Prevention First 2012

Multi-Performance Upgrade of Existing MOT Concrete Structures

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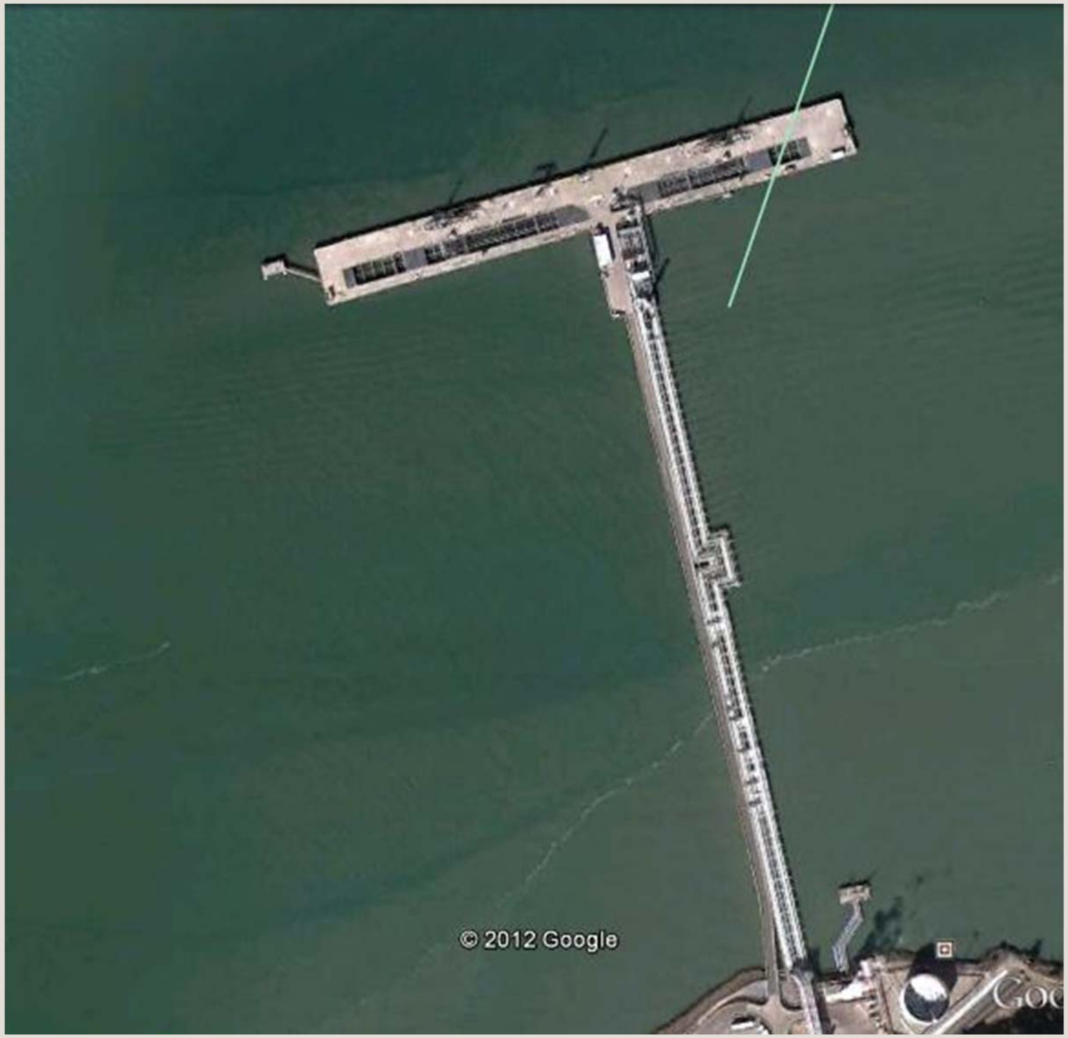
Example: Concrete Wharf Built in 1954-55 by BCG

