularly ASEAN countries, with assistance to appropriately maintain their various port structures such as concrete structures and steel structures. Because not only Japan but also many countries are plagued by aged deterioration of port structures, Port Technology Group (PTG) under the framework of ASEAN- Japan Transport Partnership Program commenced to tackle this issue as three-year project in 2009. Port infrastructure is expected to guarantee required performance of services over a long period of time. To that end, careful considerations during structure design and construction works as well as appropriate maintenance in-service period of port structures are required, taking life cycle management into account. This guideline, which contains everything needed for such strategic maintenance, was achieved from the three-year research results.

Among those who have contributed substantially to the development of the guideline are Prof. Hiroshi Yokota of Hokkaido University, Researchers from Port and Airport Research Institute (PARI) of Japan including Dr. Masahiko Furuichi, the Chair of Port Technology Group (PTG) and Dr. Mitsuyasu Iwanami, and PTG members from ASEAN countries. This guideline could not have been successfully finalized without those contributors. All countries involved could share knowledge described in this guideline on strategic maintenance for port structures and build their capacity and capability for it through three-year research and seminars. Because case studies provided by PTG members in the latter section of this guideline help significantly to understand how to apply technologies to actual maintenance practices, I hope this guideline will be in widespread use.

Finally, I would like to deeply appreciate Ocean Policy Research Foundation (OPRF) in Japan, for its financial support, to developing this guideline.

林田博

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Port Technology Group (PTG)
ASEAN-JAPAN Transport Partnership

■ 6th PTG Meeting：26.Feb.2009 (Manila, Philippines)

■ 7th PTG Meeting：24.Feb.2010 (Sihanoukvill, Cambodia)

■ 8th PTG Meeting：21.Feb.2011 (Kuala Lumpur, Malaysia)

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CONTENTS

Part 1

Common Part

1.1 General

Maintenance of port and harbor facilities should be conducted strategically.

[Commentary]

(1) Port and harbor facilities should remain in service for a long period of time, so as to properly maintain their functions. It is therefore essential to give an appropriate consideration during the initial design of the relevant structures, as well as to conduct proper maintenance since their service starts.

(2) Since port and harbor facilities generally face severe natural conditions, they often tend to suffer from performance degradation over their service period, due to material deterioration, damage of components, settlement of foundations (e.g. caissons), and scouring and sedimentation around them. Accordingly, the facilities should be maintained systematically and appropriately so as to continuously satisfy the performance requirements over their service period. A maintenance program shall stipulate a basic principle of effective maintenance, basic maintenance procedures, and a series of inspection procedures, methods, contents, timing and frequencies.

(3) Port and harbor facilities should be appropriately maintained taking the following factors into consideration: 1) natural conditions, 2) facility use plan, 3) importance and substitutability, 4) designed service period, 5) structure type, component and material characteristics of the facilities, and 6) difficulty level of inspection and intervention/countermeasure.

1.2 Life-Cycle Management-based Maintenance
Strategic maintenance of port and harbor facilities should be conducted systematically and rationally based on the Life-Cycle Management (LCM) concept.

[Commentary]

(1) Port and harbor facilities should be maintained by the following series of maintenance procedures; 1) preparation of maintenance program, 2) accurate inspection of deformation (e.g. damage, deterioration) of structures, 3) comprehensive evaluation of the inspection results, and 4) implementation of necessary countermeasures.

(2) A rational and efficient maintenance of the facilities may follow a series of maintenance procedures, based on the Life-Cycle Management (LCM) concept as shown in Figure 1.2.1. More specifically, a series of maintenance procedures are 1) preparation of maintenance program, 2) standardized inspection of current status of the facilities, 3) evaluation of residual performance and prediction of future performance degradation of the structure or components, based on the inspection results, 4) comprehensive evaluation using future facility use plan, remaining service period and life-cycle cost of the facilities, and 5) implementation of necessary countermeasure works based on the comprehensive evaluation.

(3) Quantitative evaluation and prediction of future performance degradation of the structure or components, based on the inspection results, are essential to the LCM-based maintenance.

(4) It is necessary to continuously make every effort to establish evaluation and prediction techniques for every type of structure and deformation as quantitatively and objectively as possible, while no techniques are yet available for every type with our current knowledge.

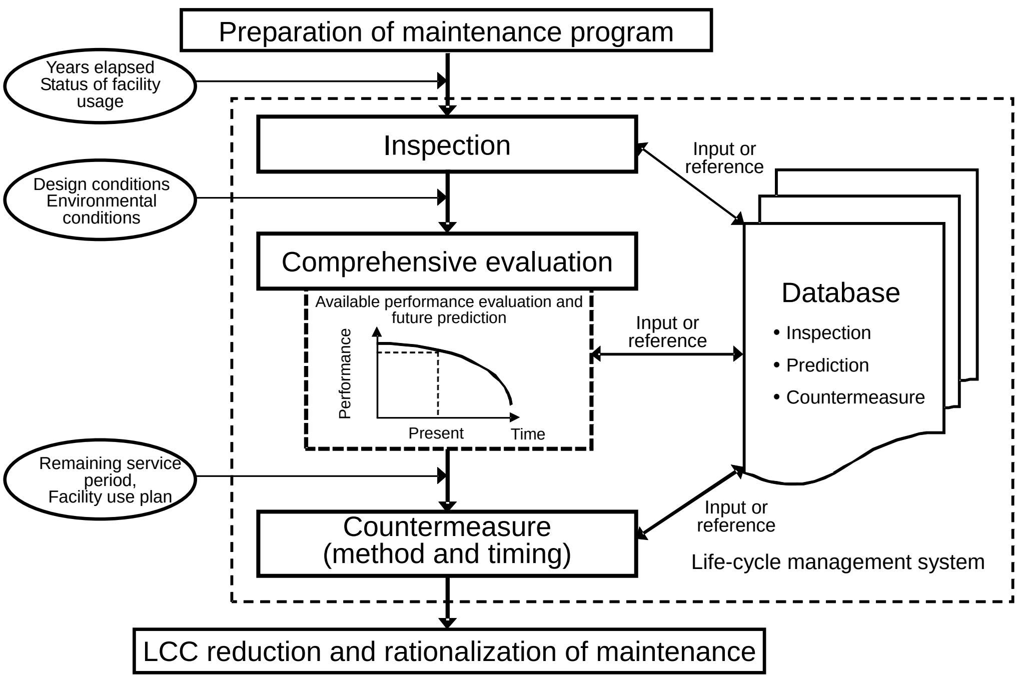


Figure 1.2.1 Flow of maintenance procedures based on Life-Cycle Management (LCM) concept

1.3 Maintenance Strategy

To achieve the strategic maintenance based on the LCM concept, a maintenance program should be formulated as a series of inspection and investigation, evaluation and repair works, by applying the suitable maintenance strategies.

[Commentary]

While almost all port and harbor facilities are designed to be in service for a period of 50 years or longer, it is not easy to maintain the serviceability of the structures and/or facilities for the long period of time under the severe conditions. Therefore, a maintenance program should be established in advance so as to satisfy the performance requirements of the facilities. From the viewpoints of 1) the purpose of the facility, 2) its service period, 3) performance requirements, 4) the design concept, and 5) its substitutability, one of the following maintenance strategies should be applied as a basic maintenance strategy and an appropriate maintenance program should be formulated according to the applied strategy.
To achieve the strategic maintenance of port and harbor facilities in Japan, the following three types of maintenance strategy were defined in the *"Technical Standard and Commentaries for Port and Harbour Facilities in Japan (in Japanese)"* published in 2007:

(1) Maintenance Strategy (Type I)

Maintenance strategy (Type I) requires that high level of precaution be taken so as to maintain structural performance of the facilities over the service period well above the required level. As shown in Figure 1.3.1, degradation or deformation, which are anticipated to remain in a minimum level over the service period, should be maintained within a minor range (above the "maintenance limit").

For example, this strategy may apply to structures of longer life than the intended service period by using concrete structures with reinforcing bars of anti-corrosion steel (for example, stainless steel or epoxy-coated steel).

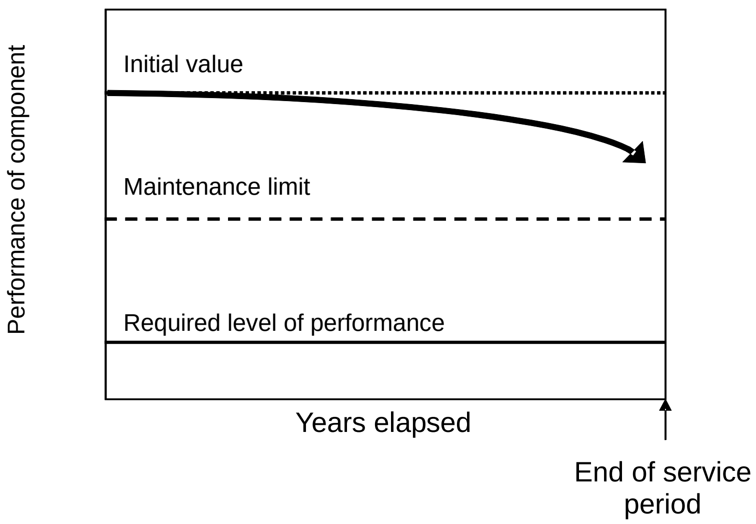


Figure 1.3.1 Maintenance Strategy (Type I)

(2) Maintenance Strategy (Type II)

Maintenance strategy (Type II) requires that small-scale repairs be repeated at each stage of early deterioration so as to maintain the structural performance of the facilities over the service period above the required level. As shown in Figure 1.3.2, degradation or deformation, which are anticipated to appear in a certain level over the service period, should be maintained within a certain range.

Typical examples of this strategy are to plan repeated surface coating of concrete structures or the exchange of anodes of cathodic protection for steel piles and sheet piles.

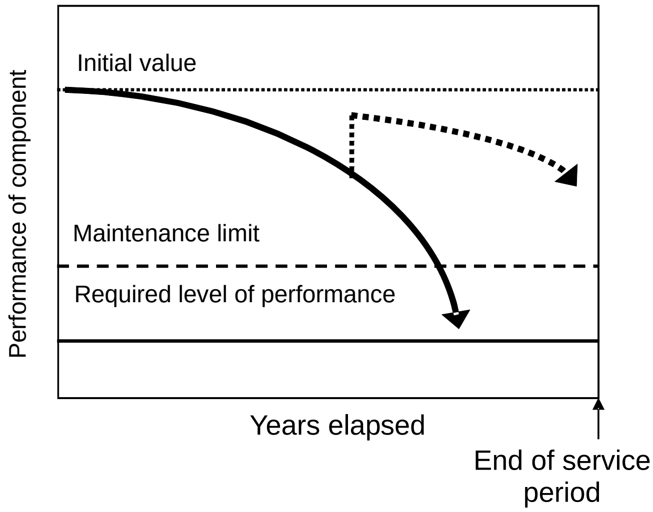


Figure 1.3.2 Maintenance Strategy (Type II)

(3) Maintenance Strategy (Type III)

Maintenance strategy (Type III) allows for a certain level of deterioration provided it meets the required level of the structural performance, and applies large-scale repair works as breakdown maintenance once or twice over the service period, as shown in Figure 1.3.3. This approach normally applies to the structures of shorter life than the overall service period, such as yard pavement and wharf fenders.

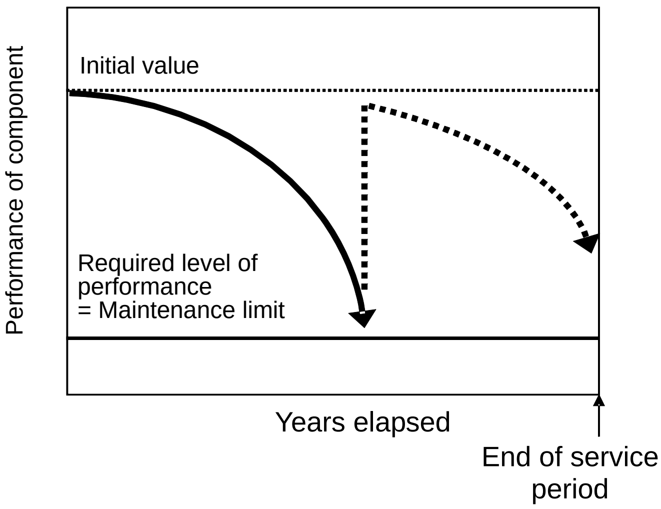


Figure 1.3.3 Maintenance Strategy (Type III)

[Appendix] Design and construction considering maintenance strategy

To ensure efficient and rational maintenance based on the LCM concept, a certain maintenance strategy should be explicitly applied even to the initial design stage as well as the appropriate maintenance stage over the service period. If a facility does not have sufficient durability in its design or construction, applying a high level of maintenance often results in increased maintenance cost and is frequently inappropriate.

Maintenance strategies described in this guideline are strongly recommended to be applied to the initial design stage of a new facility by incorporating initial performance requirements and the selected maintenance strategy.
Specifically, the following measures to be implemented on the design and construction stages may be beneficial to help facilitate maintenance works over the service period;

1) Preparing monitoring sensor holes and scaffoldings in the facility components,
2) Installing monitoring sensors,
3) Facilitating maintenance works over the service period by taking any measures in advance as planned, and
4) Facilitating replacement of deteriorated components by taking any measures in advance, if necessary.

Avoiding initial defects due to insufficient workmanship is essential for the structural design, because a series of performance verification rely on the appropriate construction works under the execution standard established separately. Similarly, this principle applies to the execution stage of countermeasure work.

1.4 Inspection
Systematic and appropriate inspection is required so as to effectively detect deformation to occur in components of port and harbor facilities, taking the “deformation-chain” concept into consideration.

[Commentary]

Since deformations to occur in the structural components of port and harbor facilities are strongly interrelated, the appropriate inspection items, methods and procedures should be selected to achieve an efficient and effective inspection by taking the “deformation-chain” concept into account. Port and harbor facilities consist of relatively complex structure being affected by a variety of external factors, so that deformations of the components occur, diffuse and progress as a chain of reactions. Rational maintenance of the facilities requires that major inspection items be focused, which may represent damage, deterioration and deformation of the components dominating their influence on the component performance.

A series of deformations, consisting of their cause, occurrence, and effect, which result in the structural performance degradation, is referred to as the “deformation-chain”, that is, fault tree. Therefore, the deformation-chain concept should be fully taken into consideration when selecting the inspection items. Furthermore, focusing on the particularly important chains among the deformation-chains is essential to achieve rational maintenance.

When performing evaluations based on inspection results, rather than using the results of a single inspection, data accumulation through periodical inspections rather than a single inspection I essential for rational evaluation. Accurate recording and storing their specific location and status are important. Likewise, recording and storing the initial status of the relevant inspection items are also important, when deformations are expected to progress in a certain period of time. Therefore, in order to ensure the objectivity, reliability and consistency of the inspection results, a series of inspection items, methods, procedures and judgment criteria should be standardized to a certain extent. Since the inspection results are expected to contribute to the maintenance management of other facilities, the inspection results over the service period as well as after their disuse or service shutdown should be stored and maintained for a certain period of time.

Inspections need to be conducted periodically and continuously in order to monitor the progress of deformations, when inspecting each part or component of the structure. In general, they confirm deformations that have occurred to the outside of a facility by visual observation and include judgment of the degree of degradation of the affected parts using the appropriate judgment criteria. The “Manual on Maintenance and Rehabilitation of Port and Harbor Facilities” in Japan classifies degrees of degradation, as determined by the judgment criteria, into four levels (a, b, c and d) shown in Table 1.4.1. The descriptions in Appendix X show general standards. Specific methods on inspections should be determined individually and based appropriately on local conditions. If some of the contents in the standards does not match actual conditions, addition or correction of inspection items, methods, frequency, points or judgment criteria may be made as required for each facility based on a full understanding of the applicable structural type and design or environmental conditions. In case special structural types or materials are used, appropriate inspection methods should be individually investigated and stipulated in advance.

Simple investigation devices such as scales, rods, levels, transits, or other pieces of measuring equipment such as inspection hammers, binoculars, or crack scales may be used to support visual observation. Other simple devices may be specially developed to help enhance inspection precision or improve inspection efficiency. These devices, however, are intended to purely support visual observation and should not be used as a substitute for direct and personal inspection of facility conditions by the inspector.

Table 1.4.1 Descriptions of inspection results

Degree of deterioration	Condition of part or component
a	Performance of the component has seriously deteriorated.
b	Performance of the component has deteriorated.
c	Performance of the component has not deteriorated, but some deformation is occurring.
d	No deformation identified.

[Appendix] Deformation-Chains in Port and Harbor Facilities

Deformations occurring in port and harbor facilities include deterioration that slowly and gradually progresses over a period of time as well as damages that accidentally occur due to a typhoon or earthquake. These deformations are collectively referred to as deformation of a structure and a component, similarly displacement and movement of a structure and component are included in this definition of deformation as well. It is important are to detect any deformations, to accurately identify their cause, and to grasp the degree of identified deformation so as to ensure appropriate maintenance of the structure. Therefore, the principle of the deformation-chain, to be discussed later, must be fully understood.

Deformations occurring in port and harbor facilities may be classified into three categories by the process of the chains, a) progressive deformation, b) accidental deformation and c) intermediate deformation. Progressive deformation is a deformation that continuously progresses for a period of time, that is, consolidation settlement of the ground, material deterioration of the structure and components, and any progressive deformation due to excessive loading surcharge. Accidental deformation is a deformation that occurs in a short period of time by external forces due to extremely rare events such as an extremely large earthquake or huge ocean waves. Intermediate deformation is a deformation that slowly and gradually progresses for a period of time by relatively large repeated external forces such as ocean waves acting on a breakwater.

Information on type, cause and degree of deformations is essential to appropriately implement the LCM-based maintenance. Furthermore, a wide variety of factors is to comprehensively be taken into consideration; 1) natural conditions surrounding the facility, 2) the facility use status and its future plan, 3) the service period, 4) degree of the facility importance, 5) substitutability of the facility, and 6) difficulty level of inspection and maintenance work, 7) structural type of the facility, 8) structural characteristics of its components, and 9) specification and quality of the component materials.

General provisions:

(1) Appropriate maintenance measures shall be implemented for port and harbor facilities, by selecting major deformations among the deformation-chains.

Since deformations occurring in the structural components of port and harbor facilities are strongly interrelated, the appropriate inspection items, methods and procedures should be selected to achieve an efficient and effective inspection by taking the deformation-chain concept into account. Ideally, comprehensive evaluation should be made through inspecting all deformations of the components, since any deformation patters may appear due to the deformation-chains. However, this may not be practical due to budgetary and labor constraints. Therefore, the practical and recommended approach is to select major deformations among the deformation-chains, which clearly represent the facility performance degradation and are easily monitored.

(2) In selecting major deformations among the deformation-chain, the whole development process of deformations shall be fully considered; their cause, occurrence and effect resulting in deterioration of the facility performance.

A series of deformations, consisting of their cause, occurrence, and effect, which result in the structural performance degradation, is referred to as the deformation-chain, that is, fault tree.

Therefore, the deformation-chain concept should be fully taken into consideration when selecting the inspection items. Furthermore, focusing on the particularly important chains among the deformation-chains is essential to achieve efficient maintenance.
Important is to understand deformation phenomena of port and harbor facilities by classifying deformation-chains. However, to accurately grasp the cause of the deformation-chain is comparatively difficult, because a variety of causes may influence on deformation of the port and harbor facilities.
The deformation chain may be classified into the following two categories from the viewpoint of the cause-and-effect-relationship among structural elements. One is the deformation-chain where deformations occur in the structural components of the facility, which independently progress; corrosion of steel piles and sheet piles or cracking and deterioration of the concrete members are the typical examples of this chain. This type of deformations is solely affected by the structural component properties rather than the facility properties, of which developing process is relatively simple. The other is the deformation-chain where deformations occurring in the different structural elements mutually interact and further diffuse to the other elements. For this type of the deformation-chain, the deformation tends to amplify its scale, because the cause and developing process are affected by the entire facility properties. However, it is not particularly important to distinguish these two types of the deformation-chains so that these two chains are treated in the same manner in this guideline.

1.5 Comprehensive Evaluation

Comprehensive evaluation shall be made based on the inspection results to determine maintenance countermeasures, by taking into account the remaining facility performance, capability to satisfy the performance requirements over the remaining service period, the facility use plan, and the importance of the facility, etc.

[Commentary]

Comprehensive evaluation shall be made to determine the level of the facility performance degradation, by summarizing the inspection results of the facility components, a progress of damage and deterioration as the entire facility. Through this evaluation, the methods of maintenance countermeasures and their timing of the implementation shall be determined, by taking into account the future facility use plan, the importance of the facility, the budgetary and maintenance work constraints, etc.

Comprehensive evaluation shall be made applying the following maintenance principles.

1) Determining urgent repairs and reinforcement of the components, and their methods
2) Determining plans of repairs and reinforcement of the components, and their methods
3) Determining components necessary to be observed for the time being
4) Determining necessary restrictions and suspension of the facility use
5) Determining revisions of the inspection plan (timing and method of the next inspection, etc.)
6) Determining renewal or demolition of the facility
7) Determining necessary urgent maintenance measures

Implementation results of the maintenance measures should be incorporated into the inspection plan as a feedback to the maintenance program.

Two typical maintenance strategies are shown in Figure 1.5.1, so as to keep the facility performance well above the required level. The strategy representing (a) requires repeated small-scale repairs of the facility at the early stage of deterioration with relatively small maintenance costs, so as to keep it in service over the service period. The other strategy representing (b) allows for a certain level of deterioration provided it meets the required level of the structural performance, and applies large-scale repair works as collective maintenance once or twice over the service period, resulting in relatively large maintenance costs. Either way, the maintenance program should be formulated taking life-cycle costs of the facility into consideration.

If deformations of the facility are expected to progress to a certain extent in the future while the current state of performance degradation is small, an intensive inspection plan should be conducted.

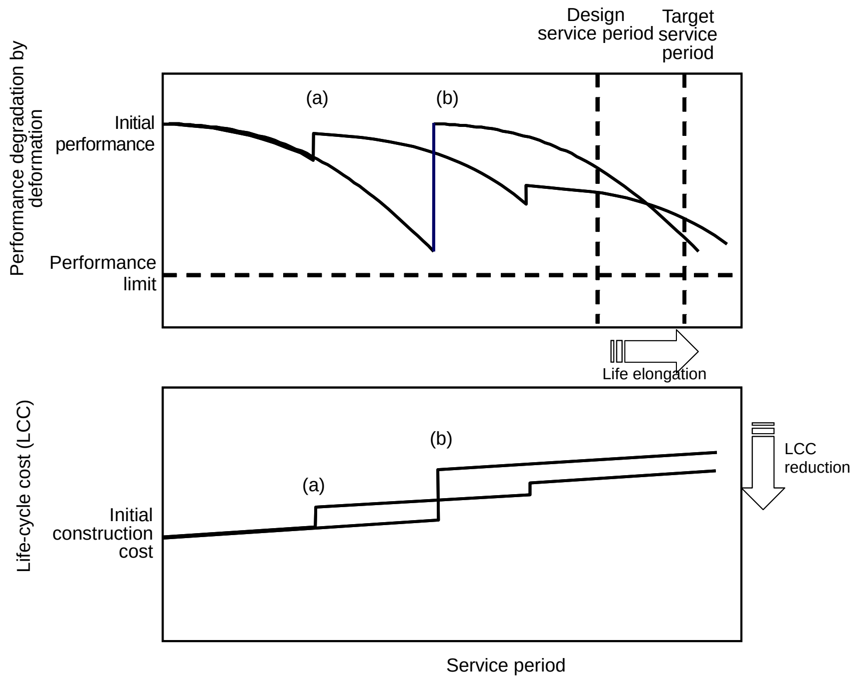


Figure 1.5.1 Life-cycle cost and maintenance strategies

The evaluation of facilities based on inspection results basically depends on the comprehensive judgment of the evaluator. In order to ensure objectivity of the evaluation, it is necessary to formulate guidelines regarding judgment criteria, evaluation levels, and the relevant processes to extend evaluation from each component to the comprehensive evaluation. However, since technical knowledge has not been sufficiently accumulated regarding methods to objectively evaluate facility performance based on inspection results, it is desirable to refine them as necessary by accumulating experiences future.

The evaluation results are defined as four grades of A, B, C, and D as shown in Table 1.5.1. Since the evaluation can be influenced by the surrounding conditions of the facility, it is necessary to perform a full review of a time series of the inspection results for each component and conduct an additional advanced analysis, if necessary.

The results of "evaluation" indicate the comprehensive degree of performance degradation of inspected facilities, in other words, a qualitative degree of degradation of the facility performance. They represent an evaluation of the facilities from the technical and engineering viewpoints, which cannot determine if the facility needs repair or other measures. Much more attention must be paid to a necessary comprehensive review based on maintenance level, degree of importance, design service period, future plans, difficulty of implementing the maintenance work, cost and other factors.

