Applications of Passing Vessel and Mooring Analysis: Modernizing the Vessel to Shore Interface

Michael Ajemian and Brent Cooper, COWI North America, will examine mooring and berthing structures at marine terminals and how passing vessel and mooring analyses can be applied to new construction and facility modification designs. They will review the impacts of increased passing vessel loads due to larger ships transiting deeper and wider channels as well as the effects of deterioration and reduction of capacity on existing structures that are approaching the end of their design service lives. The speakers will highlight the basic operations of vessel mooring and berthing, regulatory considerations, and share strategies for inspecting, maintaining, and modernizing waterfront structures at terminal facilities.

ABOUT THE SPEAKERS

Michael Ajemian, P.E., is a chief project manager at COWI North America. He has over 13 years of experience as a marine engineer-diver. He has been the Key Account Manager for a number of marine terminal operators spanning from the Northeast to the Gulf of Mexico. Ajemian has specialized in asset management of marine structures, including inspection, maintenance and rehabilitation. His experience includes above water and underwater investigations, rehabilitation and new structure design, mooring and berthing analysis, passing vessel analysis, and computer based data management systems for waterfront asset management. He also has extensive experience in site construction phase services, including managing and directing site teams responsible for material inspection and testing, rock works, concrete construction, steel construction, construction of floating structures, piling driving, retaining structures and structural rehabilitation.

Brent Cooper, P.E., is a project manager at COWI North America and has 10 years of experience in the field of waterfront civil engineering. As a project manager, he is responsible for executing and managing projects relating to the design, maintenance and rehabilitation of steel, concrete, masonry and timber marine structures. Cooper provides services including site screening, feasibility evaluation, site characterization, vessel operations and loads, new and rehabilitation design, construction scheduling, cost estimating, bid assistance and resident engineering services. His clients include various federal, state and local government agencies, utilities, as well as private and commercial clients in the U.S. and overseas.
Applications of Passing Vessel and Mooring Analysis: Modernizing the Vessel to Shore Interface

Michael Ajemian and Brent Cooper
COWI North America
COWI North America

- COWI NA is the North American arm of COWI
- Three business units with specialists in Marine, Bridge, and Tunnel engineering

Working in 24 countries and 97 international offices
Approx. 6,500 employees
World-class competencies within engineering, economics and environmental science
At any given time, 13,000 ongoing projects
85 years of history
PRESENTATION FOCUS

• Examine the primary marine structures that facilitate safe mooring and berthing at Marine Oil Terminals.

• Explore the various environmental and passing vessel forces which are applied to moored vessels loading and unloading product at bulk liquid terminals.

• Understand the key deterioration mechanisms for various types of mooring and berthing structures and how degradation impacts the demand versus capacity relationship.

• Apply mooring/berthing analyses into the modernization of the marine structures through rehabilitation and/or replacement.
MOORING AND BERTHING STRUCTURES
VESSEL MOTIONS
VESSEL FORCES ON DOCK

Mooring: Tension Force (Pull) of a moored vessel acting through vessel lines upon the dock’s mooring hardware

Breasting: Compression Force (Push) of a moored vessel acting as vessel hull compresses against the dock

Berthing: Reaction force from a fender as vessel makes initial impact upon approaching the dock
APPLIED LOADS

• Environmental
  – Wind
  – Waves
  – Current

• Passing vessel effects
WIND

Wind on Tankers:
• OCIMF

Wind on structures:
• ASCE 7-10
• Site Specific Characterization
WAVES

Wave categorization:
• Height
• Period
• Direction

Sea waves vs. swell waves

Static vs. dynamic analyses
CURRENT

Current categorization:

• Tidal / Non-Tidal
• Ebb / Flood
• Speed
• Direction
PASSING VESSEL EFFECTS

Surge

Sway

Yaw
PASSING VESSEL EFFECTS MODELING

Methodology:


Design Vessels:

• PIANC Report No. 121-2014: Harbour Approach Channels Design Guidelines
  – Table C.1 Typical Ship Dimensions from ROM 3.1
PASSING VESSEL EFFECTS

Variables:

- Moored and/or passing vessel size
- Moored and/or passing vessel draft and Under Keel Clearance (UKC)
- Passing vessel speed
- Passing vessel distance
- Channel depth and UKC
PASSING VESSEL EFFECTS DUE TO VARYING PASSING VESSEL SIZE