- 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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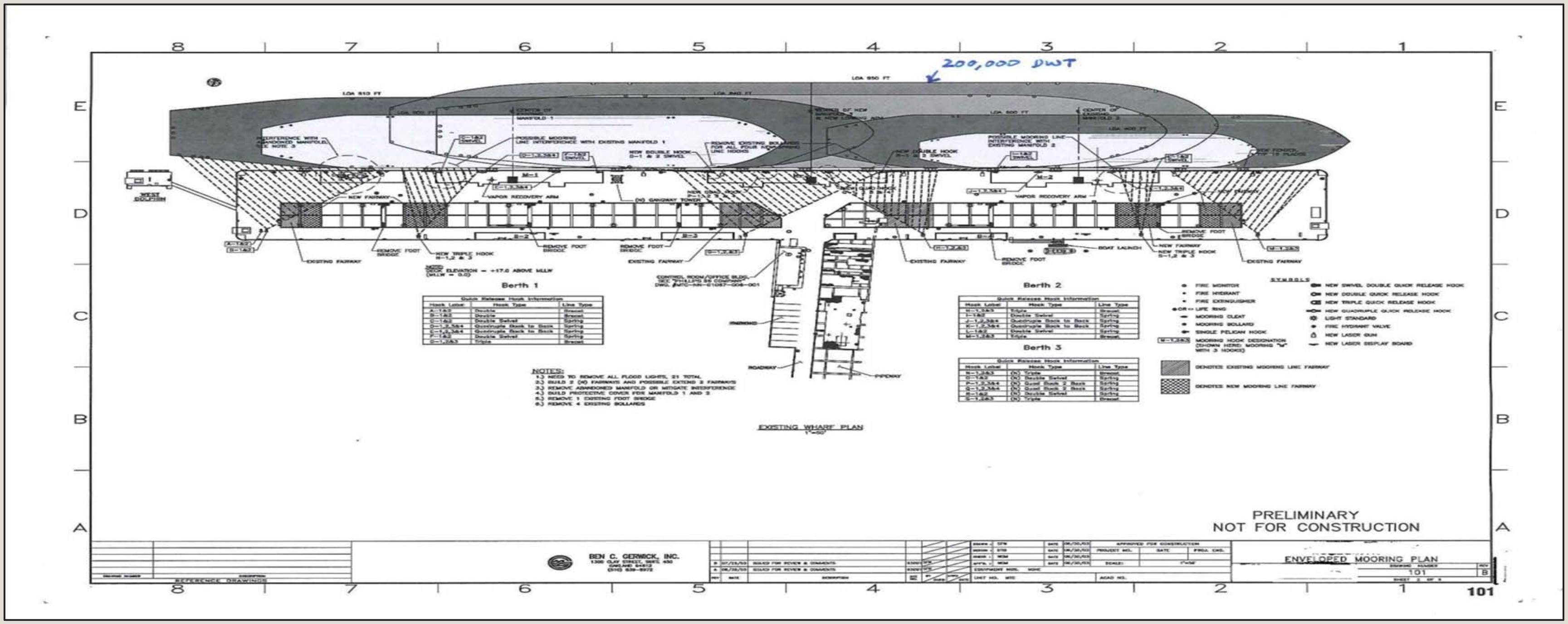
Value-Engineering Approach – Beyond Conventional Design/Retrofit Procedure

- 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.

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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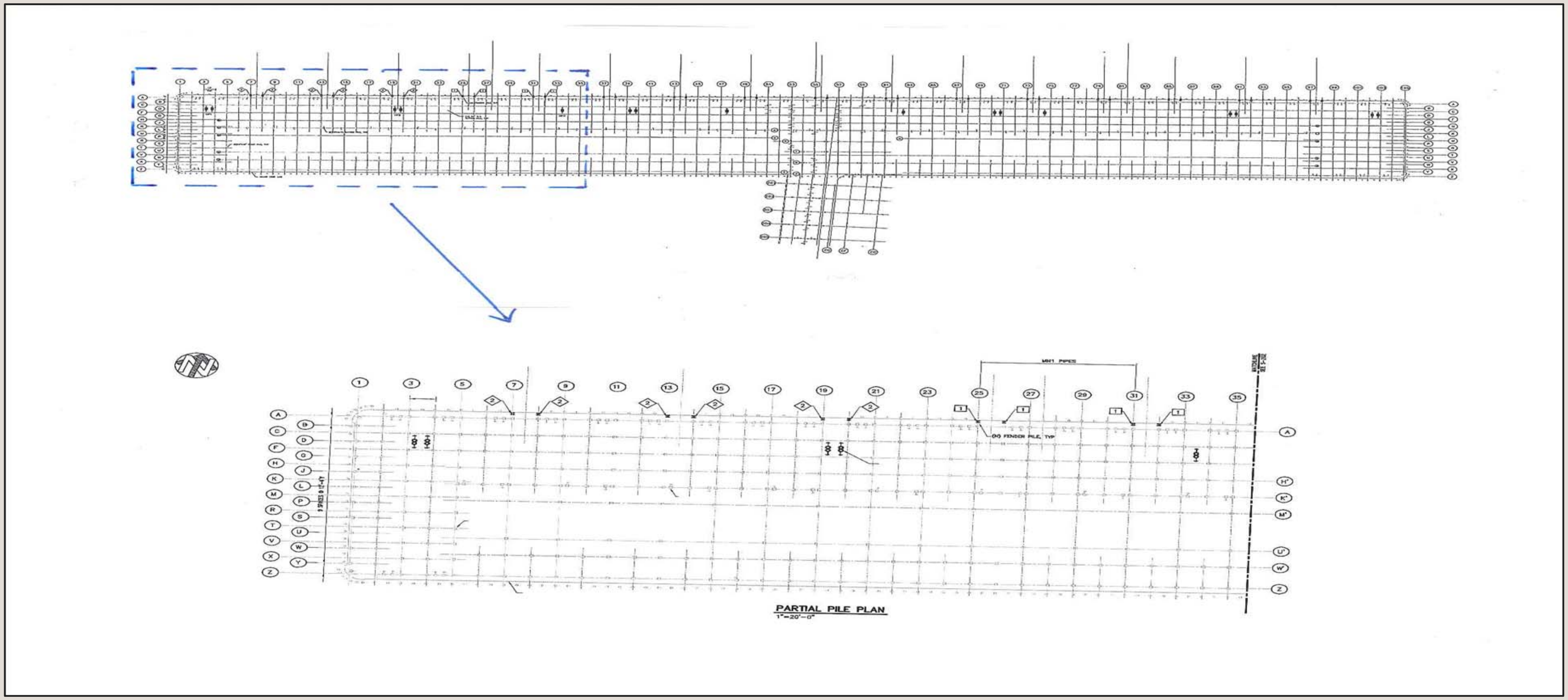
Example Concrete Wharf – Multi-Performance Upgrade in 2003-2004:

