New Marine Container Terminal at Haifa

(Hamifratz Port)

Bill Paparis, Project Manager, D. P.E.
Preliminary Port Layout
Aerial View of Existing Port
Major Issues

• Moderately high level of earthquake accelerations, and associated potential for liquefaction of hydraulic fill and breakwater/revetment foundations
• Site exposed to waves
• Difficulty in obtaining adequate quantities of suitable sand from dredging for reclamation
• Environmentally sensitive location
# Maximum and Minimum Size Vessel Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum Design Vessel (Quay 6)</th>
<th>Maximum Design Vessel (Quay 7)</th>
<th>Maximum Design Vessel (Quay 8)</th>
<th>Minimum Design Vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel Type</td>
<td>Container Ship (Maersk EEE)</td>
<td>Container Ship (Post Panamax)</td>
<td>Container Ship (Panamax)</td>
<td>-</td>
</tr>
<tr>
<td>TEU Capacity</td>
<td>18,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Deadweight Tonnage (dwt)</td>
<td>-</td>
<td>110,800</td>
<td>45,850</td>
<td>9,000</td>
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<td>Length Overall (LOA), m</td>
<td>400</td>
<td>337</td>
<td>254</td>
<td>145</td>
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<tr>
<td>Beam, m</td>
<td>59.0</td>
<td>45.6</td>
<td>32.3</td>
<td>19.5</td>
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<tr>
<td>Loaded Draught, m</td>
<td>16.0</td>
<td>15.0</td>
<td>11.78</td>
<td>7.8</td>
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<tr>
<td>Loaded Displacement, tonnes</td>
<td>240,000</td>
<td>147,000</td>
<td>62,750</td>
<td>14,247</td>
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</tbody>
</table>
3D Model Testing of Port Layout

Wave generator
• Developed seismotectonic model taking into account regional tectonic setting, historical seismicity and mapped faults, including fault slip rates.
• Most important source is the Carmel Fault, located between 1.7 km and 2.9 km from the site.
• Model also includes the Dead Sea Transform Fault and Cyprus Trench, as well as more local sources such as the Levant Fault and the Gilboa Fault.
• Model was input into a computer program and Probabilistic Seismic Hazard Assessments were conducted for return periods of 72, 475, 975, and 2,475 years.
Three Levels of Seismic Design

- Contingency Level (10% Probability of Exceedance in 50 Years): Peak Ground Acceleration = 0.38 g (M=6.5-7.0)
- Operating Level (50% Probability of Exceedance in 50 Years): Peak Ground Acceleration = 0.12 g (M=4.5-5.0)
- Contingency Level for D&H Cargo (2% Probability of Exceedance in 50 Years): Peak Ground Acceleration = 0.86 g
Main Breakwater and Lee Breakwater were considered to be PIANC Grade A (primary) structures, so that minimal damage is expected in an OLE, while the damage in a CLE is controlled and repairable, and the structure is to remain serviceable.

For the CLE the stability of the structures was assessed in terms of the magnitude of the deformation.

Maximum permissible deformation under CLE ≈ 1.0 m

Maximum side slopes were determined to be 1V to 2H.
Final Port Layout

- MAIN BREAKWATER EXTENSION
- EAST BREAKWATER CAISSONS
- EAST REVETMENT CAISSONS
- EAST REVETMENT RUBBLE MOUND
- LEE REVETMENT
- QUAY 6
- QUAY 7
- QUAY 8
3D Physical Model Testing of Main Breakwater Extension
Typical Section Along Trunk of Main Breakwater Extension
Typical East Breakwater Cross Section
Seismic OLE Slope Stability Analysis of East Revetment Caisson – 9.6 m Clay Removal

Terminal

Caisson

Soil Replacement

Kurkar
## Seismic (CLE) Displacements of East Revetment Caisson

<table>
<thead>
<tr>
<th>Displacements from FLAC Analyses for the CLE Condition</th>
<th>Allowable Displacements As Defined in PIANC Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacements at the End of Earthquake Shaking</td>
<td>Degree II Damage Level (for CLE Condition)</td>
</tr>
<tr>
<td>Horizontal Displacement at Caisson Seaward Face</td>
<td>Degree I Damage Level (for OLE Condition)</td>
</tr>
<tr>
<td>Settlement at Caisson Toe</td>
<td></td>
</tr>
<tr>
<td>Settlement at Caisson Heel</td>
<td></td>
</tr>
<tr>
<td>Titling of Caisson Seaward Facing</td>
<td></td>
</tr>
<tr>
<td>Horizontal Displacement of Backfill Directly Behind Caisson</td>
<td></td>
</tr>
<tr>
<td>Settlement of Backfill Directly Behind Caisson</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Magnitude of Displacements (Approx.)</th>
<th>Degree II Damage Level (for CLE Condition)</th>
<th>Degree I Damage Level (for OLE Condition)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 cm - 20 cm</td>
<td>30 cm to 90 cm</td>
<td>30 cm</td>
</tr>
<tr>
<td>12 cm</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>2 cm</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>0.25 degree</td>
<td>3 to 5 degree</td>
<td>Less than 3 degree</td>
</tr>
<tr>
<td>10 cm</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>30 cm</td>
<td>N/A</td>
<td>Less than 30 to 70 cm</td>
</tr>
</tbody>
</table>
Geological Profile Along Quay 6
Quay 6 Typical Cross Section
Lateral Motion of Piles and Soil Mass at Quay 6 Due to Shaking

