Multi-Performance Upgrade of Existing MOT Concrete Structures

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Multi-Performance Upgrade of Existing MOT Concrete Structures

Example: Concrete Wharf Built in 1954-55 by BCG

› T-shaped: main wharf and part of approach trestle;

› Main wharf is 1251 ft long by 136 ft wide;

› Existing wharf supported by 18"x18" vertical RC piles and HP 14x74 steel batter piles;
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Example: Concrete Wharf Built in 1954-55 by BCG

› **Project Timeline and Background:**

› Year of 2003-2004 (Before MOTEMS becomes Law) – Multi-Performance Upgrade:
  › Task 1. Terminal Upgrade for 200,000 DWT Tankers
  › Task 2. Satisfy MOTEMS seismic performance requirements in the transverse direction

› Year of 2008 – MOTEMS Initial Audit

› Year of 2010 – Seismic Performance Upgrade to meet MOTEMS requirements (longitudinal direction and other two performance deficiencies identified during MOTEMS Initial Audit)
Multi-Performance Upgrade of Existing MOT Concrete Structures:

Value-Engineering Approach:

- A Step Beyond Conventional Design/Retrofit;
- Leads to unconventional but efficient and economical upgrade design;
- Well-defined seismic behavior and risk;
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Conventional Design/Retrofit Procedure:

› Step 1. Establish multi-performance goals

› Step 2. Gather all data: drawings, geotechnical data, survey and existing conditions, etc...

› Step 3. Evaluate existing structure and identify performance deficiencies

› Step 4. Identify critical path to meet ALL performance goals

› Step 5. Identify Pros and Cons of each upgrade options

› Step 6. Communicate with MOT operators.
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Value-Engineering Approach – Beyond Conventional Design/Retrofit Procedure

› Step 1. Feasibility and Constructability Studies

› Step 2. Identify Physical limitation on adding new lateral-load resistance system

› Step 3. Work with what we already have

› Step 4. Define upgraded structural performance and associated risk acceptance criteria

› Step 5. Communicate with MOT operators.
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Example Concrete Wharf – Multi-Performance Upgrade in 2003-2004:

Task 1. Terminal Upgrade for 200,000 DWT Tankers:
› New center berth for 200,000 DWT Tankers
› New Fenders and mooring hooks, mooring line fairways and manifold
› New (10) "Hard Points" – steel pipe batter pile pairs (16)
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**Example Concrete Wharf – Multi-Performance Upgrade in 2003-2004:**

Task 1. Terminal Upgrade for 200,000 DWT Tankers:

› New "Hard Points" Layout - Total 10 Hard Points with 16 pairs of 24" diameter steel pipe batter piles (3V:1H)
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**Example Concrete Wharf – Multi-Performance Upgrade in 2003-2004:**

**Task 1. Terminal Upgrade for 200,000 DWT Tankers:**

› New "Hard Points" Details
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Example Concrete Wharf – Multi-Performance Upgrade in 2003-2004:

Task 1. Terminal Upgrade for 200,000 DWT Tankers: 3-D SAP2000 Global Model

- Maximum New Batter Pile Load = 150.5 kips under Berthing Load Combination
Example Concrete Wharf – Multi-Performance Upgrade in 2003-2004:

Task 2. Satisfy MOTEMS Requirements in the Transverse Direction

Conventional Design/Upgrade Approach with new "Hard Points":

› Batter-pile system does not offer any ductility;
› Need to drive new batter piles into the rock to develop adequate pile compression strength;
› Need adequate rock anchors to develop required pile tension capacity;
› Need more than 10 Hard Points as required by Berthing Upgrade!
› Upgraded wharf will be stiff ($T_n \approx 0.7$ sec. in the transverse direction) and subjects to very high design response spectral accelerations (1.14g and 1.7g for Level 1 and Level 2 design earthquake, respectively)
› Conclusion – Too expensive and less desirable seismic performance with no ductility.

› Need to take a step beyond – Value-Engineering Approach!
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Example Concrete Wharf – Multi-Performance Upgrade in 2003-2004:

Task 2 with Value-Engineering Approach:

Work with what we already have!

› Very thick clay deposit with dense sand layer below elev. -120' to -130'
› Berthing requirements met at piletip elev. -106' resulting end bearing less than 10% of total pile capacity
Task 2 with Value-Engineering Approach:

Work with what we already have!

- New Batter Piles behave like friction piles with little capacity loss after slipping
- Significant earthquake energy dissipation and well-defined seismic behavior
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Example Concrete Wharf – Multi-Performance Upgrade in 2003-2004:

Value-Engineering Approach:

New Batter Piles (Hard Points) have sufficient capacity to resist design berthing loads, but allow to slip under Level 1 and Level 2 Design Earthquakes

**Pros:**
- Efficient and economical upgrade design;
- Controlled seismic behavior and significant earthquake energy dissipation;
- Hard Point structure components are capacity-protected;
- Wharf retains berthing capacity after a design earthquake event (Level 1 and Level 2);

**Cons:**
- Acceptable permanent wharf displacements & Pile Slippage after a design earthquake event

Communicate with MOT Operator and CSLC.
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Example Concrete Wharf – MOTEMS Initial Audit 2008

› Wharf seismic performance (longitudinal direction) deficiency identified;
› Two other structural deficiencies identified (not cover here);
Physical and other Limitations:

› No place to drive additional piles under existing wharf deck
› Permit issues with adding more bay coverage at both ends of the wharf
› Only place available are at both ends of inside opening bays
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Example Concrete Wharf – Seismic Upgrade Design in the Longitudinal Direction in 2010

Three 3-pile Moment Frames:
› Center Pile – 66" dia.
› Outside Piles – 24" dia.
› Rigid Cap Beam
› Post-tensioning rods so moment frames resists loads in +/- longitudinal directions
› Sliding Bearing to minimize seismic load effects from the transverse direction
› Outside Piles allow to slip under Level 2 Design earthquakes;

New moment frame & connections are capacity-protected!
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Example Concrete Wharf – Seismic Upgrade Design in the Longitudinal Direction in 2010

Three 3-pile Moment Frames: 3-D SAP2000 Nonlinear Pushover Analysis
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Example Concrete Wharf – Seismic Upgrade Design in the Longitudinal Direction in 2010

3-D Moment Frame SAP2000 Nonlinear Pushover Analysis Results

› New moment frame piles/cap beams remain elastic (capacity protected);
› Moment Frame stiffness reduces when outside piles started to slip
› Transverse component adds approx. 360 kips friction load to the frame
› Transverse friction has little influence on moment frame stiffness

![3D Moment Frame (West End)](image)
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Example Concrete Wharf – Seismic Upgrade Design in the Longitudinal Direction in 2010

Value-Engineering Approach:
› Add three 3-Piles Moment Frames (Two Total) which allows outside 24" dia. piles to slip under Level 2 design earthquakes;

Pros:
› Efficient and economical upgrade design
› Controlled seismic behavior and significant earthquake energy dissipation
› New moment frame structure components are capacity-protected

Cons:
› Acceptable permanent wharf displacements after a design Level 2 earthquake event

Communicate with MOT Operator and CSLC.

Moment Frame Design Concept was Peer reviewed per CSLC request.
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Value-Engineering Approach:

A step beyond conventional design/upgrade approach which leads to efficient and economical multi-performance upgrade design.

Questions?