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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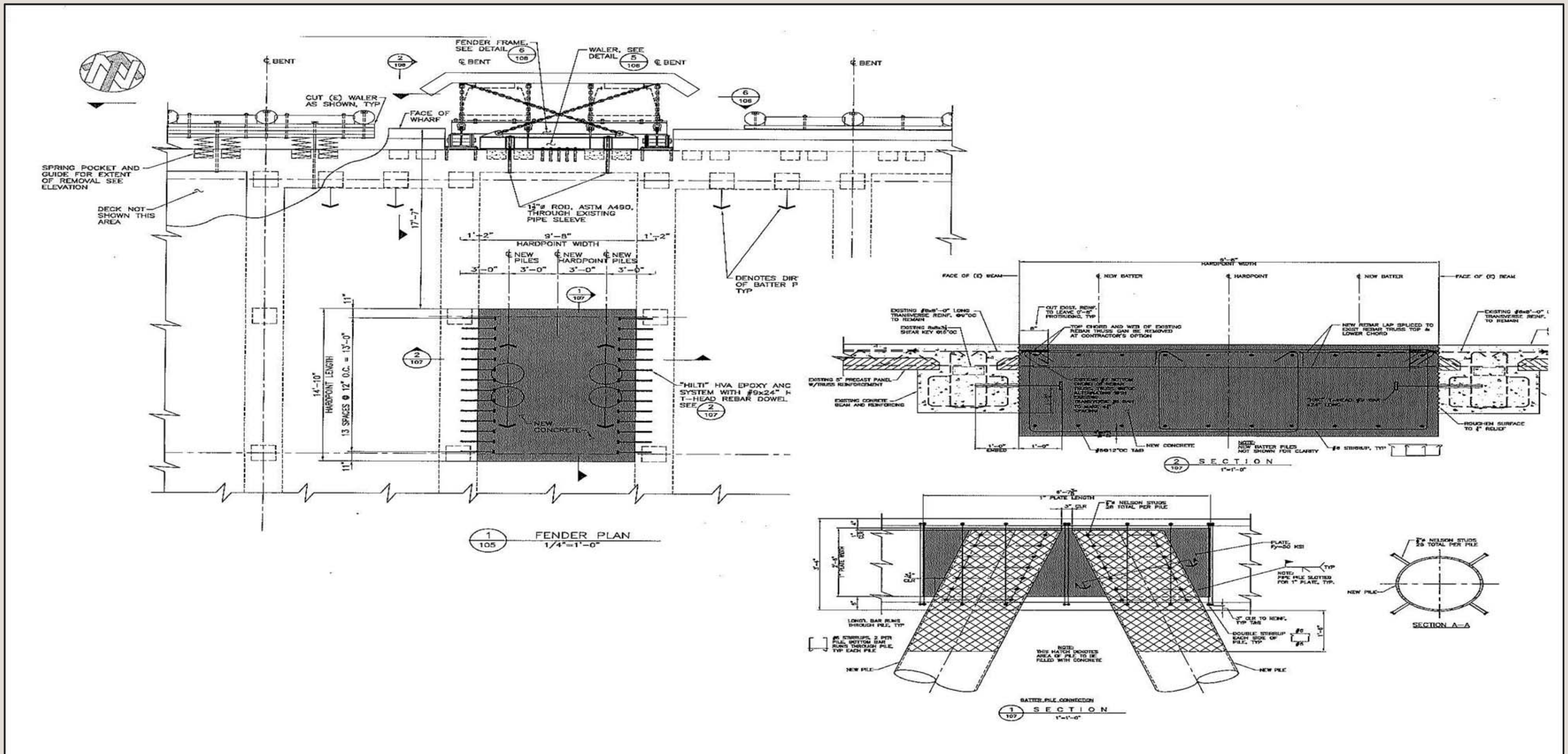
Example Concrete Wharf – Multi-Performance Upgrade in 2003-2004:

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

› New "Hard Points" Details



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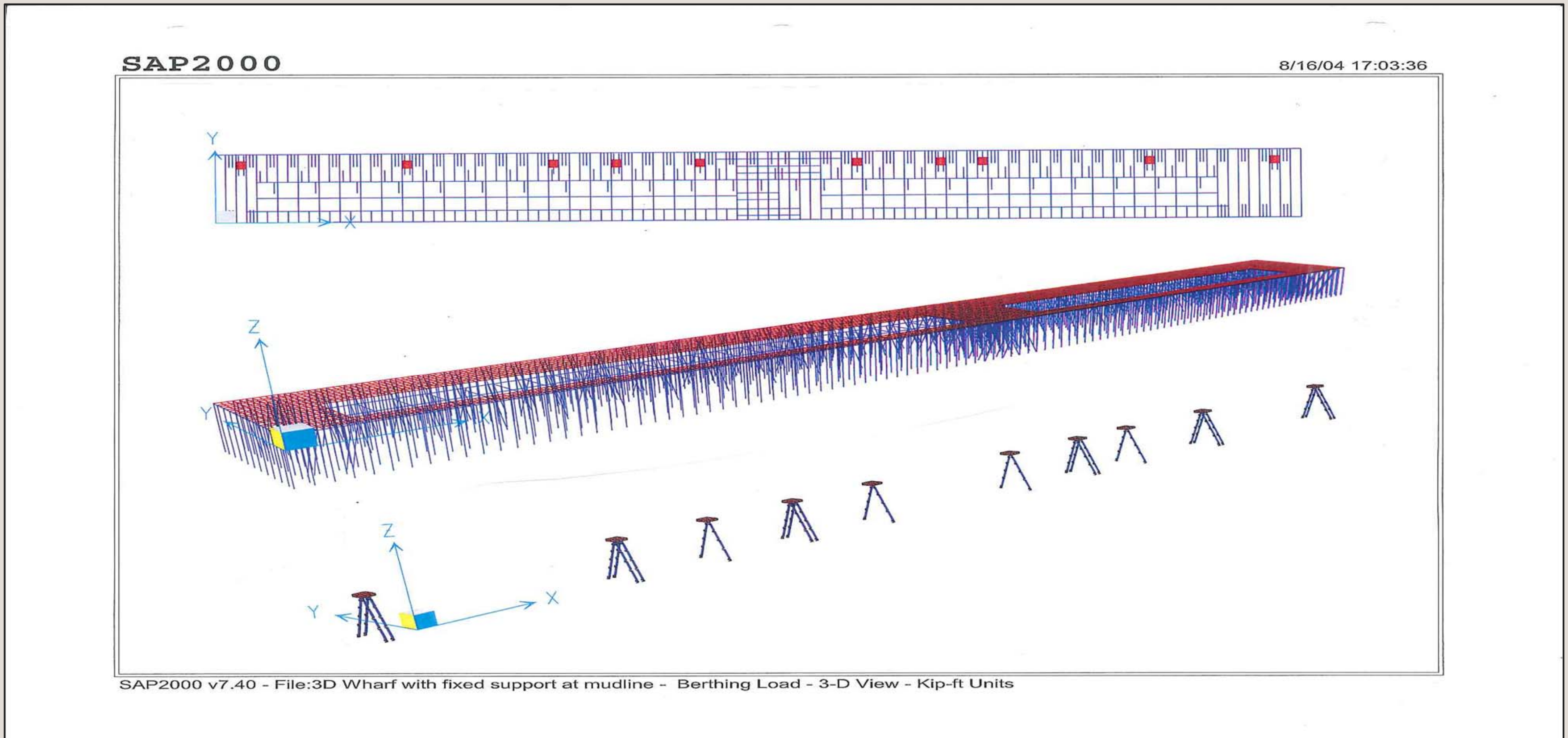
Example Concrete Wharf – Multi-Performance Upgrade in 2003-2004:

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.

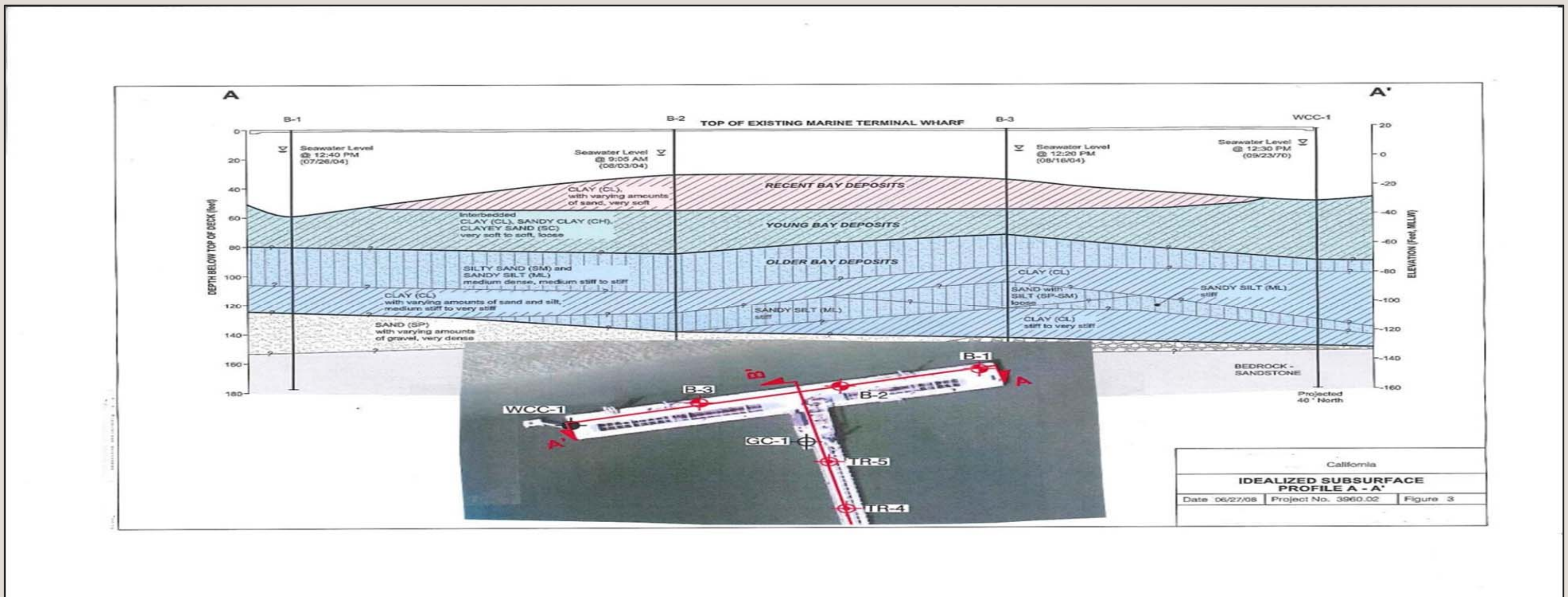
- Need to take a step beyond – Value-Engineering Approach!