Notes:
(1) The black lines represent the pre-earthquake locations of the piles, bulkhead, and deadman; and the red lines represent their post-earthquake locations.
(2) The green lines represent the deformed soil mesh.
Dredging Plan - Harbor

Entrance Channel

Borrow Area
Dredging Evaluation for EIA

- Evaluated preferred 70% (full) loading scenario and it was determined to be unacceptable from an environmental standpoint due to high levels of spillage.
- Developed dredging plans for 45% parallel loading scenario and these were used to evaluate acceptability from environmental standpoint.
- Based on this, loading of dredgers will have to be limited so as not to exceed environmental thresholds, thus resulting in higher fines content for reclamation fill.
Ground Improvement (GI)

- TYPE 1 – GI
- TYPE 2 – GI
- TYPE 3 – GI

VIBROFLOTAION WITH STONE COLUMN TEST AREA
VIBROCOMPACATION OR VIBROFLOTAION WITH STONE COLUMN TEST AREA
VIBROFLOTAION WITH STONE COLUMN TEST AREA
Construction of Lee Revetment
Casting of Concrete Caisson
Completed Concrete Caisson
Driving Main Sheet Pile Wall at Quay 6
Ground Improvement
Construction of Main Breakwater Extension
Construction of Main BW Extension Roundhead
View of Quay 7, Quay 6, and Reclamation Area
New Marine Container Terminal at Ashdod

(Hadarom Port)

Bill Paparis, Project Manager, D. P.E.
Major Issues

- Site directly exposed to high waves from Mediterranean Sea
- Moderate levels of earthquake accelerations, and associated potential for liquefaction of hydraulic fill and poor soils underlying breakwater foundations
- Potential settlement of reclamation area and breakwaters due to deep clay layers
- Concern over increased downtime in existing port due to construction staging
## Maximum and Minimum Size Vessel Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum Design Vessel (Quay 27)</th>
<th>Maximum Design Vessel (Quay 28)</th>
<th>Minimum Design Vessel</th>
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<tbody>
<tr>
<td>Vessel Type</td>
<td>Container Ship (Maersk EEE)</td>
<td>Container Ship (Panamax)</td>
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<tr>
<td>TEU Capacity</td>
<td>18,000</td>
<td>4,000</td>
<td>600</td>
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<tr>
<td>Loaded Displacement, tonnes</td>
<td>240,000</td>
<td>75,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Length Overall (LOA), m</td>
<td>400</td>
<td>270</td>
<td>125</td>
</tr>
<tr>
<td>Beam, m</td>
<td>59.0</td>
<td>32.2</td>
<td>20</td>
</tr>
<tr>
<td>Loaded Draught, m</td>
<td>16.0</td>
<td>12.0</td>
<td>7.6</td>
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</table>
Wave Agitation Plot for North-West Wave Direction
Overview of the Ashdod Port Model in Large Area Basin (CHC, Canada)
Plan of Main Breakwater Extension
Main Design Issues for Main Breakwater Extension

- Maximum significant wave height of 8.3 m
- Anticipated long-term settlement
- Potential liquefaction of underlying soils
Geological Profile Along Main Breakwater Extension
Liquefaction Assessment at Main Breakwater Extension

• Slope stability analyses were carried out for three loading conditions: (1) static; (2) pseudo static for contingency level earthquake conditions; and (3) post-seismic static loading using residual undrained shear strengths.

• The loose silty sand was determined to be liquefiable (based on a PGA = 0.12 g and M = 7.5), while the silt was determined to be susceptible to strength reduction.

• Further analyses were then carried out assuming that the silty sand is: (1) replaced; and (2) improved, and the maximum earthquake induced displacements were on the order of 60-80 cm, which is considered acceptable for this type of structure, as it can accommodate lateral deformation.

• Stone columns with an area replacement ratio of 13% were implemented to improve the silty sand.
Section of Main Breakwater Extension At Chainage 100

NOTES
1. ALL UNITS IN METERS UNLESS OTHERWISE NOTED.
2. COORDINATE GRID BASED ON NEW ISRAEL GRID.
3. ALL ELEVATIONS BASED ON ISRAELI LAND SURVEY DATUM (0.00).
4. ANCHOR CUBES SHOWN ARE ILLUSTRATIVE. PLACING OF UNITS SHALL BE IN ACCORDANCE WITH SPECIFICATIONS.
5. FOR DRAIN WALL DETAILS SEE Dwg. NO. C-261 THRU C-264.
6. FOR CONSTRUCTION TOLERANCES SEE Dwg. NO. C-.
2D Stability Testing of Main Breakwater Extension (H.R. Wallingford, UK)
3D Stability Testing of Lee Breakwater Roundhead (H.R. Wallingford, UK)
Section of Lee Breakwater at Chainage 400
Section at Roundhead of Lee Breakwater
Geological Profile Along Quay 27
# Quay 27 – Crane Loads

