PREVENTION FIRST 2012

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SEISMIC ISOLATION OF PIERS AND WHARVES USING LEAD-RUBBER BEARINGS

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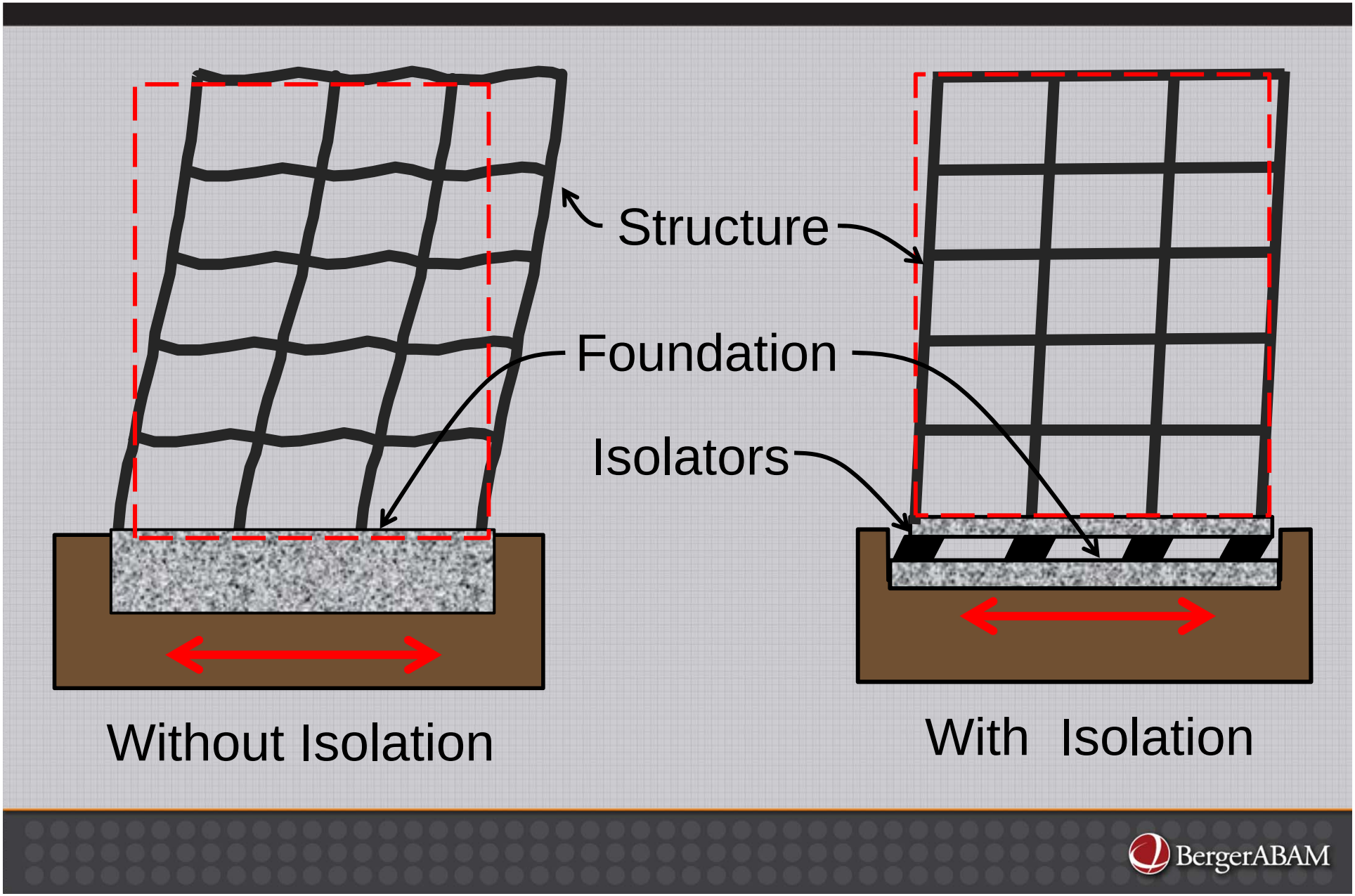
Presentation Overview

