Deep-sea Port Construction and Maintenance Techniques

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2. Recent construction cases of mooring facility at deep-sea in Japan & deep-river in Myanmar

3. Maintenance techniques (with an example case)

4. Mooring facility (structure type, design concept, construction techniques)

5. Annex (Technical Standards and Commentaries for Port and Harbour Facilities in Japan)
1. Port components (mooring facilities)

- **WHARF**: a structure built along or oblique to navigable waterway, with sufficient water depth to accommodate vessels to receive & discharge cargo or passengers.

- **QUAY**: same as wharf, with solid structure providing berthing on one side and retaining the earth on the other side.
1. Port components (mooring facilities)

Cruise ship pier (Sihanoukville port, Cambodia)

Oil jetty

Quay / wharf

Quay / wharf

PAS’s homepage

https://www.pfri.uniri.hr/bopri/documents/14-ME-tol_001.pdf
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1. Port components (mooring facilities)

2. Recent construction cases of mooring facility at deep-sea in Japan & deep-river in Myanmar

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(1) Pier structure (Onahama port)

Overview of Onahama Port

Enhance the transportation efficiency by increasing the size of ships

Current status
Panamax ships (78,000 tons class) enter to port with reduced load.

After improvement
Cape size ships (120,000 tons class) can enter to port with full load.

* Panamax ship
The largest ships that can pass through the Panama Canal (carrying capacity 60,000 - 80,000 deadweight tonnage (DWT)).

* Cape size ship
Ships that cannot pass through the Panama Canal, so have to travel around the Cape of Good Hope at the southern end of Africa (large bulk carrier capable of carrying 100,000 - 150,000 DWT).

- Planned water depth -18m, design water depth -20m
- Target vessel: 120,000 tons of coal ships (for thermal power plant)
- Use existing breakwater (caisson type) as a retaining structure behind the pier (behind the land reclamation yard)

**Source: All photos and figures were provided by Ohahama port construction office of MLIT
(1) Pier structure (Onahama port)

Quay (-20.0m) standard cross-sectional view

- Deck height: 3.5m
- Depth: -20m
- Crain rail span: 25m
- Caisson width: 12.6m

[Diagram showing the details of the pier structure]
(1) Pier structure (Onahama port)

Cross section of pier

- Foundation: Steel pipe pile (φ1500mm, \( t = 16-35 \text{mm} \)).
- Superstructure: PC prestressed concrete girder
- In recent years, the number of piles has been reduced to lower the cost, but the load per pile has increased.
- Superstructure: use factory-constructed PC members in consideration of light weight and durability.
- Furthermore, at this site, the seabed is hard with a mudstone layer, so the normal method of “Pile driving by hammer” is not applicable.
(1) Pier structure (Onahama port)

- New construction method (RS plus™) was adopted to secure the supporting force and pulling resistance of the foundation.
- Drilling with WJ-Vibro hammer → Advanced cement milk (to ensure tip bearing capacity) → Peripheral cement milk (to secure skin frictional force).

**Construction process**

1. Vibrohammer
2. Water jetting
3. Cement milk jetting on pile tip
4. Jetting pile
5. Soil cement block
6. Center jetting
7. Peripherally cement milk filling concept
8. Steel pipe inner rib plate method

- Steel pipe inner rib plate method
- Nozzle status at the bottom of steel pipe pile

(2) Cellular Bulkhead type Quaywall (Yokohama Port)

**Japan’s first! Container terminal for the world’s largest container ship**

In 2015, MC-3 terminal was completed and started service. With quay Depth of 18m, it became the deepest in Japan, and 4 cranes of 24 lines, makes it possible to accommodate super big ships.

**MC3 Quay (seismic resistant):**
- Plan depth: -18m
- Design depth: -20m
- Length: 400m (large class container ship)

**MC3 Yard:** Capacity: 13,000TEU.

**Source:** All photos and figures are provided by Keihin port construction office of MLIT

(2) Cellular Bulkhead type Quaywall (Yokohama Port)

- The largest steel plate cell quay in Japan was adopted due to seismic performance, workability, cost, etc.

