“Structural Design of the Marine Terminal”

Prevention First 2006
September, 2006
Long Beach, CA

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POLA/Pacific Energy Berth 408 Crude Oil Import Terminal Design
Structural Design of the Marine Terminal
OUTLINE

- Unique Features
- Facility Description
- Structural Design per MOTEMS
- Mooring & Berthing per MOTEMS
- Structural Details
- Design Innovation
Unique Features

- 1st New Oil Terminal Designed to MOTEMS
- Designed to meet new MOTEMS and POLA Seismic Code
- 81 ft of water depth
- Designed to accommodate VLCC’s
- 3-D analysis between structure and pipes
Facility Description

- POLA Map
- Faults
- Structural Components
POLA Map

STRUCTURAL DESIGN OF THE MARINE TERMINAL
Structural Component - Unloading Platform

- 60 ft wide x 100 ft long x 4 ft deep reinforced concrete slab
- 12-48” steel piles
- Steel piles rigidly connected to underside of slab
- 4-16” unloading arms
Structural Component - Breasting Dolphin

- 4-40 ft sq. x 4 ft deep reinforced concrete slab
- 4-48” steel piles
- Piles rigidly connected to underside of slab
Structural Component - Mooring Dolphin

- 6-25 ft sq. x 5 ft deep reinforced concrete slab
- 4-54” battered steel piles
- Piles rigidly connected to underside of slab
• 244 ft long x 22 ft wide South Trestle
• 33” deep pre-cast concrete box girders
• Combined cast-in-place and pre-cast concrete bent caps at 40 ft o.c.
• 2-42” steel piles at each bent

• 214 ft long x 37 ft wide North Trestle
• 33” deep pre-cast concrete box girders
• Combined cast-in-place and pre-cast concrete bent caps at 40 ft o.c.
• 2-42” steel piles at each bent
Structural Design per MOTEMS

- MOTEMS Risk Classification
- Seismic Performance Criteria
- Minimum Required Analytical Procedure
MOT Risk Classification

Purpose is to establish minimum seismic analysis and structural performance. Structural performance is evaluated at a two level criteria: Level 1 and Level 2.

MOTEAMS risk classification (Table 31-F-4-1)

All new MOTS are classified as high risk.

1. Exposed oil $\geq 1200$ bbls

**TABLE 31-F-4-1**

<table>
<thead>
<tr>
<th>Risk Classification</th>
<th>Exposed Oil (bbls)</th>
<th>Transfers per Year per Berthing System</th>
<th>Maximum Vessel Size (DWTx1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>$\geq 1200$</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>Moderate</td>
<td>$&lt; 1200$</td>
<td>$\geq 90$</td>
<td>$\geq 30$</td>
</tr>
<tr>
<td>Low</td>
<td>$&lt; 1200$</td>
<td>$&lt; 90$</td>
<td>$&lt; 30$</td>
</tr>
</tbody>
</table>
MOTEMS Seismic Performance Criteria

Design Earthquake Motions:
Level 1
• Minor or no structural damage
• Temporary or no interruption in operations
Level 2
• Controlled inelastic structural behavior with repairable damage
• Prevention of structural collapse
• Temporary loss of operations, restorable within months
• Prevention of major spill (≥ 1200 bbls)

Seismic Performance Criteria:
Select: High risk classification:
Seismic Performance Level: Level 1 Level 2
Probability of Exceedance: 50% in 50 years 10% in 50 years
Return Period: 72 years 475 years

TABLE 31F-4-2
SEISMIC PERFORMANCE CRITERIA

<table>
<thead>
<tr>
<th>Risk Classification</th>
<th>Seismic Performance Level</th>
<th>Probability of Exceedance</th>
<th>Return Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Level 1</td>
<td>50% in 50 years</td>
<td>72 years</td>
</tr>
<tr>
<td></td>
<td>Level 2</td>
<td>10% in 50 years</td>
<td>475 years</td>
</tr>
<tr>
<td>Moderate</td>
<td>Level 1</td>
<td>65% in 50 years</td>
<td>48 years</td>
</tr>
<tr>
<td></td>
<td>Level 2</td>
<td>15% in 50 years</td>
<td>308 years</td>
</tr>
<tr>
<td>Low</td>
<td>Level 1</td>
<td>75% in 50 years</td>
<td>36 years</td>
</tr>
<tr>
<td></td>
<td>Level 2</td>
<td>20% in 50 years</td>
<td>224 years</td>
</tr>
</tbody>
</table>

STRUCTURAL DESIGN OF THE MARINE TERMINAL
Response Spectra

![Graph showing response spectra with labels: POLA CLE and MOTEMS LEVEL 2.](image)