Table 1.5.1 Classification of evaluation results

Evaluation	Condition of facility
A	Facility performance has been degraded.
B	Facility performance degradation could occur if left unattended.
C	No deformations related to facility performance were found but continuous observation is necessary.
D	No major deformation was found and sufficient performance is being maintained.

[Appendix] Life-Cycle Cost

The life-cycle cost of the facility is the total costs of each stage of the facility life-cycle, i.e. 1) planning, 2) design, 3) construction, 4) operation, 5) maintenance, 6) demolition and removal of the facility. The life-cycle cost is presented in the following equation:

Life cycle cost = initial cost + operation and maintenance costs + demolition and removal costs

Initial cost: Cost of planning, designing and constructing the facility

Operation and maintenance costs: Costs of operation and maintenance of the facility

Demolition costs: Costs of demolition and removal of the facility:

In some cases, beneficial loss should be incorporated, resulting from the unforeseeable service restriction or suspension of the facility due to poor maintenance.
In general, the life-cycle cost should be evaluated at the planning stage of the facility, so as to minimize the total costs by accumulating the cost at each stage. Since the construction had been completed for the existing facility, however, the maintenance cost should be solely considered for it. Thus, a maintenance program should be formulated so as to minimize the maintenance costs by keeping the facility service benefit fixed, or to maximize the facility service benefit by keeping the maintenance costs fixed in a certain range.
For port and harbor facilities, it is not easy to specifically determine their life-cycle. For instance, breakwater is expected to take a longer period of time to be in service. Conversely, some facilities may terminate their original functions so that their life-cycle to end, for some reasons; deterioration of the facility, up-sizing of the vessels, and progressing way of cargo handling.
Taking those factors into account, the life-cycles of port and harbor facilities are classified into two categories: 1) physical life-cycle (in terms of facility performance) and 2) functional life-cycle (in terms of facility function). When evaluating the life-cycle cost, it is essential to appropriately judge which life-cycle dominates the cost, considering risks of the following uncertainties. The physical life-cycle faces risks of unforeseeable external forces such as earthquakes, and risks to accelerate the deterioration progress of the facility faster than expected. The functional life-cycle faces risks of outdating the original functions due to up-sizing of the vessels and progressing way of the cargo handling. Since the service period may affect the life-cycle cost evaluation, it is quite important to give full consideration to functional life-cycle of the facility as well as physical life-cycle.

1.6 Countermeasure

Necessary countermeasures shall be suitably performed based on the comprehensive evaluation.

[Commentary]

Implementation plans for the maintenance countermeasures including their types and timings are formulated based on the comprehensive evaluation results. The degree of performance recovery and required costs should be evaluated through an investigation of the countermeasure design, considering the facility site constraints.

If the maintenance countermeasures are judged necessary for the facility at present or in the future through the comprehensive evaluation, the maintenance program should be reviewed considering the remaining service period. The alternative countermeasures are generally 1) intensive inspection, 2) repair, 3) strengthening or upgrading, 4) demolition, or 5) replacement of the facility. The alternative countermeasures should be evaluated considering the life-cycle cost, available budget, the social impact and other factors of the facility in addition to the technical judgments.

1.7 Records

All the relevant records relating to the maintenance work shall be stored and maintained according to an prescribed format.

[Commentary]

All the relevant records relating to the maintenance work shall be stored and maintained according to an prescribed format. Systematically organized maintenance information of a facility serves as essential data to appropriately evaluate the remaining functions of the facility and to implement the maintenance countermeasures.
Once a great quantity of maintenance data is accumulated for a single facility, it is recommended to establish an efficient database system and to make the data easily accessible.

Part 2

National Part

Japan

1. OUTLINE OF TARGET STRUCTURE

Table 1.1 Outline of the target structure

Target structure	DK Wharf, Y Port in Tokyo Bay
Structure type	Open-type wharf (steel pipe pile and RC deck)
Management body	Y Port Public Corporation
Length	300 m (1~8 Blocks)
Area	104,926 m^2
Water depth	-12 m
Expected vessel size	35,000 DWT
Completion at	1977
Service start at	1979
Purpose	Specialized berth for automobile export

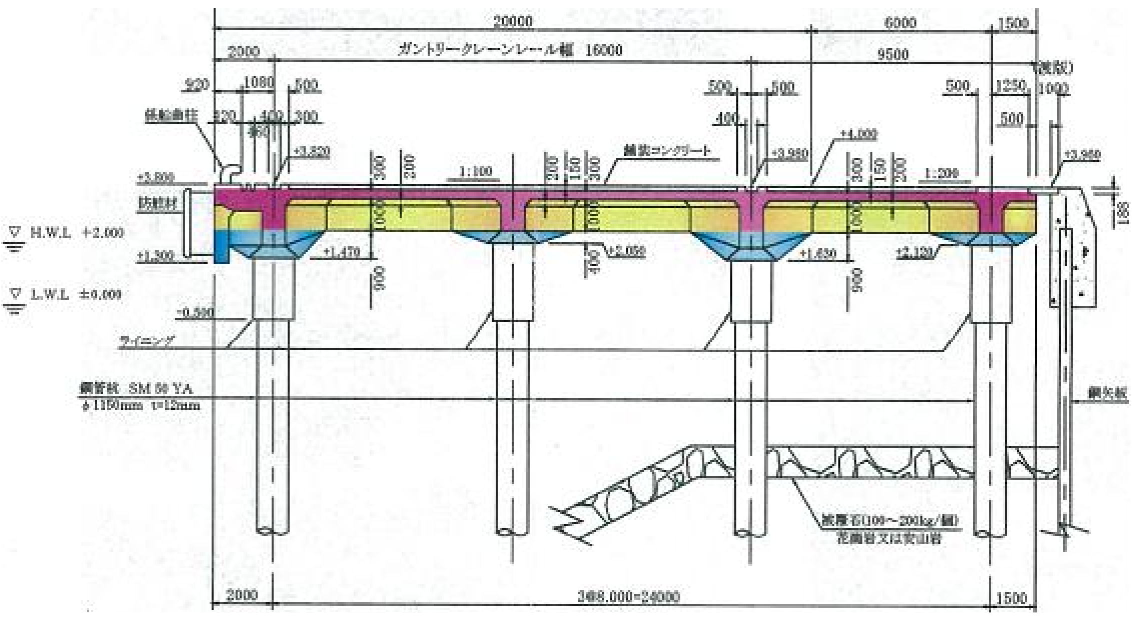


Figure 1.1 Cross-sectional view

2. MAINTENANCE POLICY AND PROCEDURE

2.1 Maintenance strategy

Three kinds of maintenance strategy are listed in Table 2.1.1. The concept of the strategy is how to guarantee the performance beyond the required level of performance and the maintenance limit. Selection of the maintenance strategy as the basic maintenance policy is necessary when formulating a maintenance plan of the target structure. The performance of each component should satisfy their performance requirements over their service life under the selected maintenance level.

Table 2.1.1 Maintenance strategy

Level	Comments
1	No performance degradation should be expected. Deterioration and deformation affecting the performance are allowed within a minor range during the design service period (that is, the performance is always kept above the maintenance limit).
2	Performance degradation should be controlled. Minor countermeasures are repeatedly applied to keep the performance above the maintenance limit.
3	Performance degradation should be expected. Major countermeasures may be applied once or twice to recover the degraded performance.

Table 2.1.2 lists the basic policy of deterioration grades judgment. The grading criteria for each part and component of the structure should be proposed by focusing on visible deterioration and deformation, which affects the performance of the component.

The maintenance strategy and maintenance limit of each component in the target structure were defined by using deterioration grades as shown in Table 2.1.3.

Table 2.1.2 Basic policy of deterioration grades judgment

Grade	Basic policy
a	Performance of component is seriously degraded.
b	Performance of component is degraded.
c	Performance of component is slightly degraded.
d	Performance of component is not degraded.

Table 2.1.3 Maintenance strategy of the target structure

Components	Strategy	M.L.*	Comments
Steel pipe pile	Level 1	Grade d	Any deterioration is not allowed, which largely influences on safety. Long-term unavailability of the service caused by countermeasures or renewal would interfere with port operation.
RC deck Protective coating at piles Cathodic protection at piles	Level 2	Grade c	Short-term unavailability of the service caused by partial repair is allowded. Long-term unavailability of the service caused by the countermeasures or renewal would interfere with port operation.
Ancillary Yard Apron	Level 3	Grade b	-

*M.L.: maintenance limit

2.2 Expected service period

The designed service life of the target structure was originally 50 years (till 2029). However, the target structure was expected to extend its service life to sustain the smooth port operation.

Inspection results in 2001 showed that the service period of steel pipe piles could be extended by the suitable maintenance works of protective coating and cathodic protection.

RC decks were exposed in the severe corrosive environment. However, optimal maintenance works will keep their performance above the maintenance limit, considering the effective period of the repair effect of each repair material

Therefore, the expected service period of the target structure was re-defined as 75 years (till 2054), under the condition that the optimal maintenance works are to be carried out.

2.3 Maintenance procedure

<u>Step 1: Inspection (see Chapter 3)</u>

Visual inspection (deterioration grading)

Measurement of chloride ion concentration in concrete

<u>Step 2: Comprehensive evaluation (see Chapter 4)</u>

Evaluation of inspection results

Deterioration prediction

Comprehensive evaluation

<u>Step 3: Countermeasures (see Chapter 5)</u>

Repair methods and timing

<u>Step 4: Future maintenance plan (see Chapter 6)</u>

3. INSPECTION

3.1 Visual inspection

Visual inspection of RC deck was carried out in January 2008. In the inspection, deterioration grades of a, b, c, d, were judged according to the criteria (Table 3.1.1) for grading RC members of superstructure in open-type wharf from the viewpoint of embedded reinforcing bars' corrosion.

Table 3.1.1 Criteria for grading RC members of superstructure in open-type wharf from the viewpoint of reinforcing bars' corrosion

Grade	Criteria
a	Slab: Map cracking (over 50%) Spalling off of concrete cover Heavy rust stain Beam and haunch: Crack along reinforcement with width of larger than 3 mm Spalling off of concrete cover Heavy rust stain
b	Slab: Map cracking (less than 50%) Much rust stain Beam and haunch: Crack along reinforcement with width of less than 3 mm Much rust stain
c	Slab: One directional crack or gel extraction Partially extended rust stain Beam and haunch: Vertical crack to longitudinal direction Partially extended rust stain
d	Nothing observed

Figure 3.1.1 shows results of deterioration grading of RC deck. Distributions of deterioration grades (Table 3.1.2) showed some signs that deterioration observed in Block Nos. 4 and 6 was comparatively severer than that in other Blocks.

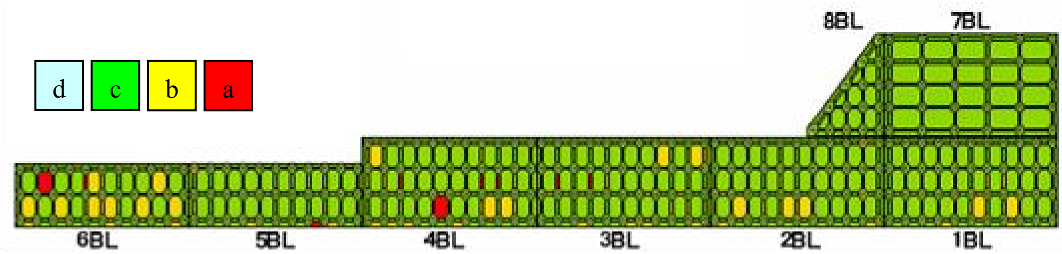


Figure 3.1.1 Results of deterioration grading.

Table 3.1.2 Distributions of deterioration grades of RC deck

Member	BL No.	Deterioration grade			
		d	c	b	a
Slab	1	0 %	93 %	7 %	0 %
	2	0 %	90 %	10 %	0 %
	3	0 %	88 %	12 %	0 %
	4	0 %	87 %	12 %	2 %
	5	0 %	94 %	4 %	2 %
	6	0 %	75 %	23 %	2 %
	7	0 %	100 %	0 %	0 %
	8	0 %	100 %	0 %	0 %
Beam	1	0 %	78 %	22 %	0 %
	2	0 %	86 %	12 %	1 %
	3	0 %	79 %	16 %	4 %
	4	0 %	63 %	30 %	7 %
	5	0 %	87 %	13 %	0 %
	6	0 %	62 %	33 %	6 %
	7	0 %	100 %	0 %	0 %
	8	0 %	100 %	0 %	0 %

3.2 Chloride ion concentration in concrete

Table 3.2.1 lists the measurement results of chloride ion concentration in concrete at the position of steel bar surface, whose cover depth was 50 mm. In the beams at Block Nos. 4 and 6 and in the slabs at Block Nos. 5 and 6, chloride ion concentrations were comparatively higher than those in other Blocks.

Table 3.2.1 Chloride ion concentration in concrete at steel bar

Member	BL No.	ID of RC member	Cl^- concentration at steel bar (kg/m^3)
Slab	1	C17	3.59
	2	E17	2.48
	3	E15	1.40
	4	G15	0.74
	5	C17	6.39
	6	C17	5.87
	7	E7	0.28
	8	C17	3.59
Beam	1	D17	5.13
	2	E18	1.04
	3	E14	1.27
	4	F15	8.14
	5	C18	1.29
	6	D17	11.48
	7	D7	0.18
	8	D17	5.13

4. COMPREHENSIVE EVALUATION

4.1 Evaluation of inspection results

Table 4.1.1 lists the evaluation of inspection results. The representative deterioration grades were judged by the following procedure;

1. The following evaluation points were set to each deterioration grade;
   grade d = 100, grade c = 99, grade b = 95, grade a = 80,
   and grade *aa* = 0 (the last and worst condition. Specially set for point calculation.)
2. Average of evaluation points in each block was calculated.
3. Representative deterioration grades were derived by the average evaluation points as follows;
   Grade D : ave. point was 95 - 100, Grade C : ave. point was 95-80,
   Grade B : ave .point was 80-60, Grade A : ave .point was under 60,

Initiation of reinforcing steel bar's corrosion was judged by the chloride ion concentration in concrete at the surface of reinforcing steel bar. In this case, the threshold chloride ion concentration for corrosion initiation was set as 2.0 kg/m^3.

Table 4.1.1 Evaluation of inspection results

BL No.	Representative deterioration grade		Corrosion of reinforcing steel bar O; corrosion starts, X; not yet	
	Slab	Beam	Slab	Beam
1	D	D	O	O
2	D	D	O	X
3	D	D	X	X
4	D	D	X	O
5	D	D	O	X
6	D	D	O	O
7	D	D	X	X
8	D	D	O	O

4.2 Deterioration prediction

Two types of deterioration prediction were carried out; 1) Deterioration prediction based on Markovian chain model and 2) Prediction of chloride ion penetration in concrete. The purpose of deterioration prediction of the former type was to evaluate the progress of deterioration of RC deck for each Block as a whole. That of the latter type was to select the repair methods and timing of each RC member. The selection of repair methods and timing were discussed in detail in Chapter 5.

Table 4.2.1 Results of deterioration prediction based on Markovian chain model

Member	Block No.	Representative deterioration grade (Year)			
		D	C	B	A
Slab	1	- 2018	2019 – 2038	2039 – 2052	2053 -
	2	- 2017	2018 – 2036	2037 – 2050	2051 -
	3	- 2017	2018 – 2036	2037 – 2050	2051 -
	4	- 2017	2018 – 2036	2037 – 2050	2051 -
	5	- 2018	2019 – 2040	2039 – 2052	2053 -
	6	- 2015	2016 – 2033	2034 – 2046	2047 -
	7	- 2019	2020 – 2039	2040 – 2054	2055 -
	8	- 2019	2020 – 2039	2040 – 2054	2055 -
Beam	1	- 2018	2019 – 2033	2034 – 2046	2047 -
	2	- 2017	2018 – 2036	2037 – 2050	2051 -
	3	- 2017	2019 – 2034	2035 – 2049	2048 -
	4	- 2017	2018 – 2028	2029 – 2040	2041 -
	5	- 2018	2019 – 2036	2037 – 2050	2051 -
	6	- 2015	2016 – 2027	2028 – 2039	2040 -
	7	- 2019	2020 – 2039	2040 – 2054	2055 -
	8	- 2019	2020 – 2039	2040 – 2054	2055 -

4.3 Comprehensive evaluation

The repair works to RC decks of Block Nos. 5 and 6 were scheduled to be executed in 2008 taking into account of the comparatively progressed deterioration.

The repair works for Block Nos. 1, 2, 3 and 4 were scheduled to be executed in 2009. In Block Nos. 7 and 8, signs of deterioration had not been observed, though the chloride ion concentration in Block No. 8 had already reached the corrosion threshold value. Therefore, repair works for those two blocks were scheduled to be carried out in the near future.

5. COUNTERMEASURE

5.1 Basic policy of repair works

Repair to RC decks in Block Nos. 1, 2, 3 and 4 of the target structure was carried out in 2009.

Selection of the repair method and area in each member was dependent on the deterioration grade, chloride ion concentration at the surface of steel bar, and the scale of deteriorated parts. The selection flow of repair works was shown in Figure 5.1.1.

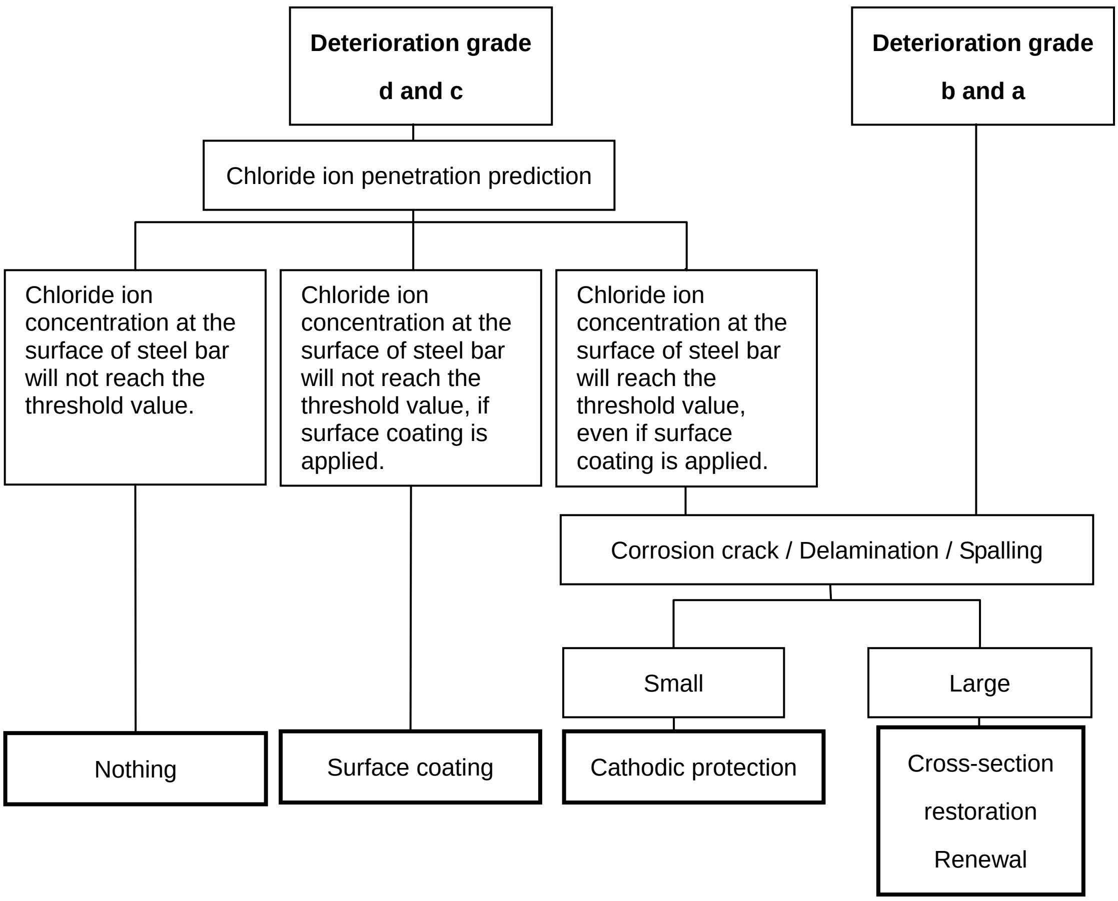


Figure 5.1.1 Selection flow of repair works

Repair works for the target structure were especially executed according to the basic policy as shown below;

1. When cross-section restoration is applied as the remedial measure, concrete shall be removed to a depth behind the reinforcing steel bars.
2. When the cross-sectional loss of a reinforcing steel bar is more than 10 %, the bar shall be reinforced by an additional steel bar.

3. The cover depth of reinforcing bars at the repaired part shall be more than 70 mm.
4. The most appropriate cross-section restoration method shall be applied to the RC deck in consideration of the work efficiency, which depends on the restoration area, volume, and working environments etc. In general, cross-section restorations by mortar spraying and mortar grouting are recommended to be applied to slabs and beams respectively.
5. Surface coating shall be applied to all the bottom surface of the RC deck.

5.2 Outline of repair works

Table 5.2.1 lists the amount and area of each repair work applied to the RC deck. Picture 5.2.1 shows the views of repair works.

Table 5.2.1 Amount and area of each repair work

Method	Item	Depth (mm)	unit	Block No.				Total
				1	2	3	4	
Coss-section restoration by mortar	Grouting	100~150	m^2	110.50	95.65	127.77	146.33	480.25
		30~50	m^2	0.92	0.00	0.00	0.00	0.92
	Spraying	100~150	m^2	140.29	127.37	79.01	119.25	465.92
		30~50	m^2	0.00	0.00	0.00	0.00	0.00
	Plastering*	100~150	m^2	10.47	22.69	13.81	15.04	62.01
		30~50	m^2	0.00	0.00	0.84	0.33	1.17
		~30	m^2	14.05	24.33	21.17	17.54	77.09
Crack injection	Epoxy	-	m	123.45	172.00	38.45	95.67	429.57
	U-cut	-	m	0.90	2.55	10.70	0.00	14.15
	V-cut	-	m	53.50	176.10	39.85	21.48	290.93
Surface coating	For splashed	-	m^2	482.85	482.85	486.53	493.16	1945.39
	Normal	-	m^2	1746.10	1744.13	1744.40	1743.28	6977.91

* Mortar plastering was applied when the area of a repaired part was less than $0.25m^2$.

Setting of scaffold

Removing cover concrete

Mortar grouting

Mortar spraying

Crack injection

Surface coating

Completion

Picture 5.2.1 Views of repair works

6. FUTURE MAINTENANCE PLAN

6.1 Inspection

Table 6.1.1 lists the schedule of the routine and visual inspection for each component of the target structure. In the routine inspection, the surface appearance of components shall be checked. In the periodical visual inspection, deterioration grading of each component shall be executed for the comprehensive evaluation of the target structure. Detailed inspection shall be conducted based on the results of visual inspection and so on.

Table 6.1.1 Inspection schedule

Component	Routine inspection	Periodical visual inspection
RC deck	-	Every 5~10 years
Steel pipe pile	-	Every 5~10 years
Protective coating	-	Every 5~10 years
Cathodic protection	-	Every 5~10 years
Auxiliary equipments	Every 1 month	Every 1 year
Apron	Every 1 month	Every 1 year
Basins	Every 1 month	Every 1 year

6.2 Comprehensive evaluation

Comprehensive evaluation shall be made through the inspection and prediction results to determine maintenance countermeasures, by taking into account the remaining facility performance, capability to satisfy the performance requirements over the remaining service period, the facility use plan, and the importance of the facility etc.

6.3 Countermeasures

Countermeasures for each structural component shall be planned based on the results of inspections and deterioration predictions. Methods and timing of countermeasures shall be planned based on the Table 6.3.1 and Figure 5.1.1, considering the life-cycle cost, service and management conditions, etc.

Table 6.3.2 lists the effective periods of repair methods for durability enhancement of RC components. Repaired RC components are recommended to re-repair or to apply some remedial measure before reaching the end of the effective period.

Based on the results of predictions and effective periods of each repair method, future repair works of the target structure will be scheduled as shown in Table 6.3.3.