Cross-sectional view of quaywall

- Crane rail span 30m
- Piles for rail foundation $D1.3m, L35m, 17t, ctc 5.5m$
- Steel Cell $D=24.5m$ $L=32m$
- Stones $D1.3m, L35m, 17t, ctc 5.5m$
- SCP (As=78.5%)
- CDM (As=50%)
- SCP (As=78.5%)
- Reclaimed soil
- Deck
- D.L -20m
- D.L +4m
- Backfill stones
- SD

SCP: Sand Compaction Pile method
CDM: Cement Deep Mixing method
SD: Sand Drain method
(2) Cellular Bulkhead type Quaywall (Yokohama Port)

① The steel plate cell is assembled on land.
② Lift the cell with a crane ship, move it by sea, and install it at site.
③ Just after installation, fill the soil inside the cell to stabilize the structure.

Floating crane (1,800t lifting capacity)
(height: 32m, weight about 400t)

Hanging of steel cell by floating crane

Crane barge (2000m³/h)
(2) Cellular Bulkhead type Quaywall (Yokohama Port)

① MC4 is also under construction by adopting the same steel plate cell quay (quay body was already constructed).

② As a future plan, there is a plan for Shin-honmoku Pier (planed water depth -18m, berth length 1,000m).

At present, we have heard that the new berth at Shin-honmoku Pier will also adopt the same steel plate cell quay.
(3) Jacket type Jetty (Thilawa Port, Myanmar)

Deep-river Port

Construction of Jacket-type Jetty of Thilawa port, Yangon River, Myanmar

Owner: Ministry of Transport, Myanmar Port Authority (MPA)
Contractor: Toyo Construction Co., Ltd. + JFE Engineering Corp. (JV)
Consultant: Nippon Koei
Construction period: 01/01/2016-03/12/2018
Field Conditions

- Rainy season: May-Oct, Dry season Nov-Apr.
- Rainfall 3,000mm (Peak: Jul-Aug)
- River: Max tide level difference = 6m, flow velocity = 6 knots (3m/s)
- Soil quality: about 20m of the surface layer is viscous soil with N=1-2

Design Conditions:
- Container ship: 20,000DWT (1,000TEU) × 2 berths
- Length of overall (Loa) = 177m
- Full load draft: 9.0 m
- Berth Length: 400m (200m × 2 berths)
- Berth planned depth: -10.0 m
- Quay deck height: +7.5 m
(3) Jacket type Jetty (Thilawa Port, Myanmar)

Typical Cross-sectional view of Jetty-type pier

- Crest height +7.5m
- Crane span 16m
- H.W.L +6.24
- M.W.L +3.28
- L.W.L +0.33
- Planned depth -10m
- Design depth -14m
- River bed -20

(3) Jacket type Jetty (Thilawa Port, Myanmar)

Outline of Jacket structure for Jetty

Steel Pipe Pile

- SPP driving
- Installation Jacket
- Installation pre-cast concrete slab and placing in-situ concrete

Overview of Jacket

Jacket size: 20m × 40m
Jacket weight: 245 ton/unit
Number of jackets: 20

Leg Pipe: Ø1552, 36t
(3) Jacket type Jetty (Thilawa Port, Myanmar)

Features of the jacket system

- Horizontal rigidity (3D-truss)
- Lightweight superstructure
- Jacket & concrete slab are constructed at the production yard on land, (shortening the construction period).
- Underwater work is almost unnecessary

Fabrication of Jacket

Number of pipes can be reduced.

Fabrication of pre-cast concrete slab
(3) Jacket type Jetty (Thilawa Port, Myanmar)

① Sifting on land side
② Lifting by crane barge (500t)
③ Shifting on river side
④ Installation

Move with roller
Temporary quay
Move by anchor
1. Port components (mooring facilities)

2. Recent construction cases of mooring facility at deep-sea in Japan & deep-river in Myanmar

3. Maintenance techniques (with an example case)

4. Mooring facility (structure type, design concept, construction techniques)

5. Annex (Technical Standards and Commentaries for Port and Harbour Facilities in Japan)
3. Maintenance techniques

Deterioration of superstructure (RC) of pier

Corrosion of steel bars in concrete of superstructure

Spalling of cover concrete

Breakage of bars
3. Maintenance techniques

Deterioration of superstructure (RC) members due to chloride ion

- Diffusion of Chloride Ion
- Corrosion
- Occurrence of the Longitudinal Crack
- Spalling of the cover concrete