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



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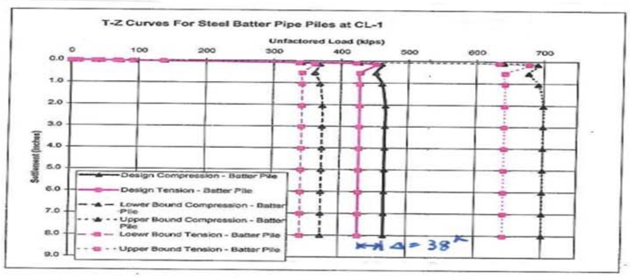
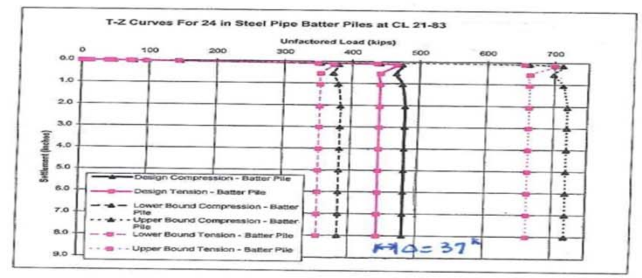
Example Concrete Wharf – Multi-Performance Upgrade in 2003-2004:

Task 2 with Value-Engineering Approach:

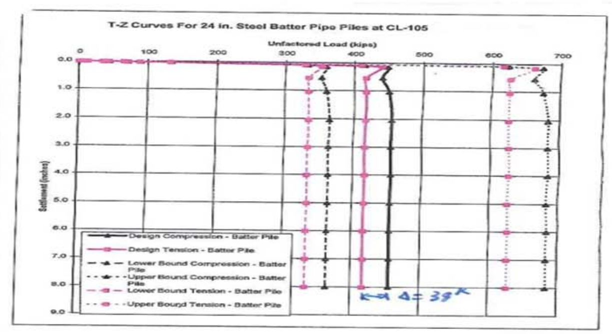
Work with what we already have!

- New Batter Piles behave like friction piles with little capacity loss after slipping
- Significant earthquake energy dissipation and well-defined seismic behavior





Existing Pile	Cut-Off Elev. [ft]	Batter [-]	Tip Elev. [ft]	Installed length [ft]	Ultimate Pile Capacity Tension [kip]	Ultimate Pile Capacity Compression [kip]
18"x18" Concrete Pile	+15	Plum	-91	106	140 to 210	220 to 520
20"x20" Concrete Pile	+15	Plum	-91	106	190 to 240	220 to 280
20"x20" Concrete Pile	+15	2.5:12	-91	108	200 to 260	230 to 290
HP14 x 73	+15	5:12	-91	115	190 to 280	200 to 290
16" Octagonal Concrete Pile	+15	2.5:12	-32 to -88	47 to 103	140 to 300	260 to 450
PP24 w. 5/8" WT	+17	1:3	-106	130	420 to 440	460 to 480
HP14 x 117	+17	Plum	-83	100	Not Evaluated	Not Evaluated



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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);