Table 6.3.1 Timing and policy of repair methods for RC components

Timing (Deterioration grade)	Repair policy	Repair methods
d	Suppression of corrosion factors supply Removal of deteriorated parts	Surface coating Cross-section restoration Cathodic protection
c		
b	Removal of deteriorated parts Suppression of corrosion progress Improvement of load-bearing capacity	Cross-section restoration Cathodic protection FRP adhesion Renewal
a		

Table 6.3.2 Effective periods of repair methods for durability enhancement of RC components

Repair methods	Re-repair work	Expected effective periods
Crack injection	Impossible	-
Surface coating	Scheduled	15 years
Cross-section restoration	Un-scheduled	To the end of designed service life
Cathodic protection	Scheduled	20 years
FRP adhesion	Scheduled	30 years

Table 6.3.3 Schedule of repair works in the future

Timing	Action
2009	Present (repair works with cross-section restoration and surface coating)
2014	Repair of surface coating, cross-section restoration of re-deteriorated parts (if necessary)
2024	2nd repair of surface coating, cross-section restoration of re-deteriorated parts (if necessary)
2039	3rd repair of surface coating, cross-section restoration of re-deteriorated parts (if necessary)
2054	End of expected service period

Cambodia

1. OUTLINE OF TARGET STRUCTURE

Table 1.1 Outline of the target structure

Target structure	A Jetty called Oil Port
Structure type	Open-type (concrete pile and RC deck)
Management body	Sihanoukville Autonomous Port
Length	Total 53 m
Width	6 m with access 11m from the main walkway and 182m from Shore.
Water depth	- 4.2 m
Expected vessel size	1200-1500DWT
Completion at	1976 (assumed)
Service start at	1977
Purpose	Discharge Fuel and Gas to Storage Tanks.

Concrete Deck with a dimension of 53m in length and 6m wide and 0.15 m thick, divided into 8 spans of 6.5 m each.

Supported by transversal concrete beams having a cross section of 0.9 m x 1.10 m. Those concrete beams are supported by concrete piles (vertical at the front side and racked at the rear side).

Two operation rooms including discharging facilities.

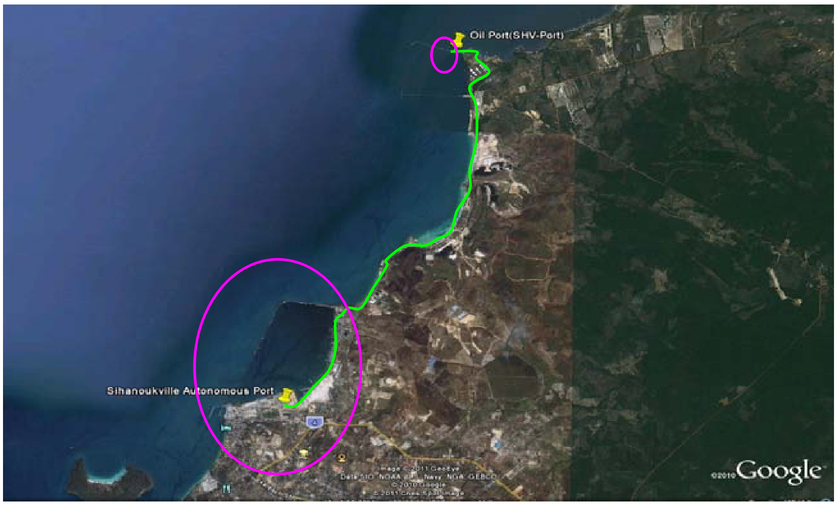


Figure 1.1 Location map

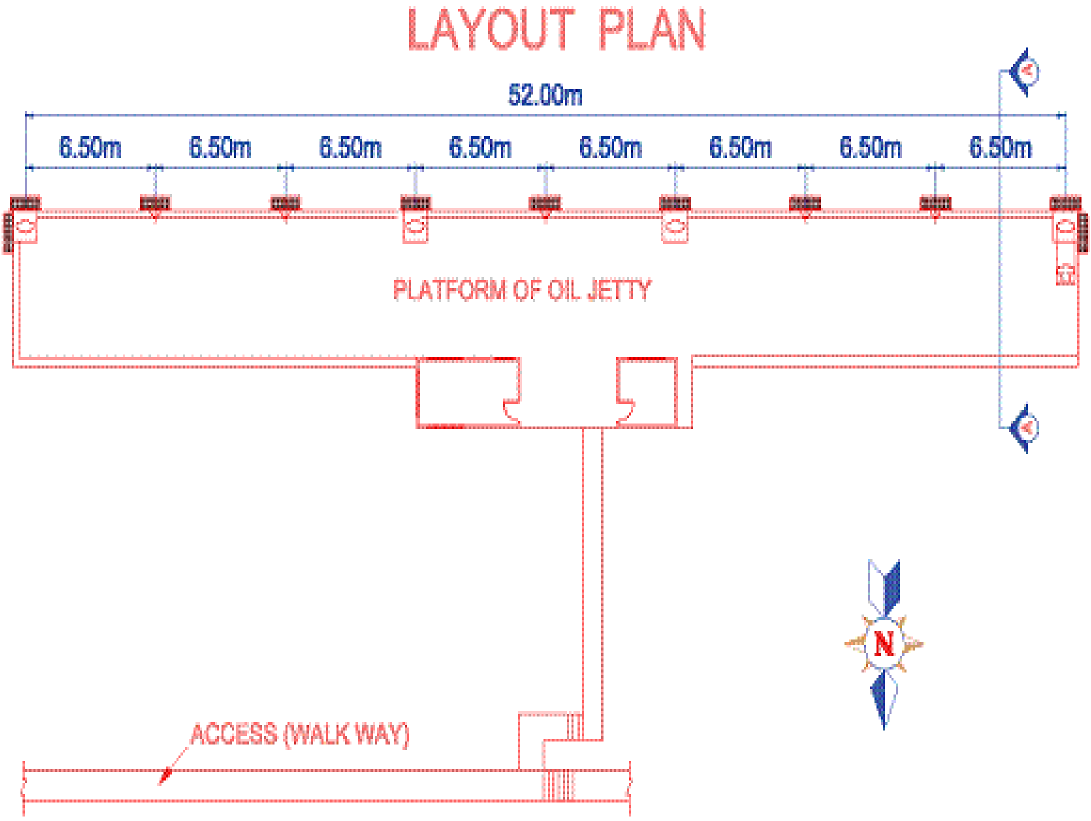


Figure 1.2 Layout plan

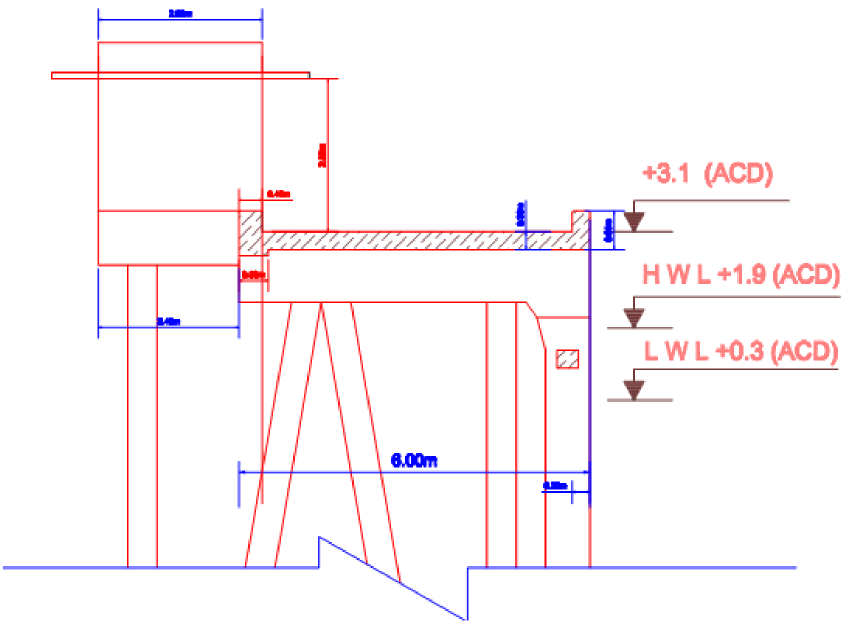


Figure 1.3 Cross-sectional view

Picture 1.1 Views of target structure

2. MAINTENANCE POLICY AND PROCEDURE

2.1 Maintenance policy

- ✓ Extension of the Structure working life as long as possible. Keeping the Jetty's performance beyond the required performance limit.
- ✓ Try to avoid costly corrective maintenance by carry out periodic inspection, focusing on visible deterioration and deformation of every component.
- ✓ Set priority of maintenance work for the jetty's component based on judgment of deterioration grades.

2.2 Maintenance procedure

<u>Step 1: Inspection (see Chapter 3)</u>

Visual inspection (deterioration grading)

<u>Step 2: Evaluation (see Chapter 4)</u>

Evaluation of inspection results

<u>Step 3: Countermeasures (see Chapter 5)</u>

Repair methods and timing

<u>Step 4: Future maintenance plan (see Chapter 6)</u>

3. INSPECTION

Visual inspection of the structure’s component (esp. RC deck and beams) are carried out in June 2009. Table 3.1.1 lists the classification of deterioration grades. All forms of damage are judged according to the deterioration grades(I-IV).The criteria for grading all RC component has been selected same as for the open-type wharf with consideration of corrosion of embedded reinforcing steel bars(see Table3.1.2 below).

Table 3.1.1 Classification of deterioration grades judgment

Grade	Basic policy
I	Performance of component is not degraded.
II	Performance of component is slightly degraded.
III	Performance of component is degraded.
IV	Performance of component is seriously degraded.

<Example of deterioration grade II~IV>

- ✓ Deterioration grade II

Longitudinal Crack appears on the RC beam.

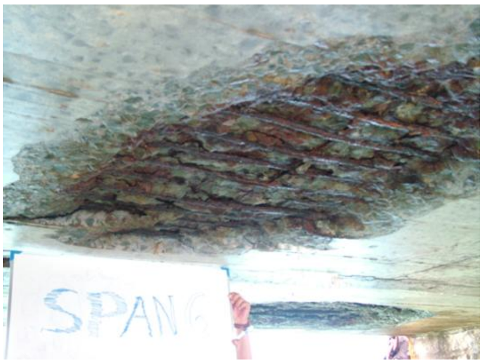
Transversal Cracks appear on RC Deck . Epoxy injection and Mortar grouting would be most likely used.

✓ Deterioration grade III

Much rust stain on edge and middle of RC beam.
Partial spalling off of concrete cover was observed.

Much rust stain and likely to be extended.
Part of the concrete section was spalled off.

✓ Deterioration grade IV



Embedded reinforced steel bars are corroded, expanded and the spalling off of the concrete cover.
Steel bars section is reduced and most are broken.

Some section of concrete beam are lost.
Corroded and broken steel bars weakens the structure component.

Table 3.1.2 Criteria for grading RC components of open-type wharf from the viewpoint of corrosion of RC steel bars (applied also for Oil Jetty)

Grade	Criteria
I	Nothing observed
II	Slab: One directional crack or gel extraction Partially extended rust stain Beam and haunch: Vertical crack to longitudinal direction Partially extended rust stain
III	Slab: Map cracking (less than 50%) Much rust stain Beam and haunch: Crack along reinforcement with less than 3mm wide Much rust stain
IV	Slab: Map cracking (over 50%) Spalling off of concrete cover Heavy rust stain Beam and haunch: Crack along reinforcement with larger than 3mm wide Spalling off of concrete cover Heavy rust stain

4. EVALUATION

Table 4.1.1 Evaluation of Inspection result

Span	Deterioration Grade	
	Slab	Beam
1	III	III
2	III	IV
3	II	II
4	II	II
5	II	II
6	IV	III
7	III	III
8	III	III

The above listed result has been roughly evaluated according to the criteria in Tab.3.1.1. There shows more or less evident of some deterioration at all components at every span. The repair works have been carried out in 2005 at spans 3,4,5 , therefore it is clearly indicated that the deterioration grade at those spans is less serious than the others.

In the future we might apply the evaluation method by giving points to each component of every span and calculate the average points for setting the deterioration grades accordingly (Japanese Example).

Furthermore, for deterioration prediction we would also consider to carry out inspection of chloride ion penetration in the concrete elements in order to determine the time schedule and to select the repair methods.

5. COUNTERMEASURE

Repair to RC decks and Beams in spans 3,4,5 were carried out in 2005.

The selection of the repair method was dependent on the deterioration grade resulting from visual inspection and by comparing with the criteria described in above Table 3.1.2.

Following methods were adopted for the past repair works:

- ✓ Repair works of target Facility was executed at the middle Spans (3, 4,

5) by means Epoxy injection into small Cracks on Deck and Supported beams(Cracks is less than 3mm wide).

- ✓ Epoxy Mortar or SIKA Grout have been used where the concrete section of the component was delaminated or about to spall off, after removal of the damage concrete and cleaning the steel bars and concrete surface.
- ✓ Where as the concrete element are serious degraded (grade IV), damaged concrete and corroded steel bars shall be removed, additional steel bars shall be replaced followed by in situ concrete or special mortar grout (restoration of cross-section).
- ✓ New Fender system shall be replaced.

The selection procedure of future repair works is shown in Figure 5.1.1:

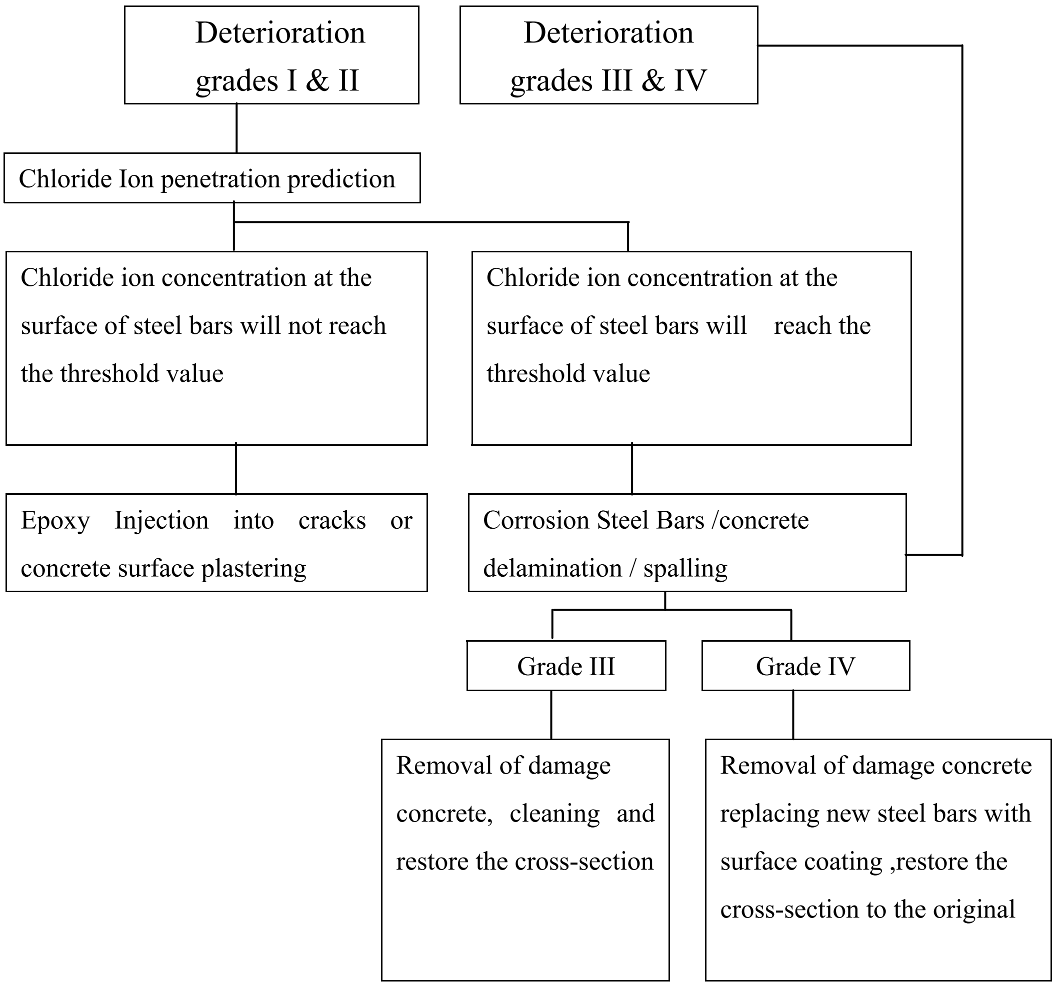


Figure 5.1.1 Selection procedure of future repair works

6. FUTURE MAINTENANCE PLAN

6.1 Inspection

- ✓ Taking into consideration not having much obstruction to the serviceability of the target facility, routine and visual inspection shall be conducted and selected appropriated repair method.
- ✓ Further detailed inspection of all component of the target structure shall be carried out depend on the result of visual inspection, evaluated and setting priority including budget estimation for repair works.
- ✓ Unscheduled Inspection has been also planned especially in emergency cases.
- ✓ Close monitoring for effective repair method and materials used shall be conducted to guarantee a long life span of the jetty.

Table 6.1.1 Inspection schedule

Component	Routine Inspection	Periodical visual Inspection
RC deck	-	Every 5 years
RC Supported Beams	-	Every 5 years
RC Concrete Piles	-	Every 5-10 years
Others Element &Facilities	Every 1 months	Every 1 year

6.2 Assessment

- ✓ To archive the expected goal, Extension of the Structure working life as long as possible and Keeping the Jetty's performance beyond the required performance limit , we need to carry out further detailed assessment through the inspection and prediction results in order to determine maintenance methods and choose the right time at the right place.
- ✓ Judgment in case of emergency should be executed when and where is necessary.

6.3 Countermeasures

Taking into consideration of all the results from inspection and deterioration prediction, countermeasures for each component of the target structure should be planned in regard of method, materials applied and timing .The repair works would have continued from 2011.

Following Tables provide those planned based methods and timing, including expected effective of repair works and schedule of future repair in the prospective of having this oil jetty operated in 20 years time.

Table 6.3.1 Timing policy of repair methods for RC elements

<table>
<tr><th>Timing
(deterioration Grade)</th><th>Repair policy</th><th>Repair methods</th></tr>
<tr><td>I</td><td rowspan="2">Suppression of corrosion factors supply
Removal of deteriorated parts</td><td rowspan="2">Epoxy Injection
Plastering with epoxy based Mortar</td></tr>
<tr><td>II</td></tr>
<tr><td>III</td><td rowspan="2">Removal of deteriorated parts
Suppression of corrosion progress
Restore as much as possible the original load-bearing-capacity of each RC component</td><td rowspan="2">Replace steel bars
Cross-section restoration</td></tr>
<tr><td>IV</td></tr>
</table>

Table 6.3.2 Expected effective of repair methods for durability enhancement of RC elements

Repair methods	Re-repair work	Expected effective period
Cracks Injection	impossible	-
Cross section Restoration	Not scheduled	To the end of service life

Table 6.3.3 Schedule of the future Repair works

Timing	Action
2011	Cracks injection , Surface plastering and cross-section restoration for every 5 years
2016	Cracks injection , Surface plastering and cross-section restoration for every 5 years
2021	Cracks injection , Surface plastering and cross-section restoration for every 5 years
2026	Cracks injection , Surface plastering and cross-section restoration for every 5 years
2031	Cracks injection , Surface plastering and cross-section restoration for every 5 years

Indonesia

1. OUTLINE OF TARGET STRUCTURE

Table 1.1: Outline of the target structure

Target Structure	The Waren Port facility, Papua Province (Indonesia)
Structure type	Open wharf (steel pipe pile and RC deck)
Management body	Port officer of Waren (government)
Length	Trestle (50 x 6) m^2, wharf (70 x 10) m^2
Water depth	-12 m LWS
Expected vessel	Actually < 1000 DWT
Completion at	1996
Service start	1997
Purpose	Local wharf (connecting people and goods to/from Serui Port)

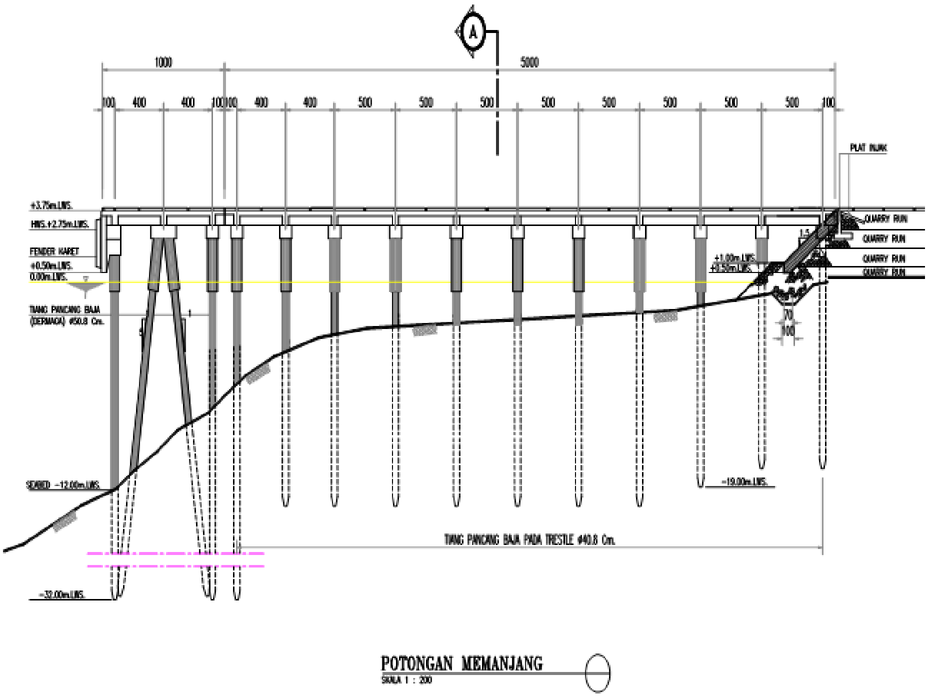


Figure 1.1 Cross sectional view

Common condition of Waren Port Facility:

The Waren Port is located in the province of Papua, that serves and accommodate all goods and people needs in 4 district. Road conditions have not developed well and are not available airport. That condition made sea transportation becomes vital transportation to be used to in/out of people and goods from and to Waren.

Until now, the Waren port as a port to serving the community flows from/to Serui because the ship will carry out goods and passengers in Serui, so goods and passengers will loaded and unloaded in Serui, continued to port around of Serui with little ship/ boat.

By an earthquake on June 16, 2010 with the strength SR 7.1 that occurred in Islands District Yapen cause port facilities (Serui and Waren port facility) were damaged. Even the Serui port cannot be repaired because the stake completely broken / cracked so it was decided to build a new pier (use concrete pile).

Damage at Pier Waren are, the discovery of concrete cover, causing the steel reinforcement in the floor and trestle bottom deck open and suffered corrosion. Necessary treatments to repair the damage are needed, so that construction can comply the safety aspects for ships and users.

Figure 1.2 Distribution of goods and passengers

Picture 1.1 Condition of bottom deck on wharf and trestle (the Waren port)

Picture 1.2 Condition of beam on Waren port

Picture 1.3 Condition of concrete pile on Serui port

Picture 1.4 Operational on Serui Port

2. MAINTENANCE POLICY AND PROCEDURE

2.1 Maintenance strategy

Treatment strategies accordance with the guidelines from the previous PTG meeting on Philippine and Cambodia is a good standard and we agree to adopt the standard to anticipate the damage port facilities in Indonesia.

Because of limited budgets and time, it is deemed necessary to conduct direct action to prevent damage of port facilities are more severe and even feared to endanger public safety.

Table 2.1.1 Maintenance strategy

Level	Comments
1	Heavy damage on port facilities. Action: It should be immediately repaired/rehabilitation (time limit to action 1 year of inspections/reports of damage)
2	Minor damage on port facilities. Action: It should be immediately repaired/rehabilitated (scheduled as the location that need to do repairs with priority from the locations of port facilities which were damaged)
3	Potential damage in case of natural disaster/outbreak because the age of the port facility has more than 20 years. Action: require periodic review to ensure structure strength

Table 2.1.2 Maintenance strategy of the target structure

Components	Level	Comment
Steel pipe pile	2	Types of damage: a. concrete cover cracked / missing; b. single pieces of steel piling at the end of the pier is lost; c. corrosion in the splash zone area is getting worse.
Pile cap	2	Type of damage: a. some concrete cover is lost;
Beam	2	Type of damage : Some concrete cover is lost; a. Steel bar D22, visible and corrosion.
Slab	1	Type of damage : a. Slab (bottom), most of the concrete cover is lost; b. Slab reinforcement corrosion is very severe. partial reinforcement has been broken and hanging;

2.2 Method implemented

The designed service life of the target structure was originally 30 years (until 2027), but due the earthquake, that facility predicted have service life will be reduced from the age of the plan.

Wharf and trestle will be repair, but to ensure the safety of service users, the new pier will be built alongside the existing dock to accommodate vessels more 500 DWT, while the existing pier will be used to serve ships with a smaller size.

The decision consideration that the cost required to restore port facility existing dock to original capabilities are expensive. In addition, the current dock size (70 x 10) m2 require the addition of long considering the number of ships that use this dock to accommodate progress and hinterland areas that rely on marine transportation.