<table>
<thead>
<tr>
<th></th>
<th>Waterside</th>
<th>Landside</th>
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</thead>
<tbody>
<tr>
<td>Maximum Wheel Load</td>
<td>tonnes/wheel</td>
<td>160</td>
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<tr>
<td>Maximum Load on Crane Beam</td>
<td>tonnes/m</td>
<td>130</td>
</tr>
<tr>
<td>Maximum Lateral Force on WS or LS Rail</td>
<td>tonnes</td>
<td>15% of Vertical Load</td>
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<tr>
<td>Anchor Pin Loads (Storm)</td>
<td>tonnes</td>
<td>200</td>
</tr>
<tr>
<td>Tie-Down Loads</td>
<td>tonnes/corner</td>
<td>220</td>
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Quay 27 – Typical Section

NOTES:
1. All units in meters unless otherwise noted.
2. All elevations based on Israeli Land Survey Datum.
Quay 28 – Typical Section
Instantaneous Steady State Wave Disturbance Plot for Construction Phase
Wave Heights at Existing Quays 23, 22, and 21
Front View of Quay 28 Model Testing
Settlement of Reclamation Area

• Due to the questionable quality and uncertainty of the original geotechnical data, settlement calculations were based on the assumption that all clay layers were normally consolidated.

• Based on the original 2009/2010 boring logs, without any ground treatment, the maximum post-construction settlements at the western area of the site were estimated to be up to 70 cm.

• Analyses indicated that a wick drain program in combination with 2 m of surcharge would be effective in reducing the post-construction settlements to 35 cm or less.

• An additional geotechnical investigation was performed during construction to attempt to minimize the uncertainty.
### General Subsurface Stratigraphy

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<th>Strata Legend</th>
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<tr>
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<td>UMS</td>
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<tr>
<td>2</td>
<td>MS</td>
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<td>3</td>
<td>ULS</td>
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<td>4</td>
<td>SL</td>
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<td>5</td>
<td>UDS</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>UC/Uc1/Uc2/Uc3</td>
<td></td>
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<tr>
<td>7</td>
<td>UK</td>
<td></td>
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<tr>
<td>8</td>
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<td>14</td>
<td>DDC</td>
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</table>

- **Upper Medium Sand**
- **Medium Sand**
- **Upper Loose Sand**
- **Silt (not seen in the reclamation area)**
- **Upper Dense Sand**
- **Upper Clay**
- **Upper Kurkar**
- **Middle Clay**
- **Middle Kurkar**
- **Lower Clay**
- **Lower Kurkar**
- **Deep Clay**
- **Deep Kurkar (Up)**
- **Deep Dark Clay**
# Time-Dependent Settlement Parameters
*(Based on Additional Geotechnical Investigation)*

<table>
<thead>
<tr>
<th>Unit</th>
<th>$\gamma'$ (kN/m³)</th>
<th>Pl</th>
<th>Cc</th>
<th>Cr</th>
<th>$e_0$</th>
<th>Cα</th>
<th>$c_v$ (m²/year)</th>
<th>OCR top to bot (PCPTs)</th>
<th>OCR top to bot (triaxial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC</td>
<td>9</td>
<td>30</td>
<td>0.295</td>
<td>0.045</td>
<td>0.898</td>
<td>0.004</td>
<td>1.5</td>
<td>2.9 to 1.5</td>
<td>2 to 1.6</td>
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<tr>
<td>MC</td>
<td>8</td>
<td>36</td>
<td>0.45</td>
<td>0.057</td>
<td>1.183</td>
<td>0.0054</td>
<td>0.75</td>
<td>1.6 to 1.2</td>
<td>1.3</td>
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<tr>
<td>LC</td>
<td>9.4</td>
<td>30</td>
<td>0.247</td>
<td>0.025</td>
<td>0.769</td>
<td>0.0036</td>
<td>1</td>
<td>2.1 to 1.3</td>
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<tr>
<td>DC</td>
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<td>23</td>
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<td>0.025</td>
<td>0.774</td>
<td>0.006</td>
<td>0.75</td>
<td>1.6 to 1.5</td>
<td>1.5</td>
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</table>
Key Post-Construction Settlement and Differential Settlement Values

Differential settlement between waterside and landside rails at Quay 27:

- 10 years after the completion of construction: 5.8 cm
- 20 years after the completion of construction: 7.4 cm
- 50 years after the completion of construction: 8.4 cm

Maximum settlement within the reclamation area:

- 10 years after the completion of construction: 15.4 cm
- 20 years after the completion of construction: 18.6 cm
- 50 years after the completion of construction: 22.2 cm
Lee Breakwater and Temporary Retaining Structure Construction
Lee Breakwater & Reclamation Area Construction
Quay 27 Construction
Quay 27 Construction
Main Breakwater Extension Construction
Overall View Looking Southeast