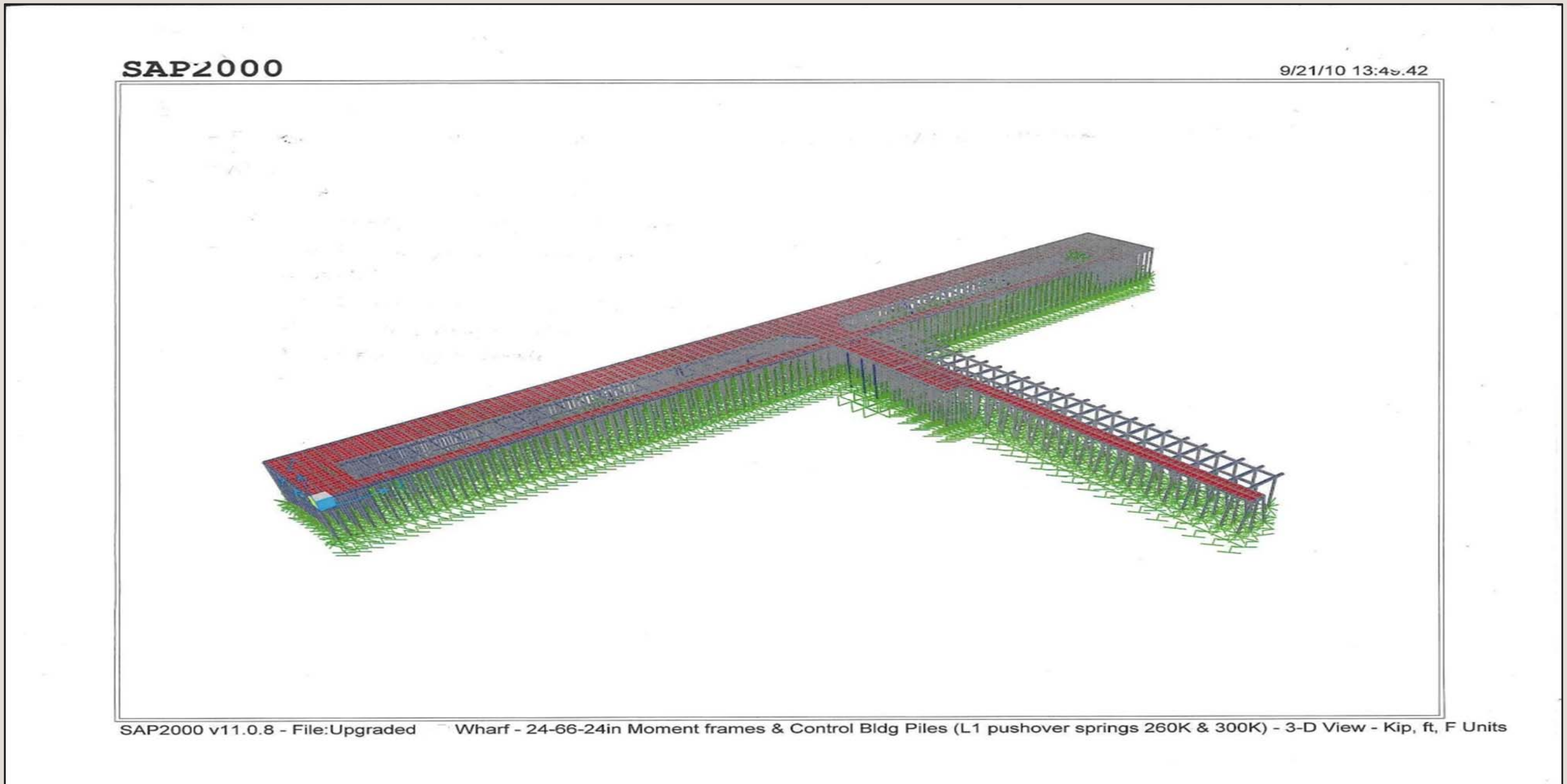
Cons:

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

Communicate with MOT Operator and CSLC.

Example Concrete Wharf – MOTEMS Initial Audit 2008

- Wharf seismic performance (longitudinal direction) deficiency identified;
- Two other structural deficiencies identified (not cover here);



