Presentation Overview

• Principles of seismic isolation
• Principles of lead-rubber bearings (LRBs)
• Applications
• MOT case study
• Broadway Pier retrofit
Behavior with and without Seismic Isolation

Without Isolation

Structure
Foundation
Isolators

With Isolation

Without Isolation
Characteristics of a Seismic Isolation System

• Added flexibility increases period of vibration and reduces force response
• Energy dissipation (damping) controls forces and displacements
• Rigidity under service demands
Lead Rubber Bearing (LRB)

Lead Core provides initial stiffness with high damping when yielded.

Internal Plate

Rubber Cover

Laminated Rubber provides flexibility and re-centers bearing after earthquake.

Flange Plate
Requirements of Marine Seismic Isolation System

- Every element tested
- Resist desired earthquake undamaged
- Saltwater resistant

Lead-Rubber Bearing
LRB Dolphin

- Batter piles are stiff and strong for service loads
- LRBs add flexibility and damping system
- LRBs capacity protect the batter piles

Example Pushover Plot

Damping vs. Displacement Plot
Uses of LRB Dolphins
“Seismic Isolation” and “Drift Control”
Applications of LRB dolphins

- **Retrofit of existing piers**
  - Seismic isolation reduces base shear, protects assets
  - Construction below deck
  - Minimize need for new piles

- **Deep water piers**
  - Drift control reduces displacements, protects assets
  - LRB dolphins strengthen pier for non-seismic demands
  - Reduces number and size of required plumb piles
Previous Applications of Seismic Isolation to Piers

POLA Berth 136 Extension (1994)
Sliding Friction Dampers

Puerto de Coronel, Chile (2008)
Use of Seismic Isolation on Piers by BergerABAM

- Retrofit of Broadway Pier – San Diego, CA (2009)
- Deep water pier (2011)
- Deep water pier with large industrial building (2011)
MOT Case Study

- Earthquake - MOTEMS POLA CLE
- No liquefaction
- Target displacement 10 inches

MOT Plan

Concrete deck
Pipe piles

60' x 100' unloading platform (ULP)

Section
Solution Using 54” Diameter Plumb Piles

- Mass = 4700 kips
- Displacement = 10 inches
- V = 2100 kips
- Damping 8%
- Steel weight in piles = 2,000,000 lbs
- **Approx. Cost = $4 million**
Solution Using 36” Piles and LRBs for Drift Control

- Mass = 3100 kips
- Displacement = 9.5 inches
- V=1170 kips
- 19% damping
- Steel weight in piles = 1,100,000 lbs
- **Approx. Cost = $2.8 million**

36” x 0.75” pipe piles plumb and battered (28 total)

36” thick deck

Section

Pile Plan
MOT Unloading Platform Case Study Summary

• 54” diameter piles
  • Thick heavy deck required to fix piles
  • Less damping – higher force
  • $4.0 million for unloading platform

• LRBs with 36” diameter piles
  • Thinner deck – less mass
  • More damping – less force
  • $2.8 million for unloading platform
Broadway Pier Seismic Upgrade – San Diego, CA

- Owner - San Diego Unified Port District
- Part of larger Broadway Pavilion project
- Completed in late 2010
- Project Team
  - BergerABAM
  - Bermello/Ajamil Partners Inc.
  - Moffatt&Nichol-Blaylock
Broadway Pier Project Overview

- Client wants new building on an aging pier
- Pier had seismic deficiencies – did not meet CBC
- No permit for new piles
- Project completion date fixed
- Limited budget
Seismic Deficiencies

- Brittle batter pile connections both directions
- Insufficient ductility in plumb piles
Solution

New Pavilion Building

- New seismic isolation bearings on new pile caps supported on the existing piles

- All work done under pier
- No building impact
- Cost $3 million
Construction Step 1

- Install falsework
- Remove pile cover
- Install stage 1 pile cap
Construction – Step 2

- Install pipe shoring
- Cut-off existing piles
- Anchor reinforcement
Construction – Step 3

- Complete stage 2 pile cap
- Install LRBs
- Complete grouting, remove shores and falsework
Summary - Applications of Seismic Isolation

• Deep water Piers
  • Drift control of plumb pile structures
  • Reduce base shear to protect assets (buildings, equipment & utilities)

• Retrofit of existing piers
  • Seismic isolation
  • Reduce base shear to protect assets
  • Minimize impacts on operations
  • Minimize number of new piles

• Questions?