Model Assumptions:
- Moored Vessel: 60k DWT, Fully Loaded
- Passing Vessel: 10k-125k DWT, Fully Loaded**
- Ship Centerline Distance: 600 ft.
- Berth Depth: 48 ft.
- Channel Depth: 48 ft.
- Passing Vessel Speed: 6 knots
- **Minimum UKC = 2.0 ft, Vessels drafting greater than 46 ft assumed partially loaded
PASSING VESSEL EFFECTS DUE TO VARYING MOORED VESSEL DRAFT

Model Assumptions:
- Moored Vessel: 60k DWT, Draft Varies 30-42 ft.
- Passing Vessel: 60k DWT, Fully Loaded
- Ship Centerline Distance: 600 ft.
- Berth Depth: 48 ft.
- Channel Depth: 48 ft.
- Passing Vessel Speed: 6 knots
PASSING VESSEL EFFECTS DUE TO VARYING VESSEL SEPARATION DISTANCE

Model Assumptions:
- Moored Vessel: 60k DWT, Fully Loaded.
- Passing Vessel: 60k DWT, Fully Loaded
- Ship Centerline Distance: Varies 400-2000 ft.
- Berth Depth: 48 ft.
- Channel Depth: 48 ft.
- Passing Vessel Speed: 6 knots
PASSING VESSEL EFFECTS DUE TO VARYING PASSING VESSEL SPEED

Model Assumptions:

- Moored Vessel: 60k DWT, Fully Loaded
- Passing Vessel: 60k DWT, Fully Loaded
- Ship Centerline Distance: 600 ft.
- Berth Depth: 48 ft.
- Channel Depth: 48 ft.
- Passing Vessel Speed: Varies 1-10 knots
PASSING VESSEL EFFECTS DUE TO VARYING CHANNEL DEPTH (UKC = 2.0 FT.)

Model Assumptions:
- Moored Vessel: 60k DWT, Fully Loaded
- Passing Vessel: 125k DWT, Partially Loaded**
- Ship Centerline Distance: 600 ft.
- Berth Depth: 45 ft.
- Channel Depth: 45 - 55 ft.
- Passing Vessel Speed: 6 knots
- **Under Keel Clearance (UKC) = 2.0 ft, Vessels partially loaded to maintain UKC
DEMAND VERSUS CAPACITY

The demand on a structure must always be less than the capacity:

\[ \frac{D}{C} \leq 1.0 \]

- Structures deteriorate over their design service life.
- Ability of the structure to sustain demand loads decreases.
HOW HEALTHY ARE YOUR MARINE STRUCTURES??

- When was your last physical? (i.e. inspection)
- Do you exercise? (i.e. maintenance)
- Have you seen a specialist about any ailments? (i.e. performed structural repairs)

**STRUCTURAL CAPACITY:**
What is your marine structure's ability to sustain the demand loads?
DEMAND VERSUS CAPACITY (CONT.)

- Compounding factors can amplify the issue:
  - Structures originally designed for smaller design vessels
  - Increase in size of vessels transiting the waterway
  - Extreme weather events

Circa 1950's Design Drawings for Marine Oil Terminal in the Northeast.
DETERIORATION OF STEEL STRUCTURES

- Corrosion
- Impact damage
- Overstressing / deformation
DETERIORATION OF TIMBER STRUCTURES

- Rot
- Ice damage / delamination
- Marine borers
- Fractures
DETERIORATION OF CONCRETE STRUCTURES

- Corrosion damage (Spalling)
- Overstress / flexure
- Chemical degradation of concrete
INSPECTION, MAINTENANCE, & REHABILITATION BEST PRACTICES

- Ensure the safety and security of:
  - Personnel & Environment
  - Vessels & Facilities
- Prevent, detect, and control pollution caused by oil or any other hazardous substance.
- Evaluation and implementation of company established risk management and tolerance policies.
- Customer requirements – Oil Companies International Marine Forum (OCIMF).
INSPECTION GUIDELINES

- Defines inspection types and frequency as well as guidelines for selection.
- Standardizes terms for individual element grading, overall condition assessment rating, documentation, and reporting.
- Provides guidance for recommended actions.
- Establishes recommended inspection team and lead inspector qualifications (Professional Engineer-Divers).
ROUTINE INSPECTIONS

- Overall assessment of the primary marine structures, assign condition ratings, and provide recommended actions.
- Inspection frequency: Generally every 3 to 5 years; dependent upon construction type, environmental conditions, and overall condition assessment.
- Typically includes a comprehensive report and prioritized recommendations to restore and maintain the service life of the marine structures.