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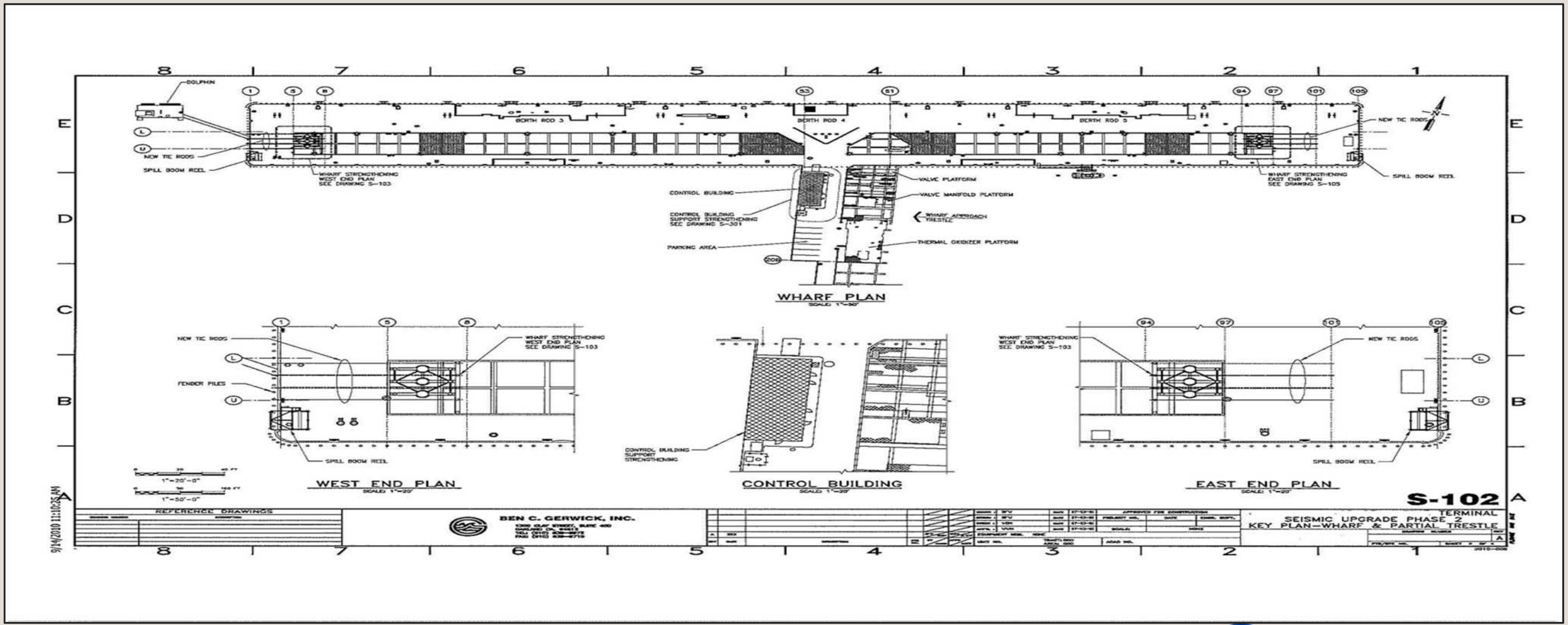
Example Concrete Wharf – Seismic Upgrade Design in the Longitudinal Direction in 2010

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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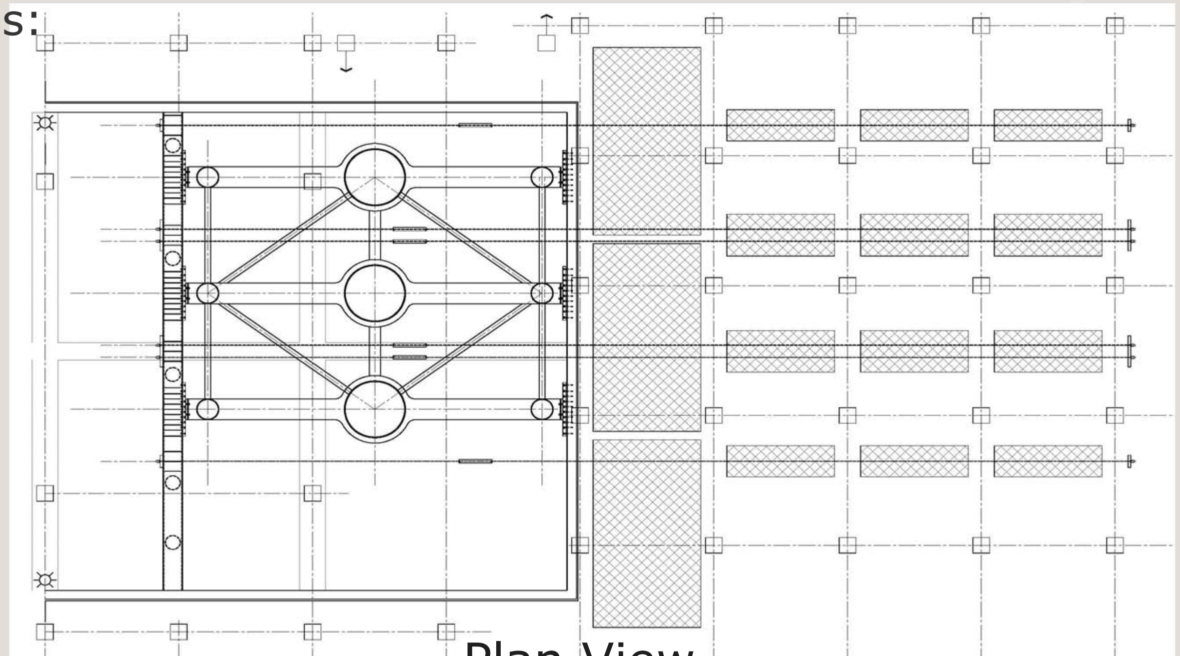
Example Concrete Wharf – Seismic Upgrade Design in the Longitudinal Direction in 2010

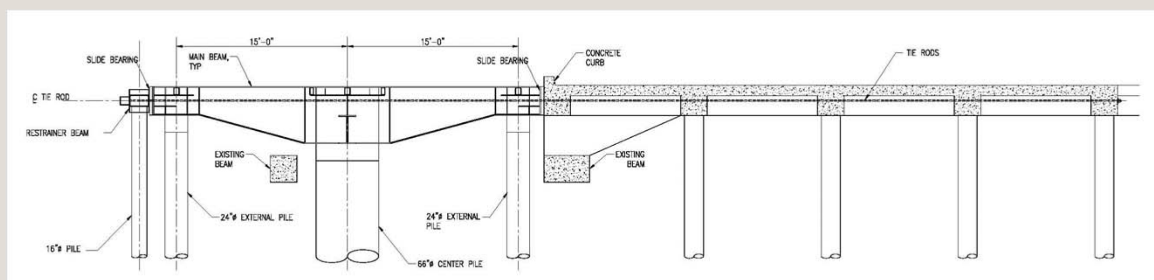
Three 3-pile Moment Frames:

- 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!