2.3 Maintenance procedure

Indonesia will try to adopt maintenance procedure from Japan (PTG team) and will be adjusted at conditions in Indonesia, because of different condition and technical situation. Indonesia until now doesn’t have a standard treatment of port facilities, so plan to taken various policies from other countries (especially Asian countries) that have proved successful in maintaining the age/power structure in accordance with the design life.

This will be our task to construct port facilities maintenance procedures so that the future will be obtained standard treatment of port facilities in Indonesia

3. INSPECTION

Site visits were conducted on June 28, 2010 for review directly and facts finding condition of Waren Port facilities after earthquake. A review of the above, still show a good condition slab. There were no cracks or damage that are visually harmful construction. Operational on wharf is still used because there was no sign of damage from the side of the wharf in common. This happens also on the trestle. Obviously, the conditions will be described in the following table:

Sections check	Field conditions	Note
Upper slab of wharf		Upper slab is not find/ visible suffered cracks/damage endangering operational. Operations are carried out as usual
Upper slab of trestle		Upper slab is not find/ visible suffered cracks/damage endangering operational. Operations are carried out as usual
Below slab of wharf		a. Most concrete jacket lost; b. Reinforcement visible fracture, corrosion has occurred in a long time; c. Damage to facilities have occurred before the earthquake; d. Another reinforcement is open by an earthquake that could potentially corrosion.
Pile cap and beam	 	a. Most concrete jacket beams cracked or missing; b. Pile cap no visible damage; c. Beam and Pile cap corroded (sea water seeping into the concrete)/concrete jacket not effective.
Steel pipe pile	 	a. Pile does not look experienced a shift. Only one pole at the end of the pier is lost; b. Necessary improvements to the protective piling in the splash zone area; c. Visually, the stake is still able to work to hold the load plan.

4. ASSESSMENT

Section check	Result	Assessment
Upper slab of wharf	No damage occurs	Required periodic review to monitor the condition to the future.
Below slab of wharf	Severely damaged	Need repairs immediately.
Pile cap and beam	Most concrete jacket lost and corrosion indicate happen inside concrete (concrete jacket not effective)	Need repairs immediately to avoid corrosion
Steel pipe pile	Still accommodate operational load and need repair concrete jacket on splash zone area.	Need repairs on splash zone area.

5. COUNTERMEASURE

a. Below slab of wharf

Necessary replacement of reinforcement and concrete cover (corrosion protection) with 8 cm thick min.

Maintenance action:

1) Cleaning reinforcement that has been broken / severe corrosion;
2) Change the connection reinforced with new bar. The connection is achieved by over-cuttings, and if not possible was done by welding. Welding done as a last alternative;
3) The use of additional reinforcement (wire mesh) to ensure the main reinforcement bonded perfectly. In addition to the new place concrete terms;
4) Implementation of concrete section;
5) Implementation of coatings for protection corrosion;

Policy after repair:

Will be applied the restrictions area on the existing wharf as the results in

improvements because the ability of service slab after maintenance is less than the load plan.
Note: For slab that not corroded will maintenance with making 8 cm-thick concrete cover.

b. Pile cap and beam

Cracks occur only happen on concrete cover on the bottom of the beam. Need the necessary replacement of concrete cover.

Maintenance action:
1) Clean the part that cracked/missing;
2) To re-casting;
3) Perform construction coating for protection from corrosion.
Note: Coating will be conducted on the entire bottom of the pier to remember the greatest damage occurred in the concrete cover.

c. Steel pipe pile

Need to identify more damage on each pipe pile to obtain the physical condition of piles in the field. Reinforcement is required at the pole which was damaged but the addition of the pole will not be made because of difficulties in implementation. Improvements made of steel sheet piling with clean concrete cover and do coating for corrosion protection.

From the discussions held after the presentation at the PTG 8th, take the following steps:
- Construction damage should not be operated until repaired construction.
- Due to a difficult location to reach, the method used should be made with precast method.
- Indonesia will try to adopt maintenance procedure from Japan (PTG team) and will be adjusted at conditions in Indonesia, due to the frequent disasters of Indonesia, such as earthquakes.

Malaysia

1. INTRODUCTION

1.1 General

KUANTAN PORT is situated at Tanjung Gelang on the eastern seaboard of Peninsular Malaysia between latitude 03^o 58' N, longitude 103^o 26.4' E, some 25 kilometres north of Kuantan, the state capital of Pahang.

Connected to the major sea lanes of the shipping world, Kuantan Port serves primarily the Pacific Rim, the Middle East, the Far East, Europe and Asean region. Sailing time from Kuantan Port to Singapore and Hong Kong takes 18 and 60 hours respectively. Sailing time to other destinations are 4 days to Tokyo, to the Middle East 7 days, Europe 23 days, the Mediterranean and the west coast of USA approximately 15 and 18 days respectively.

Kuantan Port is also well-connected by road and rail to other parts of Peninsular Malaysia and by air to major world destinations via Kuala Lumpur. Located approximately 220 kilometres away from Kuala Lumpur, Kuantan Port is about 3 hours by road or 40 minutes by air from Kuala Lumpur. Kuantan Airport is 12 kilometres to Kuantan town and approximately 38 kilometres to the Port. Public taxis are available at Kuantan Airport. As a result of this project, the target facility in Kuantan Port was repaired and protected from further deterioration.

In view of the fact that it is not possible to completely stop a wharf from deterioration, hence regular maintenance indispensable, a strategic maintenance guide is prepared for the use of the Kuantan Pot Authority, the management body of the port.

This Guide is divided into five chapters. Chapter 1 gives a brief introduction to the Guide. Chapter 2 is on the total concept of wharf management. It highlights the importance of planning and organizing the maintenance works. Chapter 3 explains and discusses common sources of problems. Understanding of the nature of these problems helps the reader to better appreciate the maintenance operations discussed in Chapter 4. Concluding remarks are presented in Chapter 5.

1.2 Brief descriptions of the wharf in Kuantan Port

The location of the Kuantan Port is shown in Figure 1.1. The plan layout of the wharf is shown in Figure 1.2.

Figure 1.1 : Location Plan of Kuantan Port (circled in red).

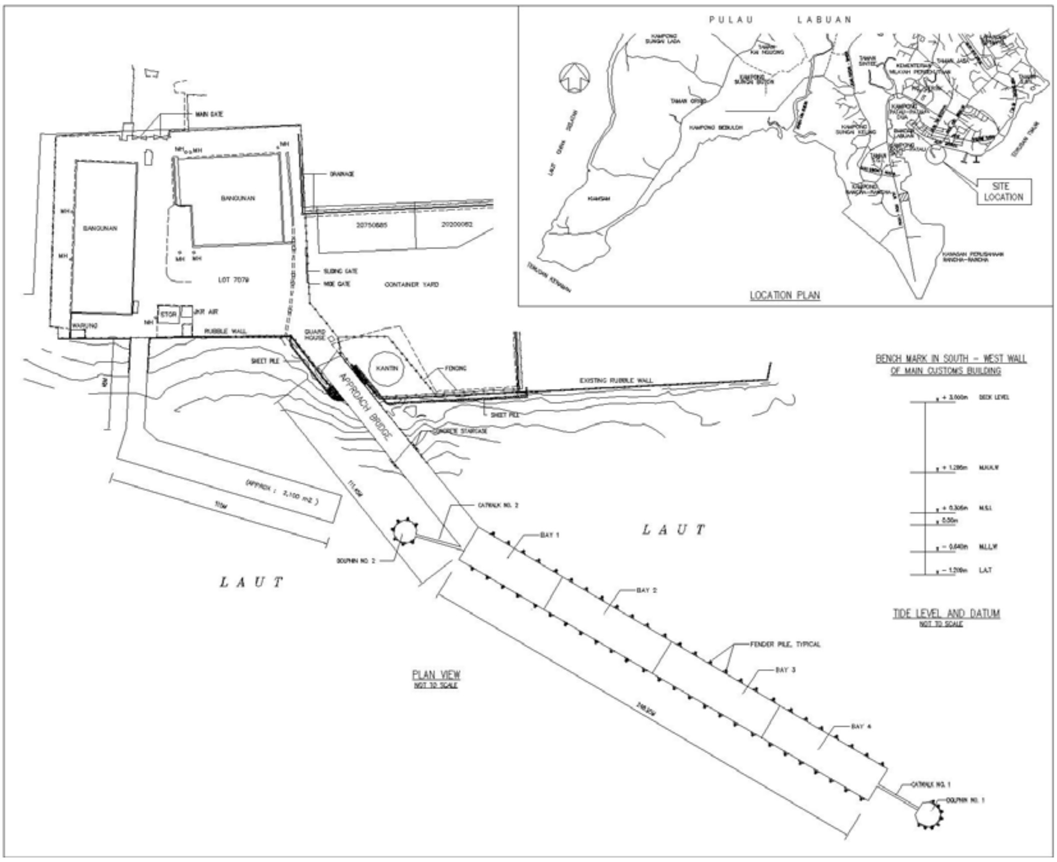


Figure 1.2 : Plan Layout for Kuantan Port Wharf

Kuantan Port Wharf

The Kuantan Port Wharf comprises a frame structure comprising of concrete slab supported by steel beam and girders, measuring an approximate length of 300m. In 2000, a project was undertaken by Kuantan Port Authority to repair the wharf, which includes the following scope of works:

- Supply and installation of the new fender pile system
- Structural steel repair and painting works
- Structural concrete repair and painting works
- Construction of new concrete staircase at approach jetty
- Construction of seawall
- Construction of revetment under existing approach jetty
- Repair and resurfacing of existing hardstanding at container yard
- Erection of new fencing and gate
- Construction of drainage system at container yard
- Demolition works to existing steel staircase at approach jetty, existing drainage system, fencing and old Kuantan Port Wharf
- Repair of existing light posts at wharf

Due to severe corrosive environment and the wear and tear as a result of ship berthing alongside the wharf, by 2004 there were already signs of corrosion and damages in the wharf components, some of which were repaired or newly installed in 2000. Some of the damages are shown in Plate 1.1 to Plate 1.7.

Plate 1.1 : Corrosion of steel beams

Plate 1.2 : Longitudinal & transverse cracks (red lines drawn alongside the cracks to highlight them)

Plate 1.3 : Substantial corrosion of steel piles

Plate 1.4 : Deformed rubber and corrosion of the fenders

Plate 1.5 : Severe corrosion of bolts, nuts and base plates of bollards

Plate 1.6 : Damaged joint leaving a gap and leakage

Plate 1.7 : Severe spalling of concrete with exposed reinforcement bar

The repair works carried out in 2008 include:

- Supply and installation of the new fender pile system (Plate 1.8 and Plate 1.9),
- Structural steel repair and painting works (Plate 1.10 and Plate 1.11),
- Sealing of cracks at deck slab by epoxy injection (Plate 1.12 and Plate 1.13),
- Structural concrete repair and painting works (Plate 1.14 and Plate 1.15),
- Installation of cathodic protection to fender piles (Plate 1.16),
- Revetment of damaged slope protection (Plate 1.17 and Plate 1.18)

Plate 1.8 : Installation of new rubber fender to replace the deformed fender.

Plate 1.9 : Completed installation of new rubber fender and coating of fender pile.

Plate 1.10 : Repaired and painted corroded steel beams and pile caps with protective coating system.

Plate 1.11 : Repaired corroded steel bollard and applied with protective coating.

Plate 1.12 : Installation of injection ports in preparation for epoxy injection.

Plate 1.13 : Sealed cracks after injection with epoxy resin.

Plate 1.14 : Removal of defective concrete prior to repair.

Plate 1.15 : Completed repair of defective/spalled concrete

Plate 1.16 : Sacrificial anodes for installation of cathodic protection system to fender piles.

Plate 1.18 : Completed revetment of damaged slope protection

Plate 1.17 : Work for revetment of damaged slope protection.

1.3 Scope

This Guide has been prepared specifically for Kuantan Port Wharf hence use of the Guide for other wharfs in Malaysia require caution as they may be different, not only in terms of construction but also the usage.

2. OVERALL WHARF MANAGEMENT CONCEPT AND WHARF INSPECTION

2.1 General

A man-made structure invariably begins to deteriorate the moment it is created and put into service. To extend the life of a wharf thus requires that it is regularly maintained.

Maintenance can be carried out regularly at a fixed interval or as and when damage is observed. The latter case often involves minor repair and as such maintenance and repair (m&r) is sometimes used as a synonym to the term maintenance.

It is important to note that maintenance is but one of the many activities in good management practice, which include inspection, inventory, maintenance & repair, rehabilitation and replacement. A proper set up of a wharf management system is prerequisite to the successful implementation of the maintenance.

2.2 Set-up for wharf management

First and foremost, a wharf management team must be set up. A proposed organisational set-up is depicted in Figure 2.1. Next, a systematic work flow in the management of the wharf should be set up. The procedure of wharf management involving a number of wharf management activities and various individuals/parties is depicted in the flow chart in Figure 2.2.1.

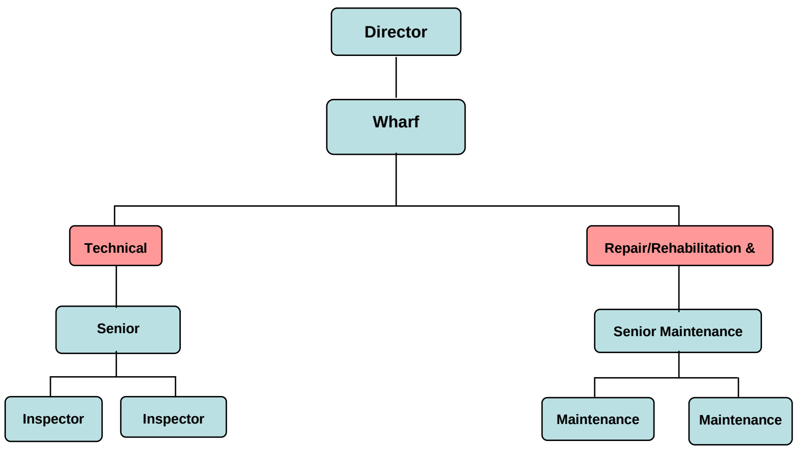


Figure 2.2.1 : Organisational Setup for Wharf Management (the Wharf Management Team)

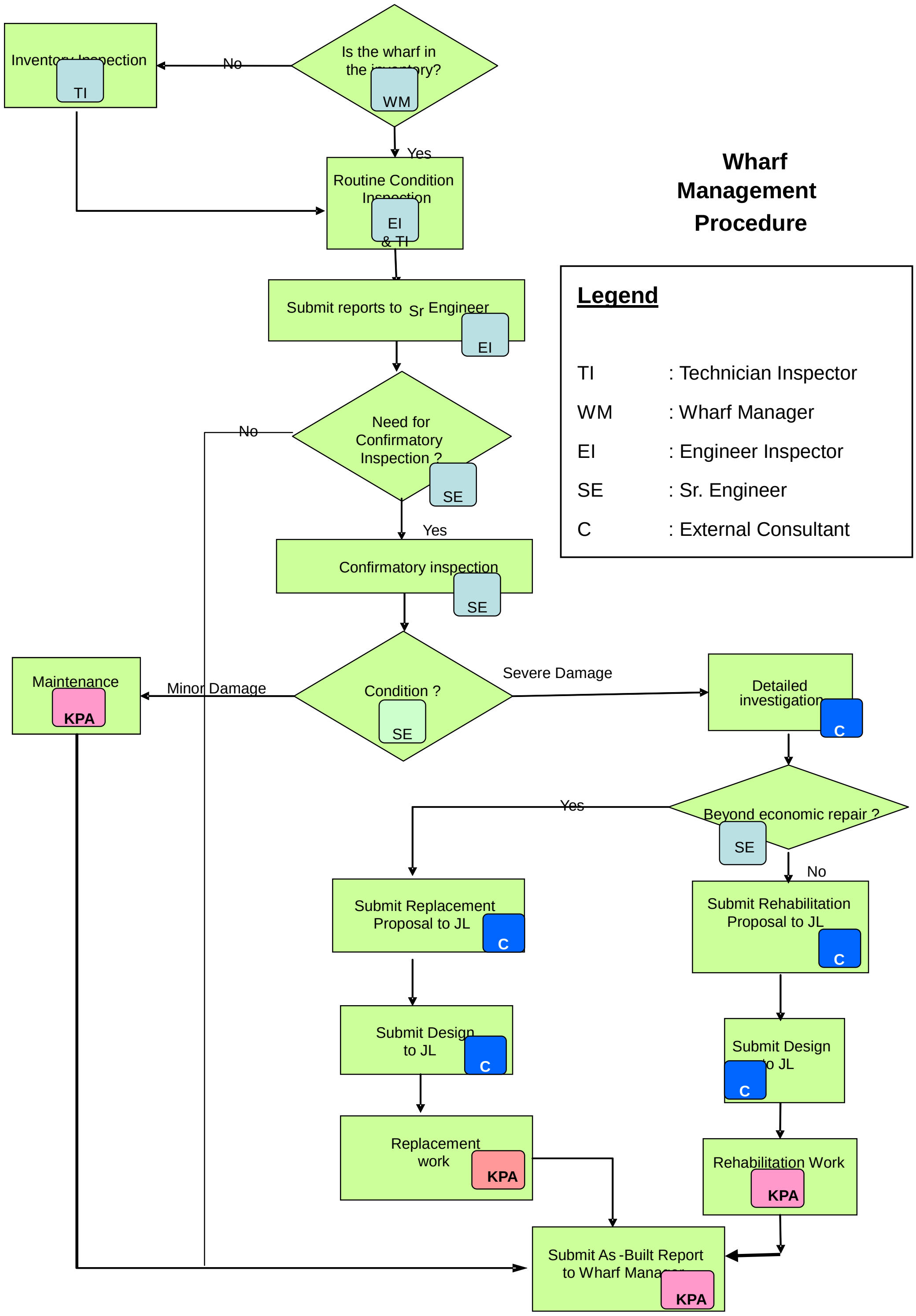


Figure 2.2 : Wharf Management Activities

2.3 Wharf Inspection

2.3.1 Conditions inspection

Annually, the inspector shall conduct a Conditions inspection and check if there are specific wharf problems. Conditions inspection is a visual inspection aims at determining the condition of the wharf component. The inspector shall determine the severity and extent of the damage by filling up a checklist and accordingly assign a rating (see Table 2.1). The component ratings for each span of the wharf are then summarized in a summary form.

Table 2.1 : Condition rating for Conditions inspection

Rating	Description
0	Inspection could not be carried out and temporarily postponed.
1	No damage found and no maintenance required.
2	Damage detected and it is necessary to record the condition for observation purposes.
3	Damage detected is slightly critical and thus it is necessary to implement routine maintenance work.
4	Damage detected is critical and in large part and thus it is necessary to implement repair work or to conduct a detail inspection to determine whether any rehabilitation works are required.
5	Being heavily and critically damaged, possibly affecting the safety of the wharf, it is necessary to implement an emergency temporary repair work immediately or rehabilitation work without any delay after evacuating the occupants and cordoning off the area.

* It is important to note that in appraising the degree of damage account must be taken of the location in the wharf where it occurs, and also of the function of the element. Critical elements are termed “Primary members”, the others “Secondary members”.

Checklists and summary forms for Conditions inspection are given in Appendix A. The damage codes used in the checklists are adopted from the 'A Guide for Bridge Inspection' published by Road Engineering Association Malaysia (REAM) in 2005.

Conditions inspection shall be carried out by engineers or technicians/technical assistants trained in wharf inspection. The inspectors must also assess the situations and decide if there is a need for temporary measures, for example, closure of the wharf. The Engineer inspectors must countersign on the inspection forms.

2.3.2 Confirmatory inspection

The Senior Engineer shall take full responsibility in wharf inspection and provide all the necessary supports to the inspectors. He shall review the inspection reports and carry out a Confirmatory inspection, if necessary. Confirmatory inspection is a more thorough inspection focusing specifically on the damage reported in the earlier conditions inspection besides confirming the ratings reported by the Technician inspectors. A damage report, in the form of pictorial documentation of the damage, shall be produced as an outcome of the inspection.

2.3.3 Diagnosis

Besides appraising the severity of the problem reported, the inspector must also carry out diagnosis to establish the source of the problem. If necessary, monitoring of the condition shall also be carried out to support the diagnosis and to determine if the problem has progressed.

The root cause of a problem cannot always be determined with absolute certainty from a single visit. Inspection may have to be repeated at intervals. Diagnosis can be achieved by studying the crack patterns. Sometimes testing (NDTs or material tests on cored samples) and/or monitoring must be carried out to support visual observations. Some of the NDT testing's that could be carried out include chloride test, carbonation test Half-cell potential survey, rebound hammer test and cover meter test – see plate 2.1

to 2.5. A thorough knowledge of the history of the components and of the wharf is also helpful. A good understanding of structural behaviour and material properties is indispensable for an accurate diagnosis. Fundamental concepts in these areas are presented in Chapter 3.

Plate 2.1 : Chloride Test

Plate 2.2 : Carbonation Test

Plate 2.3 : Half Cell Potential Survey

Plate 2.4 : Sounding (Hammer) Test

Plate 2.5 : Cover-meter Test

2.3.4 Monitoring

Monitoring movements and monitoring crack width changes can be useful as a means of confirming any supposed cause besides checking if the damage is dormant or progressive. If the cracks or movements are progressive, an immediate action must be taken.

The inspector must decide on location, frequency and type of monitoring to be carried out. Some of the common monitoring devices are:

i. Tell-tale crack glass strip

   A piece of thin glass strip is glued with rigid epoxy over the crack. Any movement will cause the glass to crack.

ii. A thin straight line is drawn across the crack (use a thin-tip permanent marker). Any movement will cause the line to skew. Measure the gap with a crack scale to determine if the movement is large.

iii. Tell Tale Crack Width Gauge monitoring device Plate 2.6.

   A monitoring gauge may also be installed rigid epoxy over the crack to monitor the horizontal and vertical movement of the structure.

iv. For more precise monitoring, 2 stud pins are fixed across the crack and the distance measured using a “Demec gauge”. The Demec gauge consists of a mechanical or a digital gauge or a digital dial gauge attached to an Invar bar (Plate 2.7). A fixed conical point is mounted at one end of the bar, and a moving conical point is mounted on a knife-edge pivot at the opposite end. The dial gauge measures the pivoting movement of the second conical point.

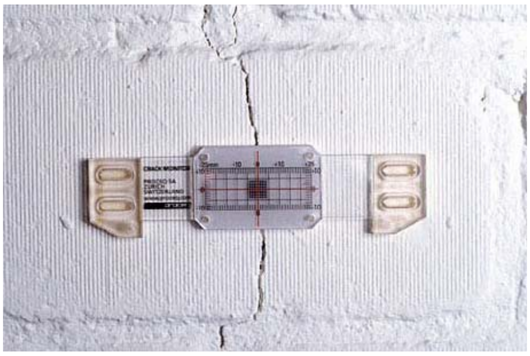


Plate 2.6 : Tell-Tale Crack Width Gauge.

Plate 2.7 : DEMEC gauge apparatus.

2.4 Referencing system

A referencing system is necessary for making sure that personnel of the wharf management team will have a common understanding in locating a problem in the wharf. The referencing system adopted for Kuantan Port Wharf is shown in Appendix B.

3. PROBLEMS IN WHARFS: Why do they occur?

3.1 General

Common types of problems that Kuantan Port Wharf experienced are:

- Cracks in RC slab
- Pot holes in RC slab
- Spalling in RC slab
- Corrosion in steel beams
- Corrosion in steel circular piles
- Damage to fender systems
- Corrosion of bollards
- Problems in joints

These problems could be due to error in design or poor construction, poor workmanship, deterioration of material or physical damage and also due to chloride attack. Though each of these problems is sometimes referred to as defect, deterioration or damage to indicate the cause of the problem, they are all identified in this Guide as "damage".

It is clear, from earlier discussions in Chapter 2, that an inspector must be sufficiently knowledgeable to carry out his duties in appraisal and diagnosis of a wharf problem; and recommending a remedial solution. In particular, a wharf inspector must have fundamental knowledge in structural behaviour of an RC structure under load as well as concrete properties, notably, the mechanisms of deterioration in concrete. This chapter aims to discuss a few important fundamental concepts as a precursor to discussion and categorization of damage.

3.2 Behaviour of Kuantan Port wharf and load-induced problems

Kuantan Port Wharf comprises a space frame structure with composite superstructure of concrete slab and steel beams and steel piles.