Performance curve

Initiation stage
Propagation stage
Acceleration stage
Deterioration stage
3. Maintenance Techniques

### Maintenance strategy

<table>
<thead>
<tr>
<th>Type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>No performance degradation is expected. Performance is always kept above the maintenance limit.</td>
</tr>
<tr>
<td>Type II</td>
<td>Minor countermeasures are repeatedly applied to keep the performance above the maintenance limit.</td>
</tr>
<tr>
<td>Type III</td>
<td>Major countermeasures may be applied once or twice for performance recovery.</td>
</tr>
</tbody>
</table>
3. Maintenance Techniques

Ex. Maintenance strategy

- Important structural component
- No substitutability
- Difficult to conduct maintenance work

Aluminum galvanic anode (Cathodic protection)
3. Maintenance Techniques

Ex. Maintenance strategy

Type II

✓ Important component to keep the serviceability of wharf
✓ Substitutability (possible to repair/update)

Type I

Cost of Epoxy-coated rebar is 2-time higher than the normal bars but, Life-cycle cost (LCC) is reduced.

- Important component to keep the serviceability of wharf
- Substitutability (possible to repair/update)
3. Maintenance Techniques

Ex. Maintenance strategy

- Good substitutability (Easy to update)
- Not important structural component
Lesson learned from bad maintenance example in Japan

Bad maintenance example in Japan

Open type wharf in Yokohama port
1969 Construction
1987 1st repair work (Surface coating) without inspection and deterioration prediction
1999 Re-deterioration
  Detailed inspection
2001 2nd repair work (Rust-proofing of steel bars, patching repair and surface coating)

Patching (cross-sectional restoration)
Restructuring a concrete section where deterioration part was removed

Surface coating
To prevent infiltration of hazardous substances, such as chloride ion and carbon oxide, into concrete by coating materials

Step 1
2
3

Inner: epoxy resin
Top: epoxy resin

Remedial measures for **removing chloride ion from the concrete** or **electrochemical repairs** before surface coating were necessary to ensure the long-term performance of surface coated RC members.
“The Guidelines on Strategic Maintenance for Port Structure” aims at providing developing countries, particularly ASEAN countries, with assistance to appropriately maintain their various port structures such as concrete structures and steel structures.

Utilization of Guidelines

- Providing basic concepts when ASEAN member countries formulate their own maintenance manual of port structures
- Providing beneficial references when ASEAN member countries plan and execute inspection and/or repair works to port structures
- Providing a good guide when the basic concepts of strategic maintenance are widely developed to other countries than ASEAN

Source: Modified from NILIM Technical Note No. 769


Image of Cover Page

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

Free download!
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 tackled this issue as three-year projects since 2009.

The three-year research results were compiled as the guideline.

Contents of Guidelines

Part 1 Common Part
1.1 General
1.2 Life-Cycle Management-based Maintenance
1.3 Maintenance Strategy
1.4 Inspection
1.5 Comprehensive Evaluation
1.6 Countermeasure
1.7 Record

Part 2 National Part
1 Japan
2 Cambodia
3 Indonesia
4 Malaysia
5 Myanmar
6 Philippines
7 Thailand
8 Vietnam

Source: NILIM Technical Note No. 769
1. Port components (mooring facilities)

2. Recent construction cases of mooring facility at deep-sea in Japan & deep-river in Myanmar

3. Maintenance techniques (with an example case)

-------------------------------------If time permits-------------------------------------

4. Mooring facility (structure type, design concept, construction techniques)

5. Annex (Technical Standards and Commentaries for Port and Harbour Facilities in Japan)
4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

- **Gravity-type Quaywall**
  - Fender
  - Apron
  - Filling sand
  - Backfilling rubble
  - Caisson
  - Rubble mound
  - Sand invasion prevention sheet

- **Anchored Sheet Pile Quaywall**
  - Fender
  - Apron
  - Tie rod
  - Anchorages
  - Steel sheet pile
  - Coating
  - Cathodic protection

- **Open Type Wharf on Vertical Piles**
  - Superstructure
  - Apron
  - Fender
  - Coating
  - Steel pile
  - Cathodic protection
  - Earth-retaining section