Plan View



Elevation View

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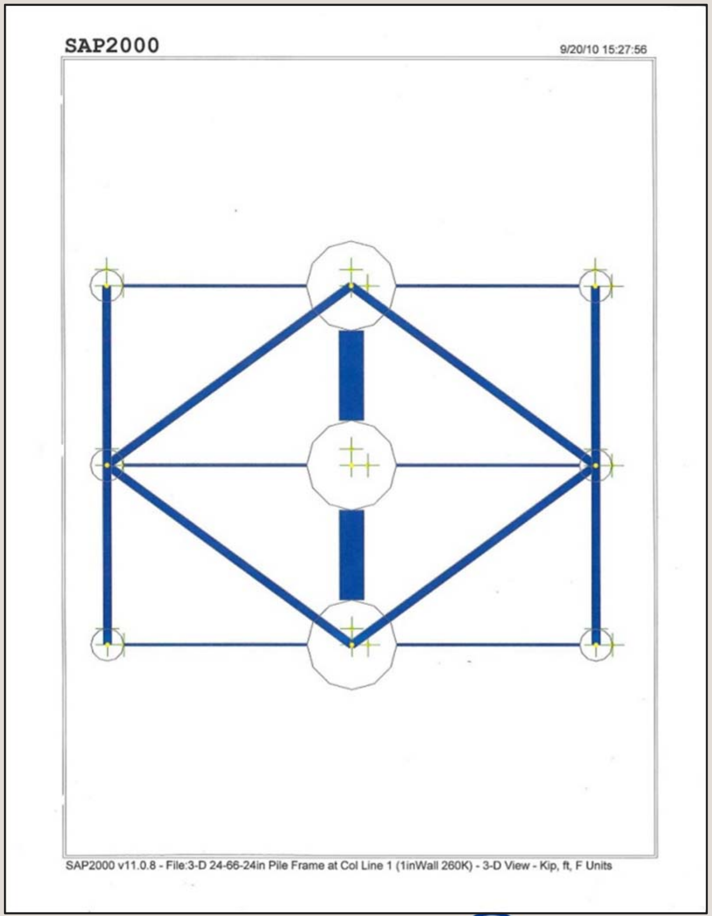
Example Concrete Wharf – Seismic Upgrade Design in the Longitudinal Direction in 2010

Three 3-pile Moment Frames: 3-D SAP2000 Nonlinear Pushover Analysis



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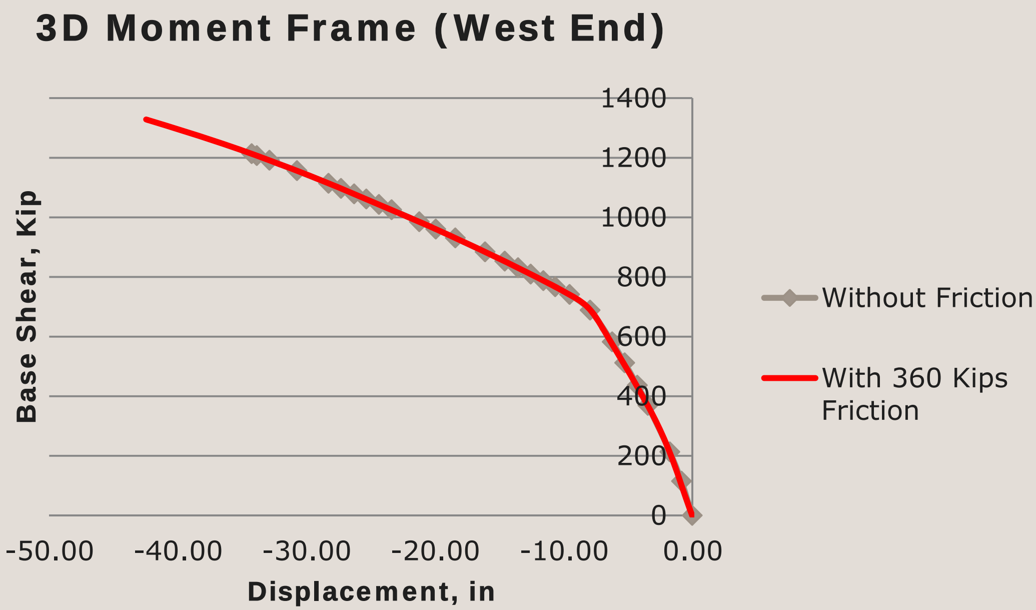
Example Concrete Wharf – Seismic Upgrade Design in the Longitudinal Direction in 2010

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



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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.

Multi-Performance Upgrade of Existing MOT Concrete Structures

Value-Engineering Approach:

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

Questions?

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