**Figure 3**

**Uniform Hazard Design Spectra**
**Horizontal Component Motions for Level 2 Earthquakes**

**THE PORT OF LOS ANGELES**
**ENGINEERING DIVISION**

**POLA Pier 400 Marine Oil Terminal**

**Job No:** 01-04  **Date:** 16-10-2005
Minimum Required Analytical Procedures:

- Select: High / Moderate
- Configuration: Irregular
- Substructure Material: Concrete/Steel
- Displacement Demand Procedure: Linear Model
- Displacement Capacity Procedure: Nonlinear Static
Minimum Analytical Procedure

Design Approach

- Basic Classification
- Seismic Performance Level

Displacement Based Design

- Develop Computer Model
- Calculate Displacement Demand
- Calculate Displacement Capacity
- Check Pile Shear
- Check P-Δ
- Design for Shear Key Forces
DIFFERENT POSSIBLE MODELS FOR DETERMINING DISPLACEMENT CAPACITY

INELASTIC FE (SOIL + PILE) MODEL

EQUIVALENT DEPTH TO FIXITY MODEL

Too complex!

Too simplistic!

STRUCTURAL DESIGN OF THE MARINE TERMINAL
Pushover Curves

Displacement, inches

Base Shear, kips

Level 1

Level 2

STRUCTURAL DESIGN OF THE MARINE TERMINAL
Displacement Demand Flow Chart

Calculate Displacement Demand

Displacement Demand = Transverse Displacement Demand x DMF

Initial Stiffness Method For Initial Check

Substitute Structure Method (Iterative)
**Displacement Demand Flow Chart**

1. **Calculate Displacement Demand**
2. **Initial Stiffness Method**
   - for initial check

   - **Initial stiffness from pushover curve**

   - **Damping = 5%**

   - \[ T = 2\pi \sqrt{\frac{W}{gK}} \]

   - **Read displacement demand from displacement spectra for 5% damping**
Demand-to-Capacity Ratio (DCR)

• Demand x DMF / Capacity  < 1.0

• DCR < 1.0
Mooring & Berthing per MOTEMS

- Mooring/Berthing Risk Classification
- Mooring Analysis
- Berthing Analysis
MOTEMS Mooring/Berthing Risk Classification

### TABLE 31F-5-1

<table>
<thead>
<tr>
<th>Risk Classification</th>
<th>Wind, ( V_w ) (knots)</th>
<th>Current, ( V_c ) (knots)</th>
<th>Passing Vessel Effects</th>
<th>Change in Draft (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>&gt;50</td>
<td>1.5</td>
<td>Yes</td>
<td>&gt;8</td>
</tr>
<tr>
<td>Moderate</td>
<td>30 to 50</td>
<td>1.0 to 1.5</td>
<td>No</td>
<td>6 to 8</td>
</tr>
<tr>
<td>Low</td>
<td>&lt;30</td>
<td>&lt;1.0</td>
<td>No</td>
<td>&lt;6</td>
</tr>
</tbody>
</table>

Based on site specific parameters:

1. Wind
2. Current
3. Hydrodynamic effects of passing vessels
4. Change in vessel draft
Mooring Analysis

Load Generated By
- Wind
- Wave
- Passing Vessel
- Seiche
- Tsunami

MOTEMS Ref.
- 3105F.3.1
- 3105F.3.1
- 3105F.3.2
- 3105F.3.3
- 3105F.3.4
The available wind duration shall be adjusted to a 30-second value, using the following formula:

*Figure 31F-3-3  Windspeed Conversion Factor [3.10]*
Figure 31F-3-4  Current Velocity Correction Factor (p. 41, OCIMF, 1997 [3.11])
Berthing Analysis

• Fender Design

Berthing Energy Demand
\[ E_{\text{vessel}} = \frac{1}{2}(W*V_n^2/g) \]

Berthing Energy Capacity
\[ E_{\text{fender}} = C_b * C_m * E_{\text{vessel}} \]

• Tanker Contact Length
\[ L_c = 2r \sin \alpha \]

• Longitudinal or Vertical Berthing Forces
\[ F = \mu N \]
### TABLE 31F-3-9

**BERTHING VELOCITY \( V_b \) (NORMAL TO BERTH)**

<table>
<thead>
<tr>
<th>Vessel Size (dwt)</th>
<th>Tug Boat Assistance</th>
<th>Site Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10,000</td>
<td>No</td>
<td>1.31 ft/sec, 0.98 ft/sec, 0.53 ft/sec</td>
</tr>
<tr>
<td>10,000 – 50,000</td>
<td>Yes</td>
<td>0.78 ft/sec, 0.66 ft/sec, 0.33 ft/sec</td>
</tr>
<tr>
<td>50,000 – 100,000</td>
<td>Yes</td>
<td>0.53 ft/sec, 0.39 ft/sec, 0.26 ft/sec</td>
</tr>
<tr>
<td>&gt;100,000</td>
<td>Yes</td>
<td>0.39 ft/sec, 0.33 ft/sec, 0.26 ft/sec</td>
</tr>
</tbody>
</table>