**Data of PAS**
4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

1. Gravity-type Quaywall

*Fig. 2.2.2 Example of Cross Section of Gravity-type Quaywall*

**Concept:** Self weight of caisson, bottom friction

**Good point:** High durability

**Bad point:** Soil improvement is needed for weak seabed layer
4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

1. Gravity-type Quaywall

Basic design concept

- Sliding failure: Equilibrium of horizontal force
- Overturning: Equilibrium of moment (overturn/resistant) at the bottom toe of caisson
- Foundation failure: Equilibrium of moment (Circular slip)
4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

1 Gravity-type Quaywall

![Diagram showing shape of the circular arc using characteristic value and design value (multiplied partial factor)]

- Shape of the circular arc using characteristic value
- Shape of the circular arc using design value (multiplied partial factor)

- **Sand**
  - Internal friction angle \( \phi = 35^\circ \) (characteristic value)

- **Stone**
  - Internal friction angle \( \phi = 40^\circ \) (characteristic value)

(Caisson)
4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

1. Gravity-type Quaywall

Source: http://hitachinaka-port-const.jp/construction.html
4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

1. Gravity-type Quaywall

4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

2. Anchored Sheet Pile Quaywall

**Concept:** Sheet pile as earth retaining, anchor, passive earth pressure

**Good point:** Simple and rapid construction

**Bad point:** Corrosion protection measure is needed
4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

2. Anchored Sheet Pile Quaywall

Basic Design Concept for

- Embedded length: Equilibrium of moment about the attachment point of tie rod
- Cross-section of sheet pile: Cross-sectional force by a simple beam model
- Cross-section of tie rod: Reaction force at the attachment point
In Japan, U-type (maximum width is about 600mm) is most popular for anchored sheet pile quaywall. Recently, a hat type sheet pile with wider width (900mm) has been introduced to reduce construction costs.

Source: http://www.jaspp.com/kouyaita/type.html
4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

2. Anchored Sheet Pile Quaywall

Steel Pipe Sheet Pile

Type of joints

In Japan, “steel pipe sheet pile” is used for anchored sheet pile quay in case of deep sea depth (about 15m at maximum)
In Japan, recently “tie wire” is commonly used instead of tie rod because “tie wire” is much easier to transport and handle at the construction site.
4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

2 Anchored Sheet Pile Quaywall

Steel Pipe Sheet Pile

Placement of tie rod for anchored sheet pile

Landside

Seaside
4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

2. Anchored Sheet Pile Quaywall

Steel Pipe Sheet Pile
Soil backfill
4. Mooring Facility *(Structure type, Design Concept, Construction Techniques)*

3. Open Type Wharf on Vertical Piles

**Concept:** Bearing capacity of pile, Rigid-frame structure

**Good point:** Light weight (suitable to soft ground)

**Bad point:** Less load capacity, corrosion protection measure
4. Mooring Facility (Structure type, Design Concept, Construction Techniques)

3 Open Type Wharf on Vertical Piles

Basic Design Concept

- Cross-section of pile: Cross-sectional force of a rigid frame structure

- Cross-section of superstructure: Cross-sectional force of a beam or a slab

Inertia force by earthquake

\[ q + w \]

\[ P_H \]
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5. Annex (Technical Standards and Commentaries for Port and Harbour Facilities in Japan)
“Technical Standards and Commentaries for Port and Harbor Facilities (TSCPHC) in JAPAN”

<Supervised by Port and Harbour Bureau (PHB) of MLIT, Japan>

[Japanese edition]*
1) TSCPHC 1979
2) TSCPHC 1989
3) TSCPHC 1999
4) TSCPHC 2007

5) TSCPHC (May, 2018)

[English edition]**
1) OCDI 1980
2) OCDI 1991
3) OCDI 2002
4) OCDI 2009***

5) OCDI2020 (Under preparation)

*Used for mostly of domestic port developments in Japan, with a long history and well-experienced.

**Used for mostly of overseas port developments by ODA of Japan.

***Publisher: THE PORTS & HARBOURS ASSOCIATION OF JAPAN (PHAJ)

**Publisher: THE OVERSEAS COASTAL AREA DEVELOPMENT INSTITUTE OF JAPAN (OCDI)

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‘Standard Specifications for Port and Harbor Works’ (2013) (English version)*

Standard Specifications for Port and Harbor Works (2013)

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Thank you for your kind attention!

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