<table>
<thead>
<tr>
<th>Condition Rating from Previous Inspection</th>
<th>Unwrapped Timber or Unprotected Steel (No Coating or Cathodic Protection)(^d)</th>
<th>Concrete, Masonry, Wrapped Wood, Protected Steel, or Composite Materials(^d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Good</td>
<td>6 Benign⁷ Environment</td>
<td>6 Benign⁷ Environment</td>
</tr>
<tr>
<td>5 Satisfactory</td>
<td>6 Benign⁷ Environment</td>
<td>6 Benign⁷ Environment</td>
</tr>
<tr>
<td>4 Fair</td>
<td>5 Aggressive⁶ Environment</td>
<td>5 Aggressive⁶ Environment</td>
</tr>
<tr>
<td>3 Poor</td>
<td>4 Aggressive⁶ Environment</td>
<td>5 Aggressive⁶ Environment</td>
</tr>
<tr>
<td>2 Serious</td>
<td>3 Aggressive⁶ Environment</td>
<td>4 Aggressive⁶ Environment</td>
</tr>
<tr>
<td>1 Critical</td>
<td>2 Aggressive⁶ Environment</td>
<td>2 Aggressive⁶ Environment</td>
</tr>
<tr>
<td></td>
<td>0.5 Aggressive⁶ Environment</td>
<td>0.5 Aggressive⁶ Environment</td>
</tr>
</tbody>
</table>
MAINTENANCE & REHABILITATION

- Maintenance and rehabilitation recommendations should be developed compared to facility’s use parameters.
- Define critical infrastructure.
- Recommendations should be prioritized to maintain the health and safety of personnel and ensure continuous operational health of the terminal.
  - Immediate: Address safety hazards to personnel
  - Priority: Help to prevent facility limitations or load restrictions
  - Routine: Perform maintenance repairs to help extend design service life
MODERNIZATION

Modernization of one or all of the mooring and berthing structures may be performed for any number of reasons:

• Operational safety
• Restoration of as-built capacity lost due to deterioration and age
• Reinforcement or increase in capacity to account for:
  – Increase dredge depth
  – Modification to the design vessel type or size
  – Increased Passing Vessel Effects
  – Increased environmental load capacity (wind speeds)
  – Modification to vessel product types (dry bulk vs liquid bulk)
  – Modification to fender system, change to berthing energy, change to fender reaction
• Full replacement of structure(s) due to exhausted design service life
• New / additional structures to optimize mooring/berthing configuration for multiple design vessels
REGULATORY CONSIDERATIONS

- Consult Municipal, State, and Federal regulators
- Requirements vary greatly by region
- Existing structure authorizations vs. additional (new) structure authorizations
- Schedule and cost implications
- Mitigation / encroachment
CASE STUDY 1: NEW ENGLAND REGION
Mooring & Berthing Structure Modernization Project

Demand:

- Increased moored vessel size
- Terminal responsible for a significant volume of refined petroleum products for much of the region.
CASE STUDY 1: NEW ENGLAND REGION

Capacity:

- Aging infrastructure with over 60 years of corrosion and reduction in steel thickness.
- Original design capacity likely for 400 ft to 600 ft liquid bulk carriers; current demand is for tankers up to 750 ft.
CASE STUDY 1: NEW ENGLAND REGION

Modernization:

• Reduce risk
• Increase capacity for larger design vessels
• Extend service life
• Phase I: Two berthing dolphins and one mooring dolphin
CASE STUDY 2: MID-ATLANTIC REGION
Deepening Adjacent Federal Channel

Demand:

• Passing vessel size (container ships) increased
• Narrow channel

10,000 TEU Passing Vessels

13,000 TEU Passing Vessels
CASE STUDY 2: MID-ATLANTIC REGION

Capacity:

• Existing structures nearing end of service life
• Unable to validate structural capacity
CASE STUDY 2: MID-ATLANTIC REGION

Modernization:

• Reduce risk
• Improve berth layout (symmetry, redistributes loads)
• Extend service life
CASE STUDY 3: GULF REGION
Modernization of Newly Acquired Facility

Demand:

• Passing vessel effects: Loads increased due to larger vessels in narrow channel
• Design vessel diversity
CASE STUDY 3: GULF REGION

**Capacity:** Limited maintenance, diminished condition modernization
CASE STUDY 3: GULF REGION

Modernization:
• Symmetrical layout
• Mooring dolphins
• Construction techniques
THANK YOU!

Michael P. Ajemian, P.E.
New England Practice Lead
COWI Marine, Boston, MA
Direct: 508.209.6445
Email: mpaj@cowi.com
Website: www.cowi-na.com

Brent D. Cooper, P.E.
Project Manager
COWI Marine, Charleston, SC
Direct: 843.375.2013
Email: brco@cowi.com
Website: www.cowi-na.com