1. If tug boat is used for vessel size smaller than 10,000 DWT the berthing velocity may be reduced by 20%.

### TABLE 31F-3-10

**SITE CONDITIONS**

<table>
<thead>
<tr>
<th>Site Conditions</th>
<th>Description</th>
<th>Wind Speed</th>
<th>Significant Wave Height</th>
<th>Current Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfavorable</td>
<td>Strong Wind Strong Currents High Waves</td>
<td>&gt;38 knots</td>
<td>&gt;6.5 ft</td>
<td>&gt;2 knots</td>
</tr>
<tr>
<td>Moderate</td>
<td>Strong Wind Moderate Current Moderate Waves</td>
<td>&gt;38 knots</td>
<td>&lt;6.5 ft</td>
<td>&lt;2 knots</td>
</tr>
<tr>
<td>Favorable</td>
<td>Moderate Wind Moderate Current Moderate Waves</td>
<td>&lt;38 knots</td>
<td>&lt;6.5 ft</td>
<td>&lt;2 knots</td>
</tr>
</tbody>
</table>

1. A 30-second duration measured at a height of 33 ft.
2. Taken at 0.5 x water depth

### TABLE 31F-3-11

**MAXIMUM BERTHING ANGLE**

<table>
<thead>
<tr>
<th>Vessel Size (DWT)</th>
<th>Angle [degrees]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barge</td>
<td>15</td>
</tr>
<tr>
<td>&lt;10,000</td>
<td>10</td>
</tr>
<tr>
<td>10,000-50,000</td>
<td>8</td>
</tr>
<tr>
<td>&gt;50,000</td>
<td>6</td>
</tr>
</tbody>
</table>

**STRUCTURAL DESIGN OF THE MARINE TERMINAL**
Structural Details

- Ship Design Parameters
- General Layout & Elevation
- Mooring Layout for VLCC
- Section at Unloading Platform
- ULP Rigid Frame Joint Detail
- ULP Reinforcing
- MD Deck & Pile Reinforcing
- MD Deck Reinforcing Plans
- N & S Trestle Box Girder Layout
- N & S Pier Layout & Cap Bm Details
## Ship Design Parameters

### Structural Design of the Marine Terminal

#### Ship Design Parameters Table

<table>
<thead>
<tr>
<th>ITEM</th>
<th>UNIT</th>
<th>VALUE</th>
<th>VALUE</th>
<th>MAXIMUM</th>
<th>MINIMUM</th>
<th>PARAMETER</th>
<th>PARAMETER</th>
<th>SHIPPER BASE</th>
<th>SHIPPER BASE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vessel Hull</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Displacement</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><strong>LDA</strong></td>
<td></td>
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<tr>
<td><strong>SEAY</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Bunkered Depth to Main Deck</strong></td>
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<td></td>
<td></td>
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<tr>
<td><strong>Loaded Draft</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ballast Draft</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Length of Parallels, Bc/Ld at Ballast Water Line</strong></td>
<td>FT</td>
<td>200</td>
<td>600</td>
<td>200</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Transverse Bc/Ld at Ballast Water Line</strong></td>
<td>FT</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Length of Vessel, Bc/Ld at Ballast Water Line</strong></td>
<td>FT</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Type of Mooring Lines</strong></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Length</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mooring Bc/Ld at Main Deck</strong></td>
<td>FT</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mooring Bc/Ld at Ballast Water Line</strong></td>
<td>FT</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Notes
1. Specific vessels' names are noted to prevent vessel-related issues in actual classes. However, individual variants will vary.
2. Based on given increases, design unit values and other supporting data are subject to the classification society and government guidelines.
3. Mooring equipment guidelines also apply.
4. These values should be obtained from the vessel constructor.
Mooring Layout for VLCC

LAYOUT PLAN FOR GENERIC TANKER (VLCC)

LOADED DRAFT AT ELT

BALLAST DRAFT AT EHT

STRUCTURAL DESIGN OF THE MARINE TERMINAL
SECTION AT UNLOADING PLATFORM

STRUCTURAL DESIGN OF THE MARINE TERMINAL
Design Innovations

• 1st New Oil Terminal Designed to MOTEMS
• Optimized Seismic Design Analysis
• Modularization of Structural Components
• Advance Design-Build Process
• Environmental Technologies
Project Photos

STRUCTURAL DESIGN OF THE MARINE TERMINAL
“Structural Design of the Marine Terminal”

Question?

Thank You!

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