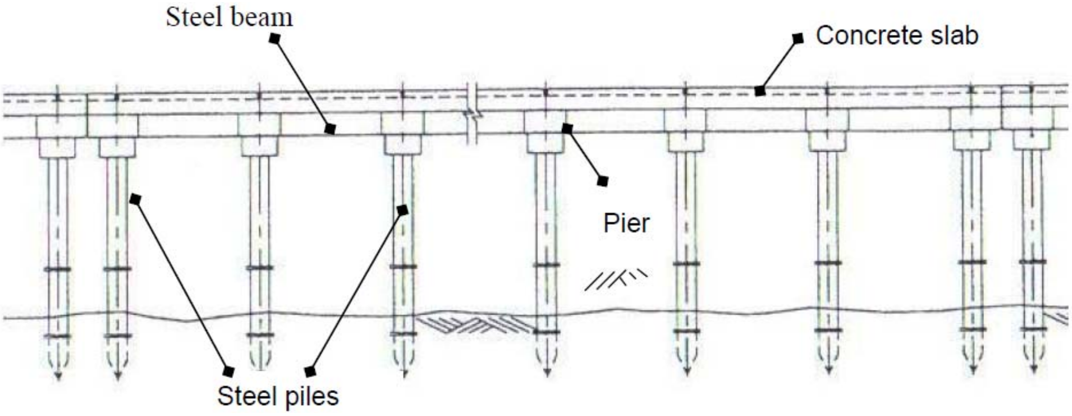


Figure 3.1 : Structural components in a wharf

The components of the wharf can be broadly divided into primary elements and secondary elements. Primary elements are those needed to carry the loads while secondary elements are those for aesthetics or protection and not for load-bearing. Examples of primary elements in a girder wharf are beam, abutment, pier, and diaphragms. Fenders, bollards and expansion joints are all examples of secondary elements.

Girder or Beams are structural members designed to withstand load that is transverse to their main axis. The load effects induced in a beam are mainly bending, torsion and shear. Piers are structural members expected to carry compression (parallel to their axis) and bending forces. The behaviour of beams and columns under uniformly distributed load can be seen from Figure 3.2 and Figure 3.3, respectively.

Note that in both cases, the tension sides of the members can be predicted from the deflected shape of the member under load; or more objectively, from the bending moment diagrams. Concrete is known to possess high resistance in compression but weak in tension. This is why engineer provides steel reinforcing bars in the tension zone of the structural member of an RC construction.

Deck Slabs are also structural members. The slab often spans over the beams and is known as a one-way slab. Its behaviour can be reckoned as individual strips of beams.

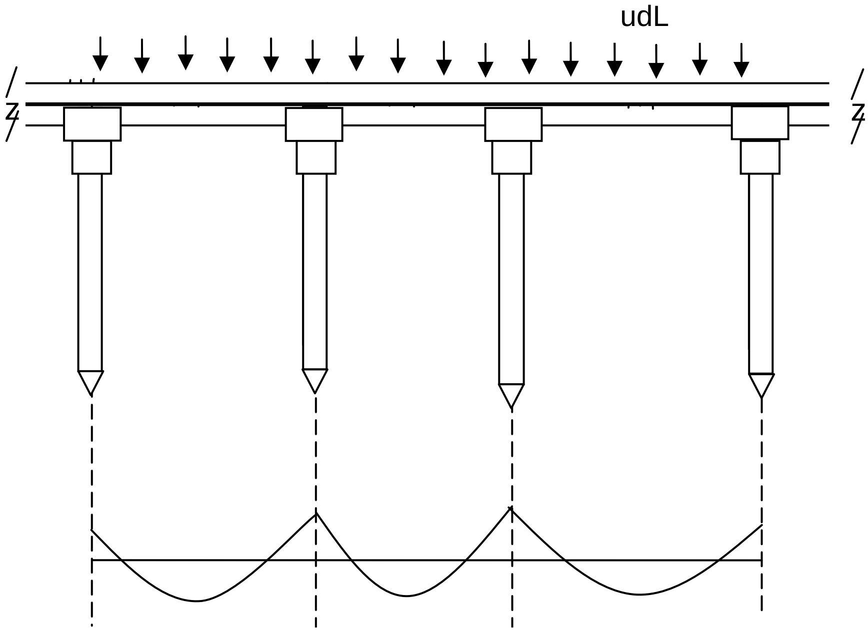


Figure 3.2 : Bending effect of a continuous beam under an uniformly distributed load (udL)

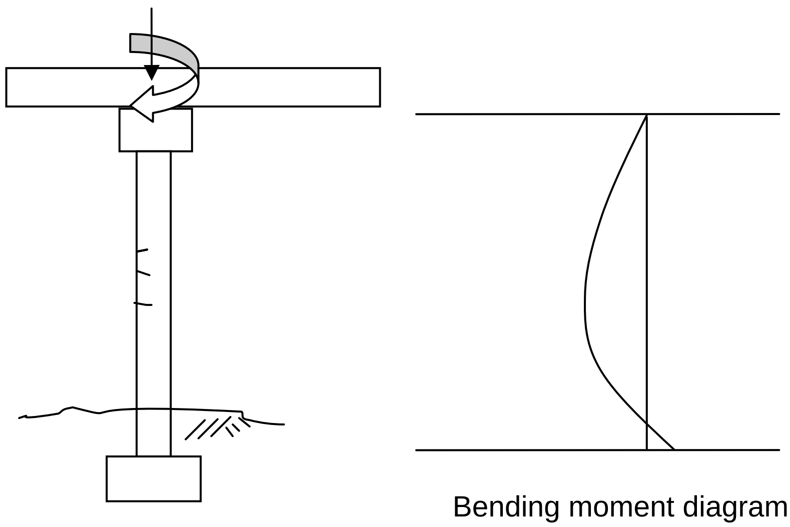


Figure 3.3 : Bending effect of a column under vertical load and moment

In order that a wharf is safe every structural element is designed such that its size has a resistance R larger than the expected effect caused by an expected action (S) during its design life. An action is anything that gives rise to stresses in a structure. It includes load which are forces acting on the structural elements or movement or deformation, which does not result from the applied loads but which causes stresses in a structure. Movement can be internal, due to shrinkage, temperature change or creep. It can also be externally applied, as in the case of differential support settlement.

Logically, when the resistance in a structural member is less than the load effects, that is R<S, failure will take place. In the more severe situation, the member will exhibit signs of distress, commonly in the form of cracks. We call this a load-induced crack and often regarded this type of problem as a “Structural problem”.

As mentioned earlier, the requirement of structural safety is ensured by keeping **R**>**S**. There can be many ways that this inequality is reversed:

- Design error: wrong estimation of R or S in design calculations
  Induce **S** or reduce **R**
- Construction error or defect
  Induce **S** or reduce **R**
- Change of use
  Induce **S**
- Change of environment, for example, ground movement
  Induce **S**
- Deterioration
  Reduce **R**

In regard to ground movement, there is a need to make a distinction between settlement and subsidence. Settlement is defined as the downward movement of a structure caused by compression of the ground by foundation loads. A total settlement of the structure is usually of no immediate concern. It is the differential settlement of the supports that is likely to induce stresses and damage to the structure. Subsidence is the downward movement of the soil caused by activity in the ground; which may or may not cause settlement of the structure. A common subsidence problem involves cracking of the slope protection at the wharf abutments. While it may initially be a serviceability problem it may be sign of problematic soil conditions. As such this should be monitored on a regular basis.

3.3 Mechanism of concrete deterioration and corrosion-induced problems

The concrete and steel components in a RC member work in “perfect harmony” not only in terms of load sharing: concrete taking compression and steel, tension. Concrete has a pH of 12.5 which provides an alkaline environment that protects the reinforcement bars from corrosion. However, when carbon dioxide penetrates into the concrete (and in the presence of water) the pH value is reduced to about 9.5 and the passivating or protective layer is destroyed. Corrosion due to carbonation can then commence.

Chloride-induced problem usually happens in marine or coastal areas. In the presence of chloride, corrosion of reinforcements can take place even for concrete in alkaline environment.

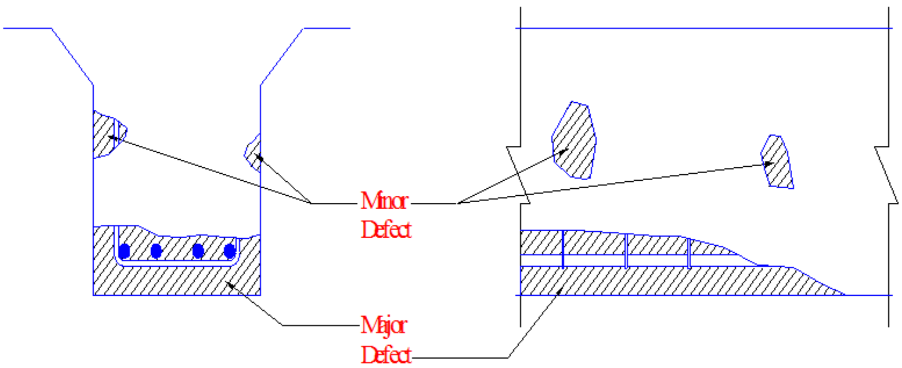


Figure 3.4 : Classification of Major and Minor Defect

Corrosion of steel from carbonation or chloride will cause it to expand and induce cracks in concrete. Cracking often leads to spalling of concrete if left unattended. Spalling is a fragment which has been detached from a larger concrete mass. This happens when small isolated areas of steel develop pitting which have expansive forces during the corrosion process. The expansive forces cause the concrete to break in small pieces. As corrosion spreads, the reinforcing bars which are tied in a grid-like position will break in a large panel. This is termed as delamination.

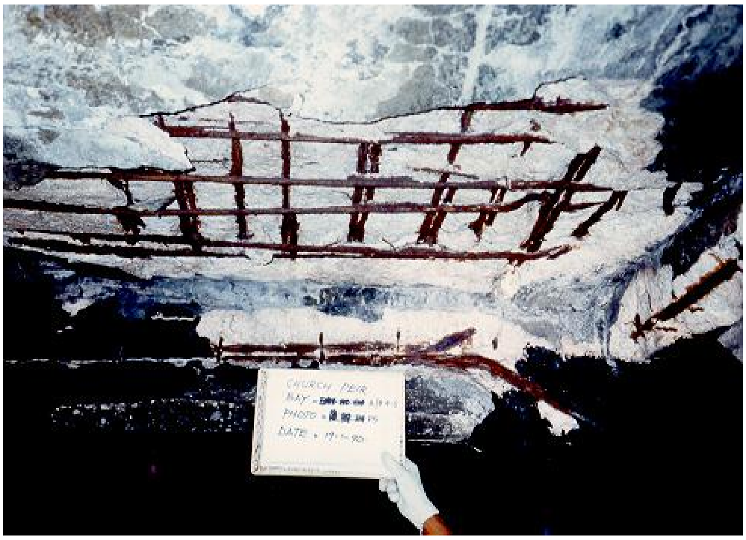


Plate 3.1 : Spalling of concrete due to expansion of corroded reinforcement.

Plate 3.2 : Delamination of concrete due to expansion of corroded reinforcement.

Another common aggressive agent is sulfates. In DEF (delayed ettringite formation) and ISA (internal sulfate attack) sulfate (e.g., sodium and calcium sulfates) in the soluble form reacts with hydrated lime in the cement to form ettringites and gypsum. These will then expand and cause disintegration in the concrete. Cracks of map-like pattern are often the results.

Problem due to deterioration of material is an entirely different type of problem from the load-induced problem. We call this corrosion-induced problem. This type of problem, there is often no immediate concern for structural safety. However, though it is not a structural problem, it may lead to one when corrosion has caused too much loss of section.

3.4 Intrinsic properties of concrete and intrinsic problems

Quite independent of the load-induced problem and corrosion-induced problem we discussed above, there is yet another type of problem associated with RC construction. This time the intrinsic properties of concrete themselves are the source of problem. Concrete shrinks when the temperature drops or when it dries up. When this shrinkage is restrained tension stresses are induced and cracking occur. This is normally known as intrinsic problem.

Non-structural cracks due to intrinsic movement in concrete can be in the following forms:

- Random pattern (Plate 3.3),
- Following line of reinforcement (Plate 3.4),
- Fine vertical cracks at regular interval in beams
- Fine vertical or horizontal cracks at regular interval in columns
- Transverse cracks at regular interval in slabs (Plate 3.5),

Plate 3.3 : Random patterned cracks in floor slab.

Plate 3.4 : Cracks in floor slab following line of reinforcement.

Plate 3.5 : Transverse cracks in slab.

Crack pattern and the time of crack appearing give a broad guide in diagnosing the type of cracks.

Intrinsic cracks affect only the aesthetics and do not endanger the stability of a structure. However, in some situations when left unattended may lead to structural problems. For example, a shrinkage crack may allow water to leak and lead to corrosion problems in the reinforcement bars that will then reduce the carrying capacity of a structural member.

There are several types of intrinsic cracks:

- plastic shrinkage cracks
- plastic settlement cracks
- thermal cracks (internal restraint and external restraint cracks)
- long term drying shrinkage cracks
- crazing or map cracks

3.5 Other causes of problem

Mechanical damage, for example, impact damage by a berthing ship sometimes does occur to a wharf. Depending on the wharf elements involved and the severity of the damage this type of problem can lead to a structural collapse of the wharf. It is important that a thorough inspection of the wharf, not restricted to conspicuous damage, be carried out. It often requires much experience and knowledge to appraisal the extent of mechanical damage. If in doubt the matter must be quickly reported to a higher authority.

4. WHARF MAINTENANCE

4.1 General

As is mentioned earlier, wharf maintenance operations ought to begin at the onset of the opening of the wharf to service. It aims to extend the life of the structure and to ensure that it functions as designed, thus ensuring public safety. Wharf maintenance is defined as the work needed to prevent deterioration or the development of incipient defects and other minor works which are repetitive and, in general, technically simple. Examples of maintenance operations are removing debris, cleaning the drainage system, localized repair of surfacing, repair of traffic damage to parapet. The implementation of the works can be classified as work which will be carried out by maintenance team or on small work order basis.

The objectives of wharf maintenance can be defined as follows:

i. Assuring safety of wharf users;
ii. Preserving serviceability and load carrying capacity of the wharf for as long as possible;
iii. Ensuring continued serviceability within the limits of available funds;
iv. Minimising interference with traffic;
v. Providing adequate ride ability and travel comfort.

However, work which fall under a category of rehabilitation or strengthening and which needs to be implemented on a contract basis are excluded from the definition. They are:

a) Any works leading to rehabilitation or betterment of the structure, whether by strengthening to carry heavier loads; or by widening; or by vertical realignment of the road surface.
b) Any specialized or extraordinary repair works of deficiencies or defects which are critical or widely spread.
c) Any restoration works of damages caused by landslide, flood, earthquake, fire and other exceptional causes.

4.2 Classification of maintenance operations

It is convenient to classify the many and varied tasks comprising wharf maintenance. Although the classifications used by different countries vary, probably being influenced by the manner in which the work is organized, a general pattern can be discerned. This classifies maintenance according to whether it is;

- Ordinary or periodical (i.e. programmable) and
- Specialised or extraordinary (i.e. unpredictable).

Ordinary maintenance is repetitive or periodical operations which are in general technically simple. Examples of ordinary maintenance are simple cleaning of the wharf (carriageways, footpaths, drains, gullies, gutters, joints etc.) by hands or mechanical means; removal of foreign material such as rubbish or parasitic vegetation; localized repair of surfacing; small restoration of traffic damage to parapets, painting of steel members/accessories, etc.

Specialised maintenance operations are those which are unpredictable regarding their necessity and are relatively more complex. It falls into two groups. Firstly the work for which there is, from experience, a high expectation that it will become necessary during the life span of some wharf. Examples are painting of structural steelwork, localized patching of concrete, replacement of joints, renewal of parts of the water proofing or drainage system, etc. Secondly, work which is unpredictable, such as correction of settlement, restoration of minor damage to slope protection, minor river-training schemes, etc.

All categories of maintenance may include work needing special skills or equipment. Even though most of the ordinary maintenance operations can be carried out by Kuantan Port Authority maintenance team, it is often necessary to employ a specialist organization or contractor for specialized maintenance work.

4.3 Types of maintenance operations

After the completion of Conditions or/and Confirmatory Inspection of the wharf, the Engineer Inspector/Senior Engineer shall propose the recommended action(s) required to tackle the problems encountered during inspection.

The type of maintenance operations for the different components of the wharf is given in Table 4.1 below.

Table 4.1 : Types of maintenance operations.

<table>
<tr><th>COMPONENT</th><th>CODES*</th><th>TYPES OF DAMAGE</th><th>MAINTENANCE OPERATIONS</th></tr>
<tr><td rowspan="4">Steel Material</td><td>1</td><td>Corrosion of Steel</td><td rowspan="2">Apply protective coating</td></tr>
<tr><td>5</td><td>Paint Deterioration</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">Loose Connections</td><td>Reinstate / Tighten bolts & nuts</td></tr>
<tr><td>Replace missing bolts</td></tr>
<tr><td rowspan="6">Concrete Material</td><td>7</td><td>Spalling</td><td rowspan="6">Patch repair or formwork repair (subject to area or size of damage)</td></tr>
<tr><td>9</td><td>Wear/Abrasion</td></tr>
<tr><td>10</td><td>Material Deterioration</td></tr>
<tr><td>11</td><td>Surface Defect</td></tr>
<tr><td>12</td><td>Delamination</td></tr>
<tr><td>14</td><td>Water Leak at deck</td></tr>
<tr><td rowspan="3">Expansion Joint</td><td>29</td><td>Abnormal Spacing</td><td rowspan="3">Replace expansion joint</td></tr>
<tr><td>30</td><td>Difference in Level</td></tr>
<tr><td>32</td><td>Rupture</td></tr>
<tr><td rowspan="4">Drainpipe</td><td>20</td><td>Drainage Blocked</td><td>Clean / Maintenance</td></tr>
<tr><td rowspan="3">21</td><td rowspan="3">No Pipe/Inadequate Pipe Length</td><td>Replace drainpipe(s)</td></tr>
<tr><td>Extend drainpipe(s)</td></tr>
<tr><td>Install drainpipe(s)</td></tr>
</table>

* Refer to REAM's publication “A Guide to Bridge Inspection”

From Table 4.1, the maintenance operations can be grouped into six (6) categories based on the types of problems and the wharf component:

a) Simple cleaning operation.

b) Small scale removal and replacement operation.

c) Small scale restoration operation.

d) Localized repairing operation.

e) Localized repainting operation.

f) Tightening of loosened bolts.

Based on the maintenance operations defined above, each maintenance technique is discussed further here below.

a) Simple cleaning operation.

Simple cleaning operation is a common wharf maintenance operation. This operation is to remove all foreign materials such as trash, dirt, debris, plastic and vegetation which have accumulated and caused dampness to wharf component. Accumulation of dirt or debris can lead to durability problems such as corrosion of beams and steel reinforcement.

Plate 4.1 : Debris retains dampness and should be removed to avoid corrosion of steel beams.

Maintenance Method

All this removal operation is done physically (by using hand) or by appropriate equipment. Dry materials are to be removed using broom and hand while brushes and towels are used to remove wet materials.

b) Small scale removal and replacement operation.

Small scale removal and replacement operation are commonly done to substitute deteriorated or damaged elements. Deteriorated elements are such as detached shear chain and damaged expansion joint. This operation also includes removal and replacement of such deteriorated or damaged elements.

Plate 4.2 : Damaged expansion joint in need of replacement

Plate 4.3 : Detached shear chain of the fender should be reinstated

<u>Maintenance Method</u>

These are specialized maintenance operations and Kuantan Port Authority should engage specialist contractor to execute the works.

c) Small scale restoration operation

This operation commonly involves reinstalling missing or damaged traffic signs, railings, bolts etc. This operation also involves tightening of loose bolts, repair of damaged welding, and restoration of minor damage to slope protection (damaged mortar to rubble pitching and rock filled gabion etc.)

Plate 4.4 : Damaged rubble pitching need restoration before condition worsen.

Maintenance Method

Misaligned or minor deformation of steel railing should be repaired and restored to original design.

All bolts and nuts at the wharf structure should be kept tight to maintain the intended functionality of the structure. Bolts and nuts, which have serious loss of sections due to corrosion, should be replaced.

d) Localised repairing operation

This operation involves repairing minor cracks at wharf concrete deck and expansion joints; minor delamination on wharf concrete deck; and minor concrete problems. The cracks in wharf concrete shall be sealed by epoxy resin injection. The minor delamination and spalling of concrete is repaired by patching.

Plate 4.5 : Cracks in concrete deck allow water to seep through them and wet the underside of the wharf deck. They can be repaired by sealing with epoxy resin.

Plate 4.6 : Minor delamination in deck slab will deteriorate further if no action is taken and therefore should be patch repaired immediately.

Maintenance Method

Crack injection with epoxy resin

Whether to repair a cracked concrete or not and the method of repair depend on nature of the cracks. Where stresses are relieved and a stabilized condition exists, cracks may be repaired by simply injecting them with a low viscosity epoxy resin.

Plate 4.7 : Crack Injection repair at the dolphin of Kuantan Port Wharf

Plate 4.8 : Crack injection repair being carried

Patch repair (concrete)

At first the defective concrete must be removed until sound concrete is found. If an exposed reinforcement bar exists, it must be cleaned and protected by painting with appropriate paint to avoid rusting. Next the affected areas must be thoroughly cleaned and applied with a bonding agent. Finally patching should be carried out using resin mortar, see Plate 4.9 to 4.15.

For extensive repair, the use of formwork is requires and the mortar is pumped into the formwork, see Plate 4.16 to 4.19.

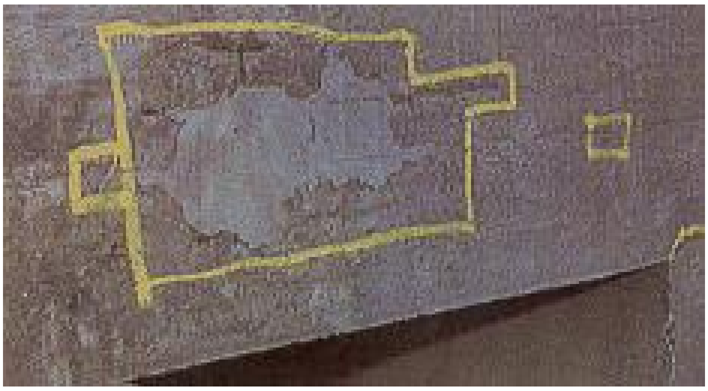


Plate 4.9 : Making Out of repair zone

Plate 4.10 : Breaking out of defective concrete

Plate 4.11 : Saw-cutting edges of repair zone

Plate 4.12 : Grit Blasting the Steel

Plate 4.13 : Priming Steel

Plate 4.14 : Wetting of substrate

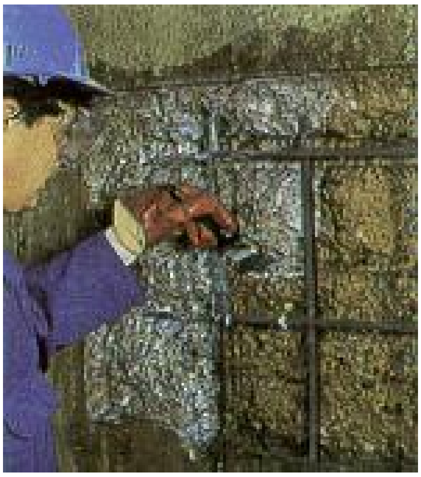


Plate 4.15 : Applying bonding aid

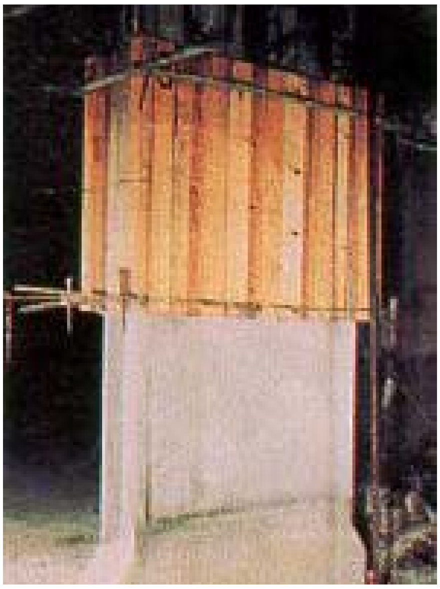


Plate 4.16 : Grout-tight formwork

Plate 4.17 : Pumping to formwork

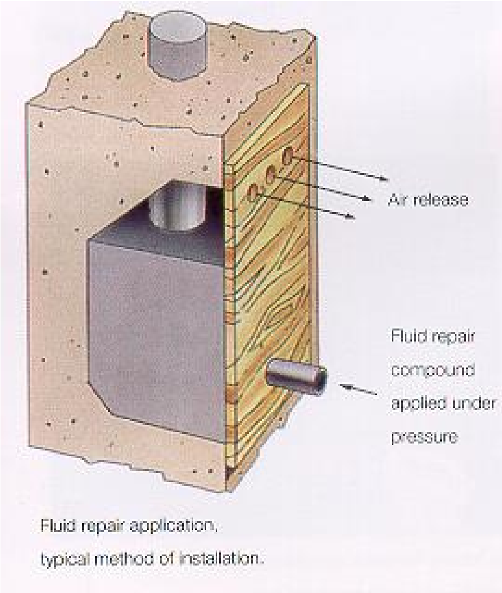


Plate 4.18 : Typical method of application for fluid repair

Plate 4.19 : Congested area of rebars

e) Localized repainting operation

Repainting operations involve repainting of steel members such as beam, chord, bearing, railing and protective coating to concrete members due to deterioration of paint or surface corrosion.

Plate 4.20 : Paint deterioration and mild surface corrosion of steel beam can lead to widespread corrosion if left unattended.

Plate 4.21 : Steel Beam appearance after coating

Maintenance Method

The repainting operation shall first be preceded by thoroughly removing the deteriorated paint and corrosion products. Then the cleaned surfaces shall be painted with suitable coating material which has to be applied layer by layer.

f) Tightening of loosened bolts

Bolts and connections must be inspected and checked for loose nuts.

Plate 4.22 : Bolts and nuts should be tightened

Maintenance Method

Bolts and other connections should be maintained in the same manner as for steel components. Tightening of loosened bolts could be done simply with appropriate instruments. Care should be taken to protect with protective coating after the tightening to increase life span of the component.

4.4 Implementation of maintenance work

In wharf maintenance, it is essential to effectively manage the wharf maintenance activity and to correctly implement the wharf maintenance operation at the wharf site. However, a successful management and implementation of wharf maintenance rely on the organisation and method as well as the staffing and their capability.

Ordinary maintenance can be done by Kuantan Port Authority workers/labourers but most of the larger or specialised tasks are done by contractors.

For contract work, particularly where complex maintenance operations are involved, the general approach is as follows:

i) Data from wharf inspection is collected by Kuantan Port Authority responsible for the jetties.
ii) Work is grouped into contracts of reasonable size. The criteria for grouping are either that the work required on several wharfs is similar or that several wharfs needing maintenance form a convenient geographical group. The postponement of some work can sometimes lead to a better grouping. For work needing specialised services grouping is particularly desirable.
iii) Contract work is apportioned for each item of work.
iv) The estimated costs include those for providing access to the parts of the structure where maintenance has to be done. This includes any fixed scaffolding or mobile platforms.

This approach enables a more accurate estimate of maintenance costs to be obtained and contributes to considerable overall savings. Careful planning of the work encourages firms to update their methods and provide staff training so that the quality of the work is improved.

5. CONCLUDING REMARKS

The Guide provides much information on the strategic maintenance of Kuantan Port Wharf. It presents a systematic description of the maintenance operations for the wharf.

Implementation of the wharf management system requires cooperation and commitment from all parties in Kuantan Port Authority. There is a body of knowledge contained in this Guide as well as the reports and other deliverables. All personnel in the wharf management team should make an effort to refer to these documents and together we would work towards improving the reliability of our wharfs through implementation of the wharf management system.

REFERENCES

1. Standard and Industrial Research Institute of Malaysia (SIRIM). Malaysian Standard Guide To Assessment of Concrete Strength in Existing Structure, November 1991
2. Road Engineering Association of Malaysia (REAM). A Guide for Jetty Inspection, The Road Engineering Association of Malaysia, Shah Alam, 2004.
3. Pengarah Jabatan Kerja Awam, Dewan Bandaraya Kuala Lumpur. DBKL Bridge Management Manual, June 2008.

APPENDICES

Appendix A: Checklists and Summary Forms for Conditions Inspection

Appendix B: Wharf Referencing System

Myanmar

1. OUTLINE OF TARGET STRUCTURE

Table 1.1 Outline of the target structure

Target structure	Bo Aung Kyaw No(3) Wharf
Structure type	Open-type wharf (pre-stress concrete spun pipe pile, RC Beam and deck)
Management body	Lanpyi Co.,
Length	183 m
Area	6624 m^2
Water depth	-10 m
Expected vessel	15,000 DWT
Completion at	1998
Service start at	1998
Purpose	Container Cargo

Natural Condition:

The highest environment temperature: 42 .C

The lowest environment temperature: 12 .C

Relative humidity: 50 ~ 90% (average)/ 100% (max.)

The design maximum wind velocity:

Working condition: 15.2 m/s (34 m.p.h, equal to Beaufort force 6)

Non-working condition: 35.6 m/s (79.61 m.p.h)

Water level:

The historical lowest water level (Dec., 1902): -0.24 m

The mean water level (to 1936): 3.121 m

The historical highest water level (Sept., 1899): 6.74 m

It is decided in the design:

The design high water level: 5.6 m

The design low water level: 0.0 m

Average Tidal Range: 5.85 m (Spring), 2.55 m (neap)

Current velocity:

The current velocity of Yangon River is 4 to 6 knots at spring.

Wave:

There is no significant wave caused by the wind at the site of the new wharf but waves caused by ships.

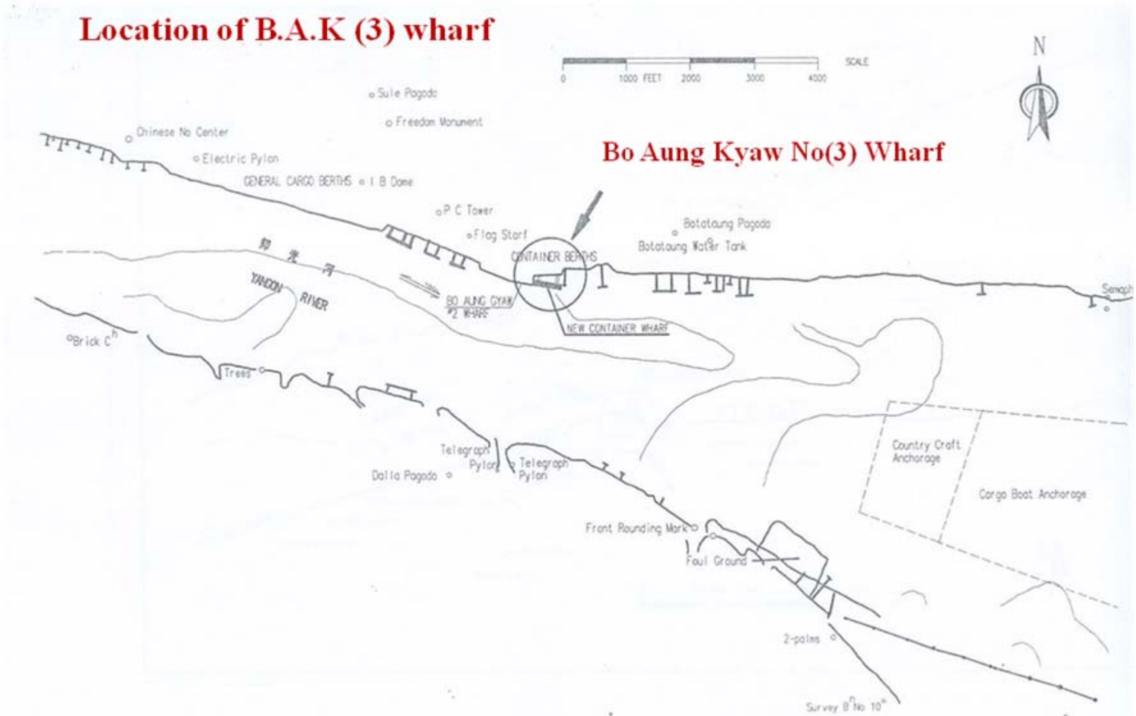
Water quality:

The water quality was analyzed in Jan., 1996. In the six samples, the pH value is 7.4 ~ 7.5 and no Cl^-. There is no corroding influence to the concrete structure.

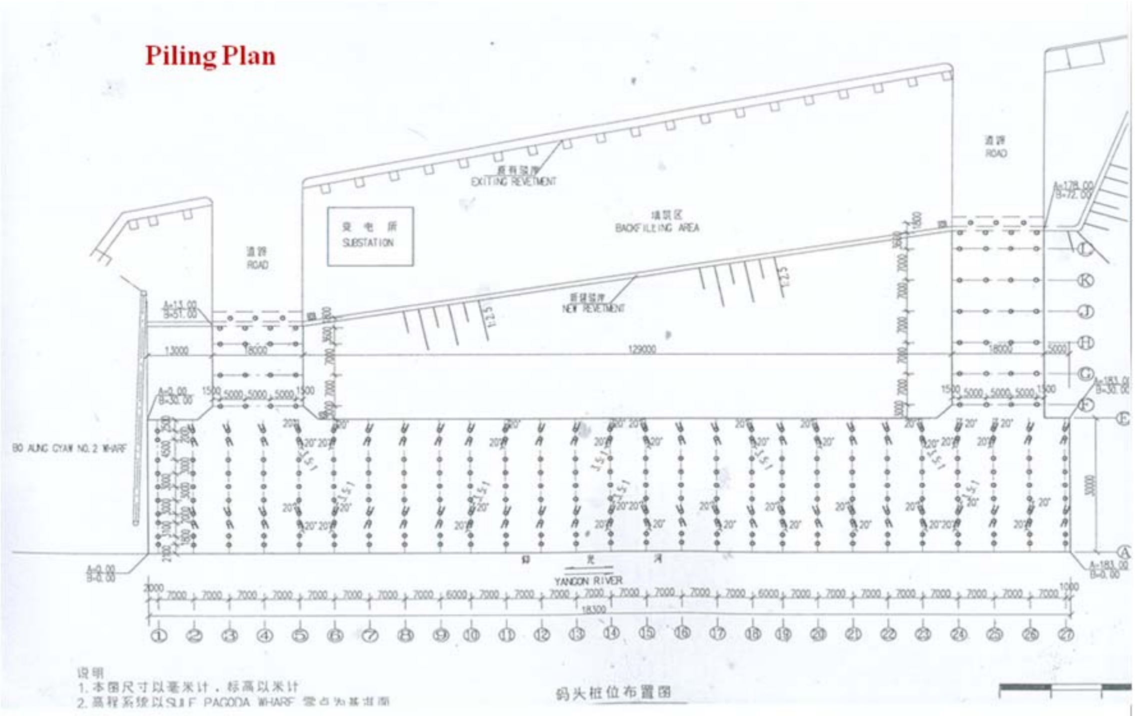
Chloride ion concentration in river water:

The Chloride ion concentration in river water was 0% in 2 Nov. 2005. This was due to the fact that the measured day (2 November) was just after rainy season. The Chloride ion concentration in river water is high in the dry season when the water level decrease. On the other hand, that is very low in the rainy season when the water level increases.

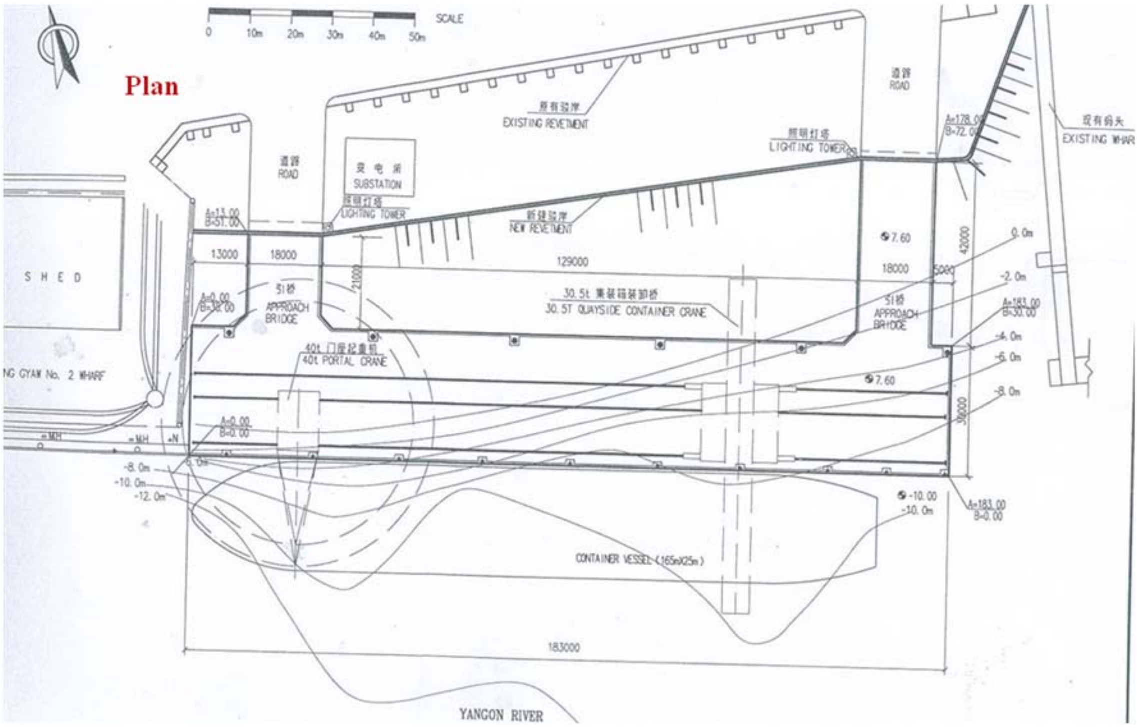
Source: PTG Activities in Yangon, Myanmar by Dr. Yokota and Party. In 2005

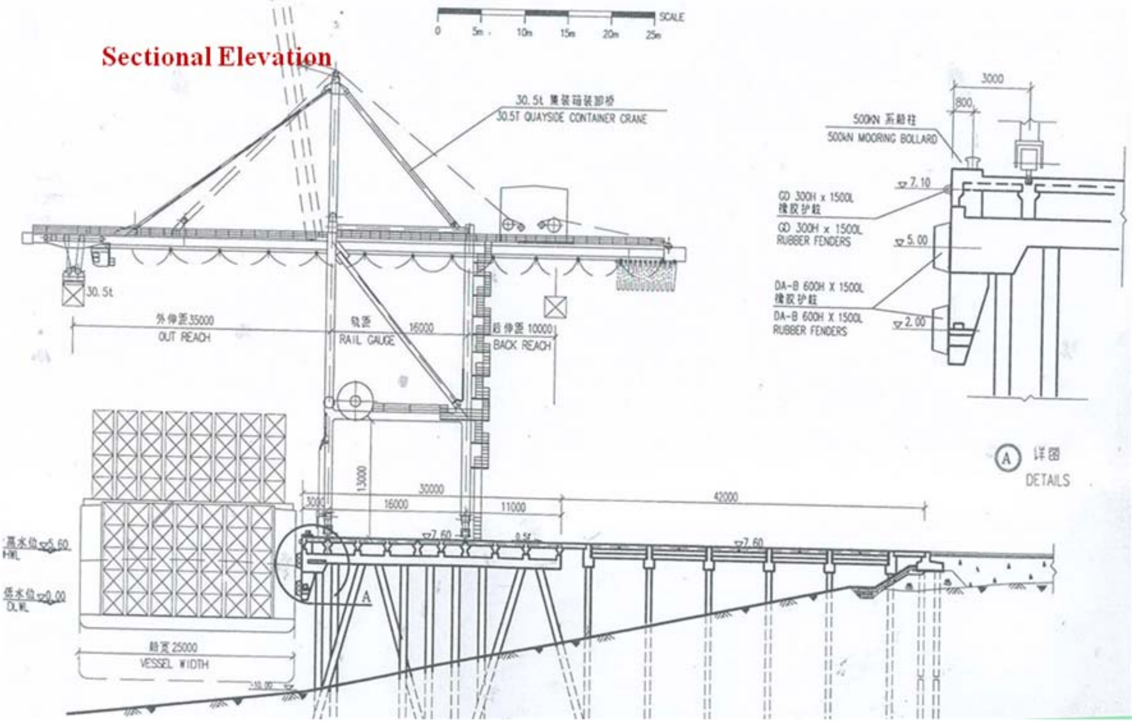


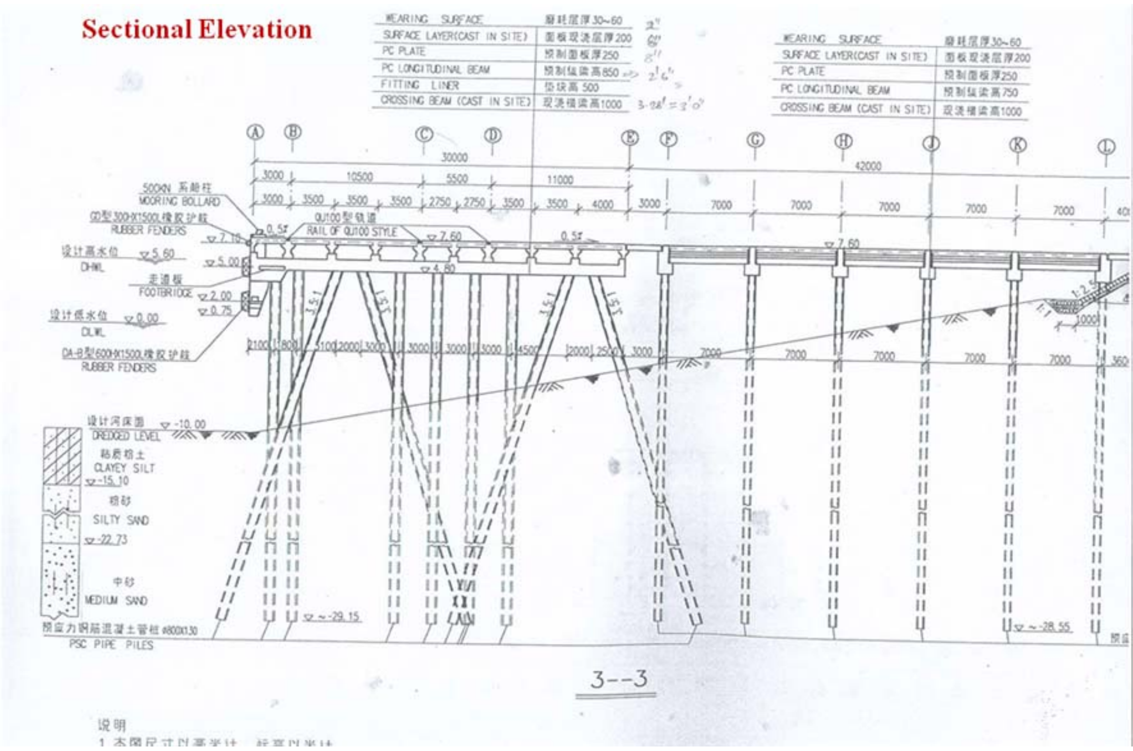
Piling Plan



Plan




Sectional Elevation
SCALE
30.5t 集装箱装卸桥
30.5T QUAYSIDE CONTAINER CRANE
外伸距35000
OUT REACH
轨距 16000
RAIL GAUGE
后伸距 10000
BACK REACH
30.5t
500KN 系船柱
500kN MOORING BOLLARD
GD 300H x 1500L 橡胶护舷
GD 300H x 1500L RUBBER FENDERS
DA-B 600H X 1500L 橡胶护舷
DA-B 600H X 1500L RUBBER FENDERS
A 详图
DETAILS
30000
16000
11000
42000
船宽25000
VESSEL WIDTH


Sectional Elevation
WEARING SURFACE 磨耗层厚30~60
SURFACE LAYER(CAST IN SITE) 面板现浇层厚200
PC PLATE 预制面板厚250
PC LONGITUDINAL BEAM
FITTING LINER 垫块高500
CROSSING BEAM (CAST IN SITE) 现浇横梁高1000
500KN 系船柱
MOORING BOLLARD
RUBBER FENDERS
QU100型轨道
RAIL OF QU100 STYLE
设计高水位
DHWL
走道板
FOOTBRIDGE
设计低水位
DLWL
DA-B型600HX1500L橡胶护舷
RUBBER FENDERS
设计河床面
DREDGED LEVEL
粘质粉土
CLAYEY SILT
粉砂
SILTY SAND
中砂
MEDIUM SAND
预应力钢筋混凝土管桩
PSC PIPE PILES
3--3
说明

Pictures 1.1 Views of target structure

2. MAINTENANCE POLICY AND PROCEDURE

2.1 Maintenance strategy

Table 2.1.1 Maintenance strategy

Level	Comments
1	No performance degradation should be expected. Deterioration and deformation affecting the performance are allowed within a minor range during the design service period (that is, the performance is always kept above the maintenance limit).
2	Performance degradation should be controlled. Minor countermeasures are repeatedly applied to keep the performance above the maintenance limit.
3	Performance degradation is expected. Major countermeasure may be applied once or twice for performance recovery.

For B.A.K. No(3) wharf , Now, we will use one of the appropriate strategy mentioned above for maintenance.

Table 2.1.2 Basic policy of deterioration grades judgment

Grade	Basic policy
a	Performance of component is seriously degraded.
b	Performance of component is degraded.
c	Performance of component is slightly degraded.
d	Performance of component is not degraded.

According to the visible inspection, the deterioration grade for B.A.K.No(3) wharf is ‘d’ up to now.

There is no rust stain or cracks on bottom surface of R.C decking, beam, pile caps and piles. No concrete spalling off can be seen.

Table 2.1.3 Maintenance strategy of the target structure

Components	Strategy	M.L.*	Comments
Pre-stressed conc.: Spun pipe pile	Level 1	Grade d	Any deterioration is not allowed because of its large influence on safety. Long term of the service restriction due to the service amendment or renewal would interfere to the port operation.
RC Pile Cap, beam and RC deck	Level 2	Grade c	Short term of the service restriction due to partial repair is possible. Long term of the service restriction due to the service amendment of renewal would interfere to the port operation.
Ancillary on yard and Apron	Level 3	Grade b	

*M.L.: maintenance limit

2.2 Expected service period

The designed service life of the target structure was originally 40 years (till 2038). However, the target structure was hoped to extend its service life for keeping the smooth port operation.

Inspection results in 2009 (11 years after completion) showed that the service period of pre-stressed conc.: spun pipe piles can be extended by the original protective coating protection.

We have already checked R.C pile caps, beams & Decks are in good condition and we will keep their performance above the maintenance limit.

Therefore, the expected service period of the target structure was re-defined as 55 years (till 2053) because of the present situation of the structures, then, the optimal maintenance works shall be carried out.

2.3 Maintenance procedure

<ins>Step 1: Inspection (see Chapter 3)</ins>

<ins>Step 2: Assessment (see Chapter 4)</ins>

<ins>Step 3: Countermeasures (see Chapter 5)</ins>

<ins>Step 4: Future maintenance plan (see Chapter 6)</ins>

3. INSPECTION

Visual inspection of RC piles, pile cap, beam and decking was carried out in January 2009. In the inspection, deterioration grades, grade a ~ d, were judge according to the Table in next slide, the criteria for grading RC members of open-type wharf from the viewpoint of corrosion of embedded reinforcing bars.

Table 3.1.1 Criteria for grading RC members of superstructure in open-type wharf from the viewpoint of reinforcing bars' corrosion

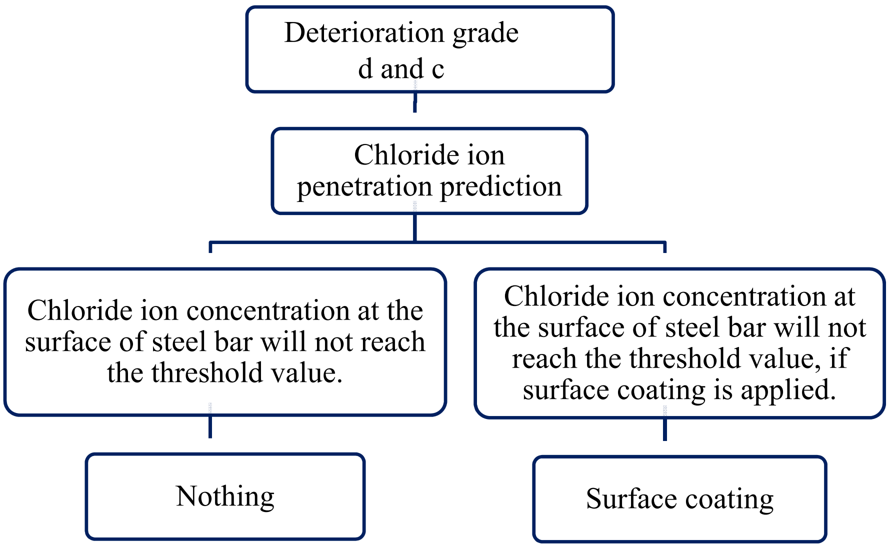
Grade	Criteria
a	Slab: Map cracking (over 50%) Spalling off of concrete cover Heavy rust stain Pile cap, beam and haunch: Crack along reinforcement with width of larger than 0.3 mm Spalling off of concrete cover Heavy rust stain
b	Slab: Map cracking (less than 50%) Much rust stain Pile cap, beam and haunch: Crack along reinforcement with width of less than 0.3 mm Much rust stain
c	Slab: One directional crack or gel extraction Partially extended rust stain Pile cap, beam and haunch: Vertical crack to longitudinal direction Partially extended rust stain
d	Nothing observed

For the B.A.K No(3) wharf, Criteria for grading R.C members of open-type wharf in present condition is grade 'd' nothing is observed.

4. ASSESSMENT

According to the visual inspection, nothing observed, that is why there is no deterioration on the structure up to now. Anyway, in coming future, we need to inspect chloride ion concentration for corrosion initiation of steel bars. We will consider Deterioration Prediction and Comprehensive Evaluation in coming Future.

5. COUNTERMEASURE



6. FUTURE MAINTENANCE PLAN

6.1 Inspection

Table 6.1.1 Inspection schedule

Component	Routine inspection	Periodical visual inspection
Pre-stressed conc.; pipe pile, pile Cap	-	Every 5 years
RC deck, L Beam, T.B	-	Every 5 years start from 2009
Protective coating	-	Every 5 years
Auxiliary equipments	Every 1 month	Every 1 years
Apron	Every 1 month	Every 1 years

We may conduct the unscheduled inspection depend on the results of primary inspection.

6.2 Assessment

We need to do the assessment of BAK No(3) wharf structure, in future are as follow;

- The performance of a structure should be assessed, considering the progress of deterioration, (relevant deteriorating mechanism) based on the result of Inspection.
- The judgment on the performance degradation of a structure should include the determination on whether remedial measures are necessary or not.
- Judgment for emergency measures should be made if necessary.
- Identification of cause (Trouble-shooting)
    - The deformation can be mended or repaired
    - If the cause is not identified, a scrutiny will be made

6.3 Countermeasures

Countermeasures for each structural component shall be planned based on the results of inspections and deterioration predictions. Methods and timing of countermeasures shall be planned based on the next Table.

Table 6.3.1 Timing and policy of repair methods for RC components

<table>
<tr><th>Timing (Deterioration grade)</th><th>Repair policy</th><th>Repair methods</th></tr>
<tr><td>d</td><td rowspan="2">Suppression of corrosion factors supply
Removal of deteriorated parts</td><td rowspan="2">Surface coating
Cross-section restoration
Cathodic protection</td></tr>
<tr><td>c</td></tr>
<tr><td>b</td><td rowspan="2">Removal of deteriorated parts
Suppression of corrosion progress
Improvement of load-bearing capacity</td><td rowspan="2">Cross-section restoration
Cathodic protection
FRP adhesion
Renewal</td></tr>
<tr><td>a</td></tr>
</table>

Table 6.3.2 Effective periods of repair methods for durability enhancement of RC components

Repair methods	Re-repair work	Expected effective periods
Crack injection	Impossible	-
Surface coating	Scheduled	15 years
Cross-section restoration	Un-scheduled	To the end of designed service life

Table 6.3.3 Schedule of repair works in the future

Timing	Action
2011	Surface coating and others if necessary for every 5 years
2016	Surface coating and others if necessary for every 5 years
2021	Surface coating and others if necessary for every 5 years
2026	Surface coating and others if necessary for every 5 years
2031	Surface coating and others if necessary for every 5 years

Philippines

1. OUTLINE OF TARGET STRUCTURE

Table 1.1 Outline of the target structure

Target structure	R.C. Pier - 2 of Catbalogan Port in Samar
Structure type	Open-type pier with reinforced concrete piles and monolithic superstructures
Management body	PPA - Port Management Office of Tacloban
Length	141 meters
Width	15 meters
Area	2,115 sq.m.
Design water depth	-5.00 meter from MLLW
High Water Level (HWL)	+1.80 meter
Low Watere Level (LWL)	-0.15 meter
Vessel Particulars	2,000 GRT Passenger Vessel / 1,000 DWT Cargo Ship
Completion	Early 1970's
Service start	Early 1970's
Vessel Traffic	Passenger and General Cargo vessels

The target facility is an open-type reinforced concrete pier which has been in service for over 30 years. General cargoes are handled in this pier utilizing medium scale cargo handling equipment such as forklift. Periodic and systematic maintenance work had not been carried out to the facility. But because of visible cracks and isolated had size holes on the deck surface were observed due to improper handling of cargoes, underdeck investigation was conducted in 2008.

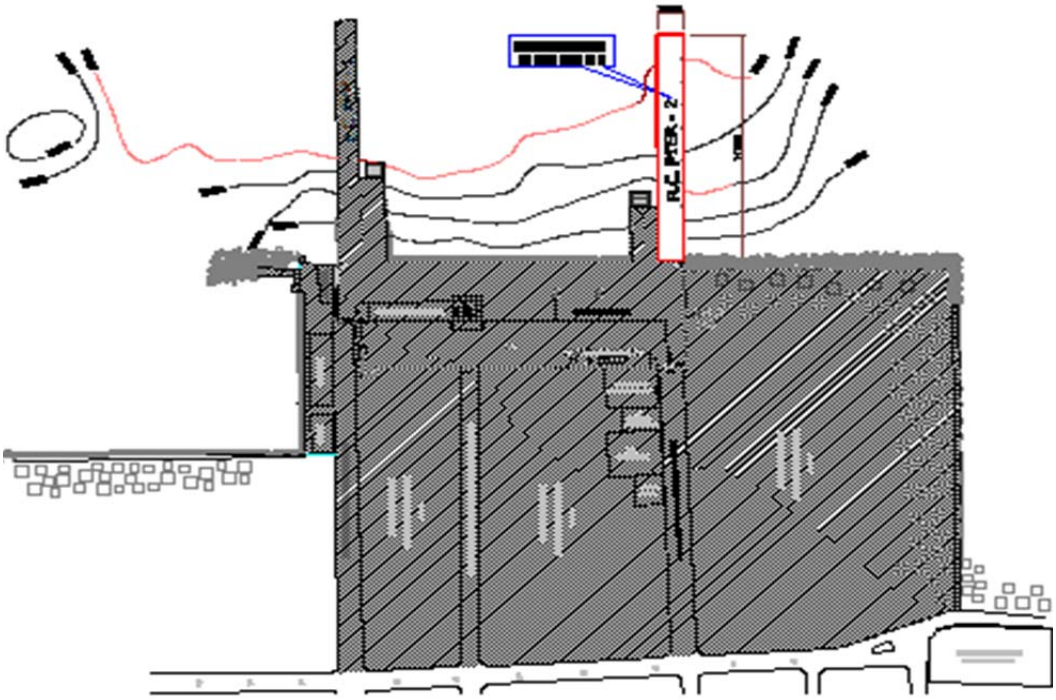


Figure 1.1 Development Plan of Port of Catbalogan in Samar (Location of facility)

Figure 1.2 Deck view of R.C. Pier - 2

Figure 1.3 Longitudinal view of R.C. Pier – 2

Figure 1.4 Underdeck view of portion of R.C. Pier - 2 showing damaged r.c. beams

Figure 1.5 Underdeck view of portion of R.C. Pier - 2 showing damaged r.c. deck

Figure 1.6 Underdeck view of portion of R.C. Pier - 2 showing damaged r.c. piles

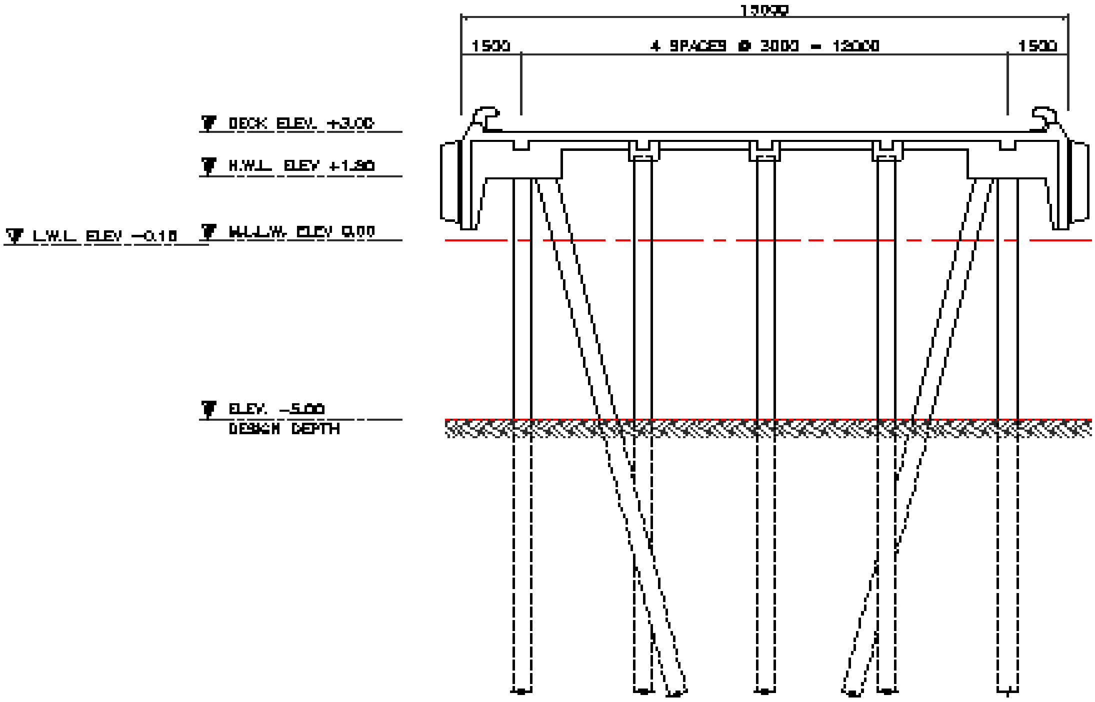


Figure 1.7 Cross-sectional view of the facility

2. MAINTENANCE POLICY AND PROCEDURE

2.1 Maintenance strategy

The maintenance strategy is categorized in 3 schematic levels as indicated in Table 2.1.1. It is important that sound judgment of the engineering office be employed in determining which repair scheme shall be adapted to a particular structural member. The adopted repair scheme will define the actual performance of the entire facility for the design service period.

Table 2.1.1 Maintenance strategy

Scheme	*Actual condition of structure*	*Repair methodology*
1	Structural cracks not exceeding 5mm in width and minimal spalling of concrete.	Epoxy injection and mortar application. Application of FRP system.
2	Corroded rebars and spalled concrete. Temporary concrete plaster with marine organisms.	Corrosion treatment for rebars. Removal of plastered concrete and cleaning of surface. Application of FRP system.
3	A portion of severely corroded rebars and spalled concrete.	Subject for rebars replacement and re-concreting of damaged section. Application of FRP system.

The degree and intensity level of deterioration should be properly defined using specific grading parameters as shown in Table 2.1.2. In this grading criteria, the judgment of the engineer is of great essence in order to achieve the design service period of the structures.

Table 2.1.2 Basic parameters in determining the deterioration grade of structural member

Grade	*Basic parameter*
a	No structural damage is seen or identified.
b	Structural member is slightly deteriorated that needs surface protection.
c	Structural member is deteriorated that needs immediate treatment.
d	Structural member is seriously deteriorated that needs replacement.

In determining the deterioration grade of each structural member of the target facility, the inspectorate team of the engineering division should be well-acquainted with technical knowledge to achieve uniformity and consistency of judgment.

2.2 Expected service period

The design service life of the rehabilitated target facility is extended to 25 years. This is in accordance with the referendum from the technical consultant of the Fiber Reinforced Polymer (FRP) system being adopted in this project. The primary advantage of using the FRP system is its physical property to totally seal the structural components from oxidation that prevent the intrusion of chloride ion thru the concrete surface and consequently protecting the structure from premature damage.

2.3 Maintenance procedure

<u>Step 1: Inspection (see Chapter 3)</u>

<u>Step 2: Assessment (see Chapter 4)</u>

<u>Step 3: Countermeasures (see Chapter 5)</u>

<u>Step 4: Future maintenance plan (see Chapter 6)</u>

3. INSPECTION

3.1 Visual inspection

In 2008, visual inspection for the whole structures of Pier-2 was carried out. Underdeck inspection revealed the concrete spalling on the bottom surface of r.c. deck and along the longitudinal surface of the beams that made the reinforcing bars exposed to salinity. This made the steel reinforcement highly corroded. Some piles were also seen damage on the concrete surface and the reinforcing bars corroded.

In 2009, detailed inspection for planning the repair scheme of each structural member was conducted. The detailed inspection includes the evaluation of the degree of damage of rebars and categorizing if needed a corresponding replacement. Also, the scraping of marine barnacles on pile surface along the splash zone is done to determine the extent of the damage.

The deterioration state of each structural component is presented in Table 3.1.1.

Table 3.1.1 Status of structural components according to deterioration grade

<table>
<tr><th>Area of inspection</th><th colspan="2">Structural status</th></tr>
<tr><td rowspan="4">Actual underdeck ocular inspection involves:
- Number & dimension of cracks per panel
- Concrete covering
- Corrosion manifestation on concrete surface
- Degree of deterioration of rebars</td><td>a</td><td>- No structural damage is observed</td></tr>
<tr><td>b</td><td>Slab:
- minimal hairline crack
- minimal rust stain on concrete surface
Beam:
- minimal transverse and longitudinal hairline crack
- minimal rust stain on concrete surface
Pile:
- minimal horizontal and vertical hairline crack
- minimal rust stain on concrete surface</td></tr>
<tr><td>c</td><td>Slab:
- spalled concrete
- exposed corroded rebars
Beam:
- spalled concrete
- exposed corroded rebars
Pile:
- spalled concrete with marine organisms
- exposed corroded rebars</td></tr>
<tr><td>d</td><td>Slab, Beam & Pile:
- severe concrete spalling extended beyond the line of main reinforcing bars
- highly corroded rebars with only 50% or more of bar diameter is remaining</td></tr>
</table>

4. COMPREHENSIVE EVALUATION

4.1 Evaluation of inspection results

Based on the result of the inspection on the physical damage and deterioration of the entire structures, and the consolidated data gathered on the site, repair schemes/ methodology that might be employed for each structural member were discussed and evaluated by the engineering team.

Although Pier-2 of the Port of Catbalogan has been in service more than 30 years, the Port Management Office of Tacloban was very hesitant to choose the conventional method of repair. This is because the conventional method requires the total demolition of the entire superstructures while employing built-up method for the repair of r.c. piles. Such method is very costly and will definitely stop the port operation during construction stage, which is approximately 1-1/2 to 2 year time. The Catbalogan Port is a very busy port because it is the main gateway going in and out of the province of Samar. Therefore, the temporary stoppage of operation of Pier-2 would hamper the trading transactions of the province and considerably reduce the total revenew of the Port of Catbalogan.

On the other hand, when employing or adopting the repair methodology of the FRP system, the port operation will not need to stop during rehabilitation process. This is because the system does not require demolition works and utilizes only hand held tools and not heavy equipments. Moreover, the adoptation of the system was programmed only for six months with project cost considerably lower than the conventional one.

5. COUNTERMEASURE

5.1 Basic policy of repair works

By diligently obtaining adequate field data during inspection and strictly adopting the parameters of the chosen repair methodology and scheme, the system is expected to work out effectively during the design service period of the target facility.

In general, the basic priciple of the chosen repair system can be summarized as follows:

1. For lightly-damaged members where cracks are seen, notch is cut along the line of cracks, then holes are drilled 150mm apart to insert the injection ports. Apply epoxy mortar along the notch and let it cure. Pump/inject the epoxy grout through the injection ports starting from the lowest port going upward to the highest port.
2. For highly-damaged members where rebars are exposed and corroded, evaluate whether rebars should be replaced, or otherwise, clean and apply rust converter prior to application of epoxy mortar to its original geometry.
3. After employing basic principle 1 or 2, finally, wrap the structural members with Fiber Reinforced Polymer system for sealing and prevent the intrusion of chloride ion into the concrete. This will promote superior protection from early deterioration of the repaired components.

5.2 Outline of repair works

Table 5.2.1 Breakdown of repair works for particular scheme

Structural component	Scheme	Quantity
Slab	1	Nothing found under this scheme
	2	180 panel of 3 m x 3 m 98 panel of 1.5 m x 3 m 4 panel of 1.5 m x 1.5 m
	3	3 panel of 3 m x 3 m 2 panel of 1.5 m x 3 m
Beam	1	94 of length 3 m 104 of length 1.5 m
	2	302 of length 3 m
	3	19 of length 3 m
Piles	1	307
	2	81
	3	37

6. FUTURE MAINTENANCE PLAN

Periodic survey and inspection of the rehabilitated structures of R.C. Pier-2 is programmed by the Port Management Office of Tacloban to monitor the condition of the structure and detect possible early deterioration. With this, early maintenance shall be employed to achieve the expected service period of the target facility.

Shown above are the actual photographs of the completed repair project of R.C. Pier-2 at the Port of Catbalogan.

Thailand

1. OUTLINE OF TARGET STRUCTURE

Table 1.1 Outline of the target structure

Target structure	Koh-Sri chang wharf
Structure type	Reinforcement concrete Jetty (Foundation: steel pipe piles with in-situ cast concrete, Deck: pre-stressed slabs)
Management body	Local municipality (Koh-Sri chang)
Length	341 m
Area	3030 m^2
Water depth	-4 m (MSL), HWL = 0.914 m, LWL = -0.975 m
Expected vessel	Passenger ferry and fishing boat with length up to 20 m
Completion at	2001
Service start at	2001
Purpose	Passenger and multi-purpose terminal

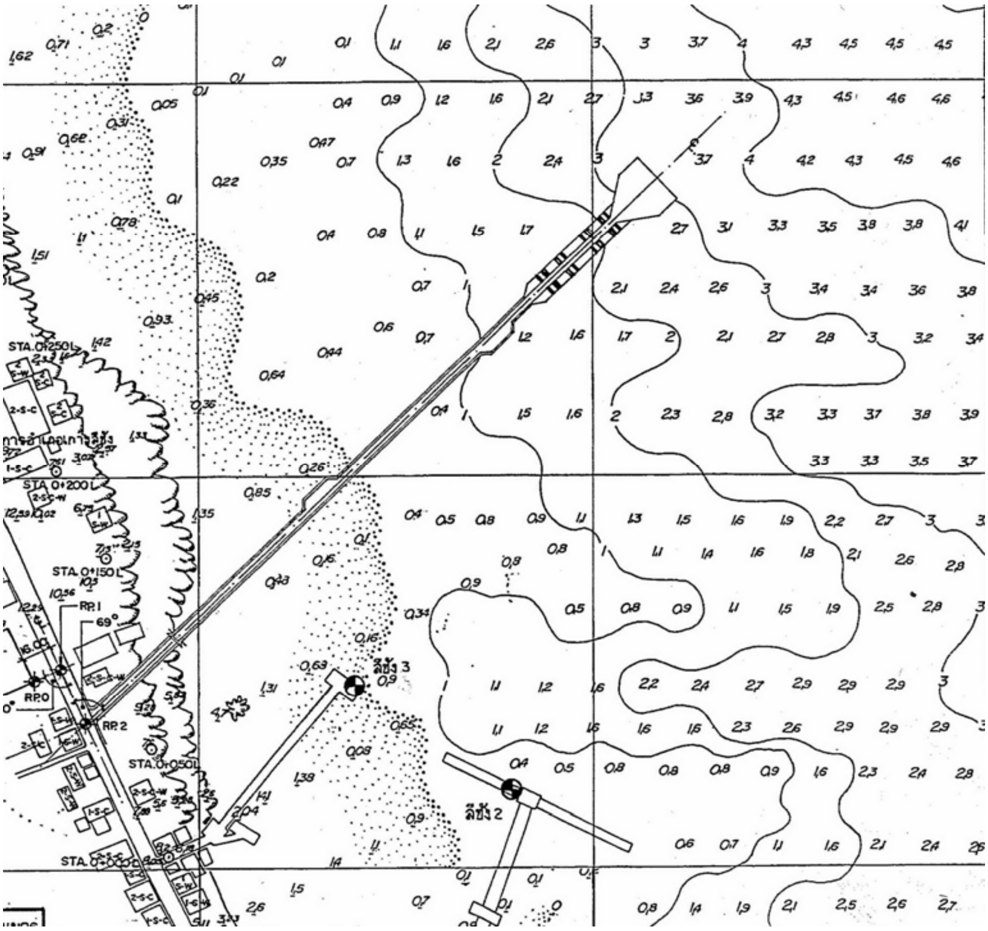


Figure 1.1 Plan view (From navigation map)


Figure 1.2 View of Sri Chang jetty

Figure 1.2 Bridge to the wharf

Figure 1.3 Wharf with fishing boats

2. MAINTENANCE POLICY AND PROCEDURE

2.1 Maintenance strategy

The maintenance strategy for port can be categorized into 3 levels (Table 2.1.1). Identification of the maintenance strategy is essential to determine countermeasure for repaired structure. Generally, the primary principle is to maintain the performance of each structural component to satisfy requirements over the service period.

Table 2.1.1 Maintenance strategy

Level	Comments
1	No performance degradation is expected over the service period. It is ensured that deterioration and deformation affecting their performance are minor at all time until the end of its use.
2	Performance degradation is controlled. Periodic inspection is conducted to detect any deformation at early stage. Minor countermeasures are executed repeatedly to maintain the performance above the maintenance limit.
3	Performance degradation is expected. Major countermeasures are executed as a collective maintenance once or twice over the service period in order to maintain the performance of components beyond the design requirements.

The deterioration grade of structure is classified based on the performance degradation. Basically, the judgment criteria for each deterioration grade is shown in Table 2.1.2.

Table 2.1.2 Classification of deterioration grade

Grade	Basic policy
A	Basic judgment criteria
B	Performance of component is seriously deteriorated
C	Performance of component is deteriorated
D	Performance of component is slightly deteriorated with some deformation

In consideration with maintenance strategies and deterioration grades, a visual inspection on the target structure is conducted to identify the deterioration grades. To consider a maintenance strategy for the repair work, important factors, such as the facility use, suspension of service, remaining service period, etc. are taken into consideration. As a result, proper maintenance strategies are selected as shown in Table

2.1.3.

Table 2.1.3 Maintenance strategy of the target structure

Components	Strategy	M.L.	Comments
Pre-stressed concrete slab	Level 2	Grade A	Most slabs are <u>seriously deteriorated</u>, and pose danger to environment<u>. All pre-stressed slabs are to be replaced with more durable slabs</u>. After replacing slabs, short term of the service restriction due to partial repair, such as protective coating, is possible.
Concrete beam	Level 2	Grade B	Concrete beams are extensively deteriorated. <u>It is decided that a repair work is to be made at the same time as the pre-stressed slab.</u> After completion of repair work, short term of the service restriction due to partial repair, such as protective coating, is possible.
Hand rail and curb	Level 2	Grade B	Hand rails and curbs are deteriorated extensively. Some deterioration is more serious than others. After completion of repair work, short term of the service restriction due to partial repair, such as protective coating, is possible.
Passenger shelter	Level 3	Grade A	Shelters <u>are seriously deteriorated</u>. A repair work requires an immediate replacement of the shelter with more durable materials.
Steel pile	Level 1	Grade C	As the reinforcement concrete is casted in the steel pipe, it is not possible to investigate its bearing capacity. Visual inspection on the steel pipe surface reveals <u>rust stain extensively seen over the splash zone</u>. A repair work is to remove rust stain and conduct protective coating successively.

*M.L.: maintenance limit

2.2 Expected service period

Although the designed service life of the target structure is approximately 50 years, the inspection on each component shows that serious deterioration occurs at early stage mainly due to corrosion problem. An investigation on each component of the target structure was made, by means of conducting a visual inspection as well as studying the design condition, such as the type of concrete, covering distance, facility use and effect from tidal level. The result reveals that several factors led to deterioration at early stage, such as unsuitable type of concrete, insufficient covering distance of reinforcement, false workmanship during construction process, etc.

Due to request for the repair work made by the local management body, it is decided that the major repair work to be made in order to maintain performance of the target structure above the requirement over the designed service life. In addition, small-scale repair work will also be implemented at some stage in the future to ensure the required performance of the structure.

2.3 Maintenance procedure

Step 1: Inspection (see Chapter 3)

Step 2: Assessment (see Chapter 4)

Step 3: Countermeasures (see Chapter 5)

Step 4: Future maintenance plan (see Chapter 6)

3. INSPECTION

Primary inspection was conducted on the target structure in March 2009. The deterioration level of each component is defined using the criteria of deterioration grading similar to the Japanese prototype. The result is shown in Table 3.1.1

Table 3.1.1 The criteria for deterioration grading.

<table>
<tr><th>Inspection area</th><th colspan="2">Criteria</th></tr>
<tr><td rowspan="4">Visual inspection conducted on;
- Dimension of crack
- Number of crack
- Concrete covering
- Rust stain
- Deformation</td><td>A</td><td>Slab:
- Map cracking (over 50%)
- Spalling off of concrete cover
- Heavy rust stain
Beam
- Crack along reinforcement > 3 mm wide
- Spalling off of concrete cover
- Heavy rust stain</td></tr>
<tr><td>B</td><td>Slab
- Map cracking less than 50%
- Much rust stain
Beam
- Crack along reinforcement < 3 mm wide
- Much rust stain</td></tr>
<tr><td>C</td><td>Slab
- One directional crack or gel extraction
- Partially extended rust stain
Beam
- Vertical crack to longitudinal direction
- Partially extended rust stain</td></tr>
<tr><td>D</td><td>Nothing observed</td></tr>
</table>

- Slab:

  - The pre-stressed slabs of 1.0 x 6.0 x 0.25 size were constructed for the connection bridge, while the in-situ casted slabs for the jetty terminal. Serious deterioration is visually observed on the pre-stressed slabs, whereas the in-situ cast concrete slabs show little deterioration. The visual inspection observes map cracks more than 50% and covering concrete spalling heavily to the surface of rebar.

- Beam:
    - Different deterioration grades are observed on the beams. The deterioration grade A appears longitudinal cracks larger 3 mm wide along the main rebar, and the deterioration grade B appears both longitudinal and vertical cracks less than 3 mm wide. Rust stain is clearly observed extensively on the beam surface.

- Hand rail and curb:
    - Hand rails and curbs are partially deteriorated with different grades. For serious deterioration, large cracks with heavy rust stain on the concrete surface require a renewal of the structure. Whereas, less deteriorated part can be repaired according to the concrete repairing work.

- Passenger shelter:
    - <u>The concrete columns are severely deteriorated</u> with large cracks and heavy spalling off , and therefore an immediate repair work is required. It is decided that a renewal of the entire structure is to be implemented as a countermeasure.

- Steel pile:
    - The surface of steel piles is apparently corroded with rust stain, especially within splash zone area. Given the pile is constructed as a steel pipe with reinforcement concrete which forms a main part for bearing capacity, the corrosion on the surface is believed to have no effect on the bearing capacity. However, a countermeasure is selected to remove the corrosion and enhance the steel pipe surface with protective coating.

- Other components:
    - The pavement is still in good condition. A few square meters of crack is detected, and thus a concrete repairing work is recommended.
    - All bollards are deteriorated with small cracks and rust stain. Minor repair work is recommended.

4. ASSESSMENT

Despite the target structure is in an early stage of service life period (9 years), the main components, i.e. pre-stressed slabs, beams are deteriorated to some extent mainly as a result of corrosion. Investigation led to a conclusion that the main causes of early deterioration are due to insufficient concrete covering, inferior concrete mix design, and false workmanship during construction process. The thickness of 4 cm concrete covering was inadequate for such construction located in marine environment. The cement type-I, which was used for the pre-stressed slabs and other relevant RC components, provided no protection against Chloride and Sulphate penetration. The problem with false workmanship is subject to the inappropriate manner in removing the rebar that were used as parts of the scaffolding. The remaining holes after removal of the rebar were not sealed properly, and consequently led to Chloride and Sulphate penetration. These abovementioned processes were the causes for deterioration of each component at early stage.

During an assessment, there is concern for the elevation of the structure. Some hypothesis claims that the jetty is too low considering the tidal level, therefore is a main cause for early deterioration. However, there is evidence to prove of its irrelevant matter as the in-situ cast concrete slabs, which were at the same height as the severely deteriorated pre-stressed slab, showed no significant sign of deterioration. In conclusion, the main causes for early deterioration of each component are subjected to the inappropriate concrete type, inadequate concrete covering and the holes of the removed rebar. Therefore, the consideration for countermeasure gives special attention to these problems.

In consideration with the deformation chain, the deteriorated pre-stressed slab is considered as a major concern as it forms the main functional performance of the target structure. Therefore, the selection of maintenance strategy for the pre-stressed slab inevitably influences the solution for other components. The maintenance strategy III is chosen as a countermeasure for the deteriorated pre-stressed slabs as they were severely deteriorated, and thus required immediate replacement with more highly durable material. For other components, i.e. beams, hand rails and curbs, the selection for the countermeasure takes into account, apart from the deterioration status, the serviceability of the target structure. The local management body who is in charge of the operation of the jetty, requests that the repair work should be completed at once, in order to avoid frequent interference to its operation. Therefore, the concrete repair work is then selected as a countermeasure for all of the deteriorated RC components.

In consideration with the deterioration of the steel pipe with in-situ cast concrete, the importance of the component plays a key role in the selection of the maintenance strategy. Despite small corrosion posing little effect to the bearing capacity, it is decided that the maintenance strategy I is chosen as a conservative countermeasure.

In conclusion, a large-scale repair work is decided to be carried out in order to maintain the performance of each component above the requirement over the designed life service, as well as to satisfy the request of the municipality regarding the serviceability of the jetty. Moreover, for the remaining service life of the target structure, the maintenance strategy II is expected to be conducted in order to achieve a reasonably cost-effective repair work according to the life cycle management theory.

5. COUNTERMEASURE

5.1 Basic policy of repair works

The selection of the repair work method is dependent with the characteristic of each component and the deterioration grades. For the pre-stressed slabs, the severely deteriorated parts with the deterioration grade a require immediate replacement. The existing slabs are to be demolished, removed, and replaced with more highly durable slabs, respectively.

For the beams, hand rails and curbs, the inspection result shows both small and large corrosion cracks, delamination and spalling. The repair work method is chosen accordingly, with small deterioration condition, surface coating is to be implemented, whereas large deterioration condition, cross-section restoration and surface coating is chosen as a countermeasure.

Despite insignificant impact of the corroded surface of the steel pipe, the maintenance strategy I is chosen in order to prevent further major deterioration. The surface coating is to be implemented to the steel pipe surface.

In general, basic principle of the repair work procedure can be summarized as follows (refer to the Japanese prototype, p. JPN-10 –JPN-11);

1. When cross-section restoration is applied as the remedial measure, concrete shall be removed to a depth behind the reinforcing steel bars (2 cm as recommended)
2. When the cross-sectional loss of a reinforcing steel bar is more than 10%, the bar shall be reinforced by an additional steel bar.
3. The cover depth of reinforcing bars at the repaired part shall be more than 70 mm. This is realized by enlarging the cross-section at the repairing section.
4. The most appropriate cross-section restoration method shall be applied to the RC deck in consideration of the work efficiency, which depends on the restoration area, volume and working environments etc. In general, cross-section restorations by mortar spraying and mortar grouting are recommended to be applied to slabs and beams respectively.
5. Surface coating shall be applied to all the bottom surface of the RC deck.
6. The repair work on the steel pipe surface should be implemented in consideration with workability condition due to tidal level.

5.2 Outline of repair works

Table 5.2.1 lists the quantity of repair work applied to each component.

Table 5.2.1 Quantity of repair work

Item	Quantity	Remark
1. Demolish and remove pre-stressed slabs	1,632 m^2	
2. Repair beam B1, B2, B3, B4, B4X, B5, B8		
3. Replacement pre-stressed slab	1,632 m^2	
4. Concrete pavement	1,632 m^2	
5. Curb (0.25 x 0.20 m.)	18 m	
6. RC Hand rail	116.2 m	
7. Walk way	32.2 m	
8. Bollard	20 unit	
9. Protective coating	3,951 m^2	

6. FUTURE MAINTENANCE PLAN

The repair work is conducted in order to maintain the performance of the target structure above the requirement <u>over the remaining service period (approximately 40 years)</u>. During the service period, minor repair work will be periodically carried out to ensure the required performance.

Vietnam

1. OUTLINE OF TARGET STRUCTURE

Table 1.1 Outline of the target structure

Target structure	Wharf number 7,8, Hai Phong main Port in Hai Phong city
Structure type	Steel pipe pile with a layer of steel anchor
Management body	Hai Phong Port
Length	Wharf number 7: 163.6 m; Wharf number 8: 163.6 m; Total: 327.2 m
Water depth	-8.7 m
Expected vessel	10,000 DWT
Completion at	1973, 1974
time check	2007
Purpose	General berth

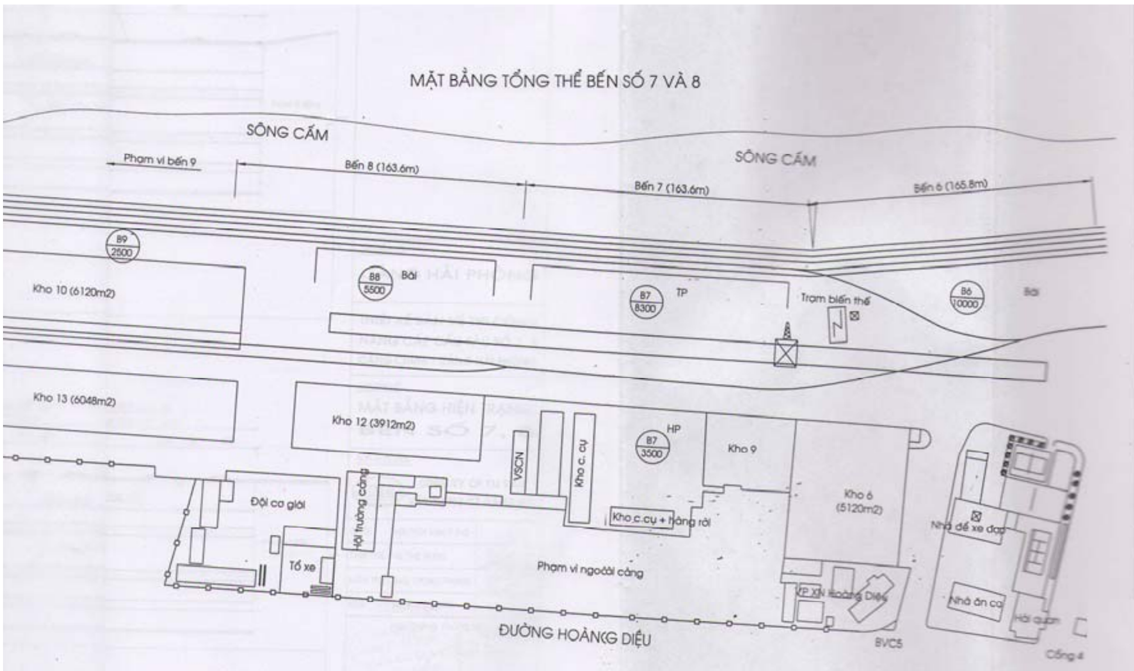


Figure 1.1 Plan view of Wharf

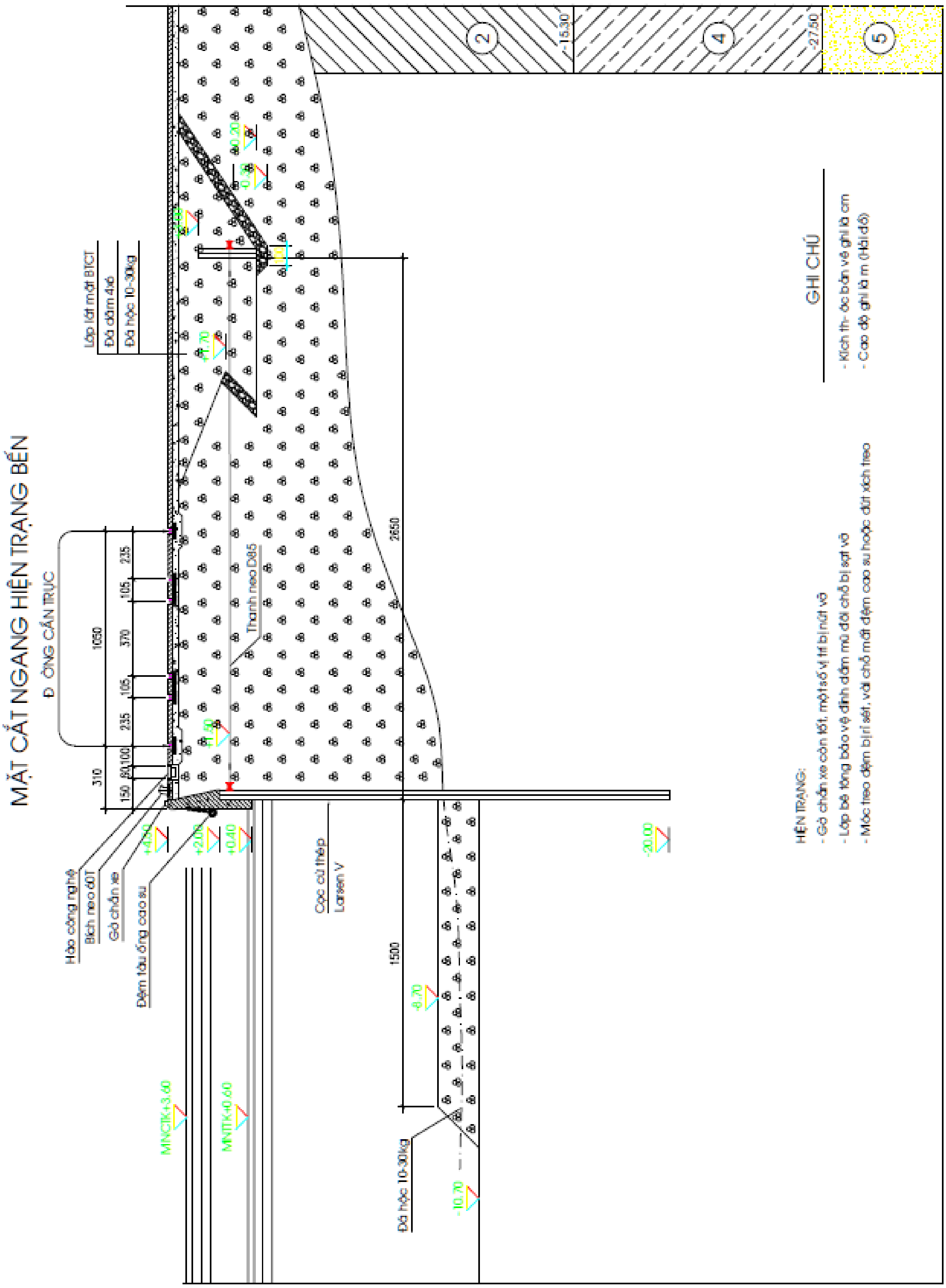


Figure 1.2 Cross-sectional view

2. MAINTENANCE POLICY AND PROCEDURE

2.1 Maintenance strategy

In the past, Vietnamese ports were less interested in maintenance issues, Ports only repair when damage occurs. The maintenance of the port received more attention than the past when Vietnam Maritime Administration has Decision 109/QD-CHHVN on 10th March, 2005 promulgate regulations of operation port techniques Including provisions for periodic inspection port as follows:

- Wharf structures by reinforced concrete: 1 time for 5 years;
- Wharf structures by steel piers: 2 times for 5 years
- The auxiliary equipment on the wharves: 1 time for 1 year.
- Depth water area of the port, at least once time a year.

Ports are only receiving the anchoring of vessels, cargo handling when test results are sufficient safety conditions in accordance with design.

2.2 Maintenance procedure

<u>Step 1: Inspection (see Chapter 3)</u>

Survey of natural conditions
Surveying the current status of port

<u>Step 2: Assessment (see Chapter 4)</u>

Evaluation of the quality status of the port
Evaluate bearing capacity of the port works
Assessment capability to ensure stability of the port works

<u>Step 3: Countermeasures (see Chapter 5)</u>

Conditions specified port operators
Repair works carried out ports

<u>Step 4: Future maintenance plan (see Chapter 6)</u>

3. INSPECTION

3.1 Survey of natural conditions

3.1.1 Meteorological Characteristics

- Wind: Prevailing wind direction and wind speed.
- Storm: The number of hurricanes in the port area and the maximum wind speed in storm.
- Rain: The total rainfall, monthly rainfall average maximum and minimum

3.1.2 Hydrological characteristics

- Tides: style of tidal in the region, the highest water level, the lowest water level
- Water flow: Water flow into larger water season and low water season, the average speed.

3.1.3 Geological conditions

The soil layer thickness and the consolidation of soil.

3.2 Surveying the current status of port

3.2.1 Survey measurements

- Measuring the elevations of parts of the work ports
- Measured the size of parts of the work ports, the distance between the Bollards, between the foot crane, crane rails and trains.

3.2.2 Visual inspection and describe the current status of the port works

*) Observations and describe the current state of the structural parts include:

- Concrete in front of wharf
- Concrete cap beams, pedestal Bollard, cover trench technology, vehicle barriers on the wharf
- The status textured back yard wharf
- The state of the Fender system
- The status of Bollard 75T

*) Quality inspection of parts of reinforced concrete structures with modern equipment:

- Check the strength of reinforced concrete by means of shooting
- Check the consistency of concrete by ultrasonic method

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4. ASSESSMENT

4.1 Evaluation of the quality status of the port

a. Structural of key wall:

Port straight line and ensure the position does not move to the water area.

Table 4.1 The sum results of quality control sections of reinforced concrete wharf number 7

No	Parts of the port structures	Concrete strength (Kg/cm^3)	Homogeneity of the concrete	comments
1	Reinforced concrete wall outside the beam caps	331.18	0.912	Good
2.	Reinforced concrete cap beams.	335.20	0.910	Good
3	Bollard base	333.26	0.908	Good
4	reinforced concrete block car	341.95	0.914	Good

Table 4.2 The sum results of quality control sections of reinforced concrete wharf number 8

No	Parts of the port structures	Concrete strength (Kg/cm^3)	Homogeneity of the concrete	comments
1	Reinforced concrete wall outside the beam caps	333.39	0.920	Good
2.	Reinforced concrete cap beams.	330.21	0.911	Good
3	Bollard base	333.27	0.917	Good
4	reinforced concrete block car	340.11	0.914	Good

b. The structure of the port and yards:

In the process of exploitation wharf number 7 and 8 were conducted on a regular basis to repair the damage or degradation of surface structures and yards to safe for production.

c. Rail system:

Crane rail system has been repaired and replaced all of the new sleepers, laying asphalt surface within the range between the rails, safe to operate.

d. Bollard:

There are 12 Bollards 75T of 2 wharf ensure the quality, not cleft or crack.

e. Fender:

Fender with rubber cylindrical form F400-200, L = 2 m horizontal hanging position has some damage:

- Broken chain on one side and it drops below: 06 fender
- Broken chain dropping fender loss: 04 fender

f. Steel pipe pile - Larsen V

Determine the thickness of the steel pile left:

No	Wharf	Year (Build-check)	years operation	Corrosion speed (mm/year)	Thickness of Steel pipe pile corroded (mm)	Thick steel pipe piles left (mm)
1	Number 7	1973-2007	34	0.062	2.108	18.892
2	Number 8	1974-2007	33	0.062	2.046	18.954

4.2 Evaluate bearing capacity of the port works

4.2.1 Check the bearing capacity of the facility

- Check the biggest stresses in piles corresponding to the thickness of steel pipe piles Left.

No	Wharf	$\sigma^{TC}max$ (kg/cm^2)	$\sigma^{TT}max$ (kg/cm^2)	$[\sigma]$ (kg/cm^2)	comments
1	Number 7	1196.2	1704.6	2800	Good
2	Number 8	1470.9	2096.1	2800	Good

- Check the depth of buried piles.

No	Wharf	Tmax (m)	T request (m)	T current (m)	comments
1	Number 7	8.80	9.91	11.3	Good
2	Number 8	9.86	11.18	11.3	Good

- Check the conditions in tension in the bar anchorage.

No	Wharf	σ^{TC}max (kg/cm^2)	σ^{TT}max (kg/cm^2)	[σ] (kg/cm^2)	comments
1	Number 7	1272.5	1813.3	2100	Good
2	Number 8	1390.9	1982.0	2100	Good

4.2.2 Check the bearing capacity of Bollard 75Tons

S^{TT} = 61.5 Tons < 75 Tons

Comments: Good

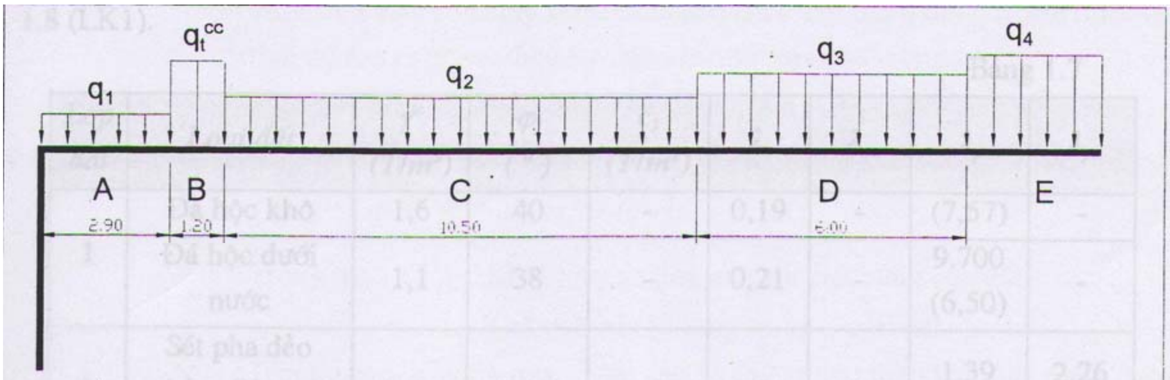
4.2.3 Check the strain energy of the fender F 400-200, L =2000 m

$E_{\Phi400}$ = 3.44 Tm Deformation corresponding fender is 50 %

- By 22 TCN 122-94 $E_{\Phi400} < Eq = 5.5$ Tm
- By Sumitomo $E_{\Phi400} < E = 7.5$ Tm

Comments: fender is not enough capacity to work as designed.

4.3 Acssment capability to ensure stability of the port works



Hình 1.4: Sơ đồ tải trọng khai thác trên bến

No	Load	Type of load	Regional arrangement	Range layout
1	$q1= 2.0\ T/m^2$	Goods	A	From the edge of wharf to the front of foot crane.
2	$q1^{CC} = 6.96\ T/m^2$	2 cranes next to each other	B	Within the front of foot crane.
	$q1^{CC} = 6.64\ T/m^2$	A crane.	B	Within the front of foot crane.
3	$q2= 4.0\ T/m^2$	Goods	C	From back edge of the front of bridge crane to the rear end of the bridge crane.
4	$q3= 6.0\ T/m^2$	Goods	D	From the back edge of the bridge crane to the rear behind yard 6m
5	$q4= 10.0\ T/m^2$	Goods	E	Continuation region D on the rear yard
6	$H_{NEO} = 5{,}03\ T/m$	force ships anchor		put at the edge of wharf

Table 4.3.1 Check the stability of the sliding flat ground anchors block piers

No	Wharf	Case load	Kmin	[K min]	comments
1	Number 7	- Design load - reduce the load q3 to the outer edge of the wheel can slide the wall anchors	1.422 2.341	1.565 1.565	Good
2	Number 8	- Design load - reduce the load q3 to the outer edge of the wheel can slide the wall anchors	0.955 1.905	1.565 1.565	Good

Table 4.3.2 Check the stability of the entire slide deep piers by sliding surface arcs

TT	Wharf	Case load	Kmin	[K min]	comments
1	Number 7	- Design load	0.704	0.978	Not enough
		- Reduce the load q3 on a rear yard, the remaining load is q4	0.792	0.978	
		- Reduce the q3 load on the entire rear, unused payload q4	1.023	0.978	Good
2	Number 8	- Design load	0.699	0.978	Not enough
		- reduce the q3 load to the outer edge of the wheel can slide the wall anchors.	0.749	0.978	
		- Reduce the load q3 on the entire rear, unused payload q4	1.018	0.978	Good

5. COUNTERMEASURE

5.1 Conditions specified port operators

5.1.1 For vessels up to 10,000 DWT up to and anchoring at the wharf with conditions

- Speed boat dock: $V_t = 0.12$ m/s
- Maximum wind speed allowed when the ship moored at wharf: $V_g = 18$ m/s
- Maximum water flow speed: $V_c = 2.38$ m/s

5.1.2 For the buffer vessel

When the ships dock should have to tug boats and ships designed to ensure a collision while at least two fenders to speed vessel mentioned in 5.1.1.

5.1.3 Controlled load port operators in the following diagram

- From the edge of wharf to the front of foot crane: q1 = 2 T/m^2
- Within the foot crane: q2 = 4 T/m^2
- From the back edge of the bridge crane to the rear behind yard 6m: q3 = 6T/m^2

5.2 Repair works carried out ports

- For an existing concrete structure is damaged, to conduct light chiseling, rough and pour concrete to create and perfect each section.
- Repair fender F400-200, L = 2000 on positions lost or fall off the chain.

6. FUTURE MAINTENANCE PLAN

- Check regularly and periodically in accordance with the port works for early detection and maintenance organization works to ensure safe operation.
- Held soon replaced the fender system capable of absorbing energy of ship design.
- Over time, the key wall systems of Hai Phong main port by Larsen V steel pile will be corroded more and more and it will make to reduce of bearing capacity and lifetime of the project. Therefore, solutions should have anti-corrosion soon, protect for the old system and other parts of the steel piers under the Hai Phong main port.

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