- Principles of seismic isolation
- Principles of lead-rubber bearings (LRBs)
- Applications
- MOT case study
- Broadway Pier retrofit

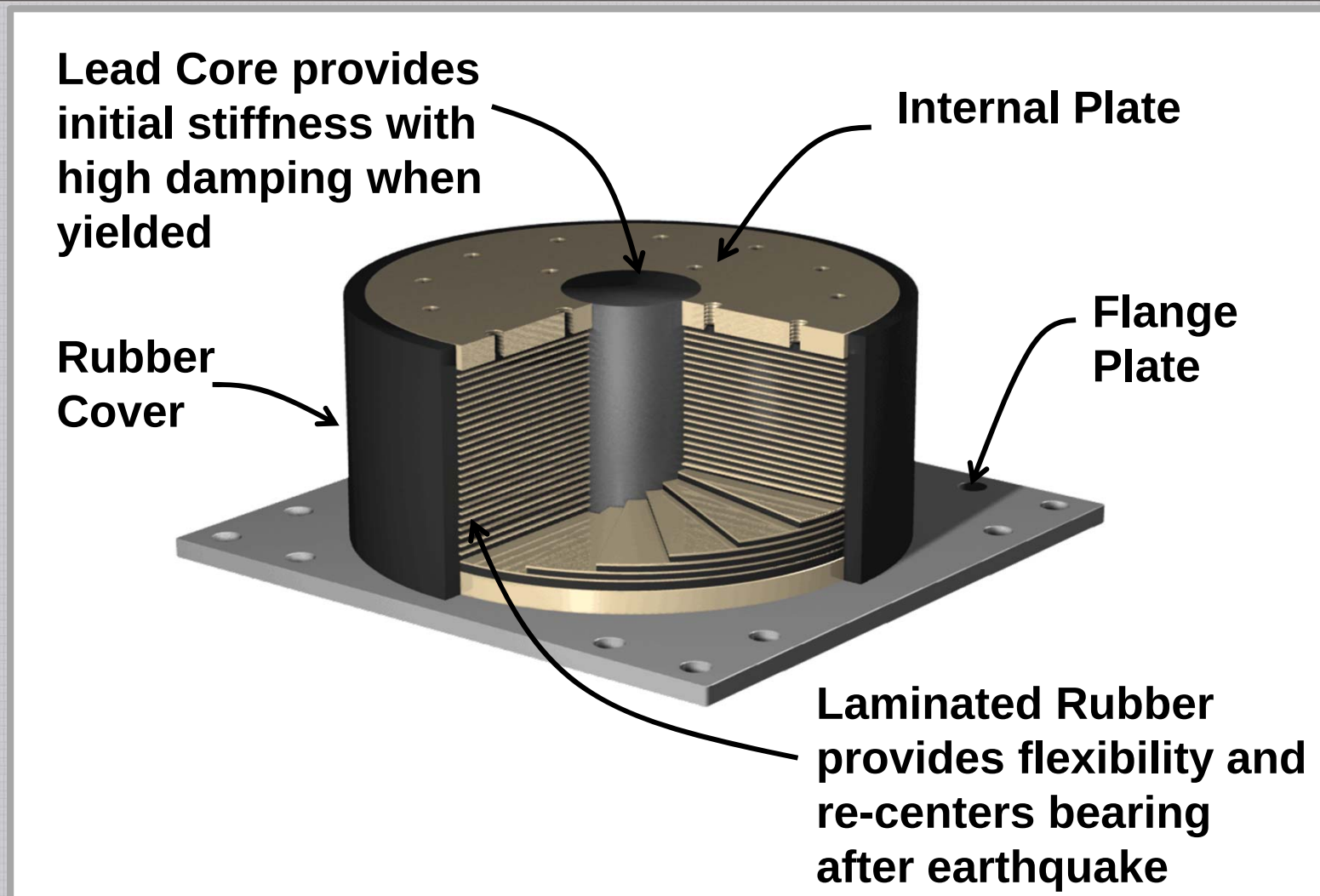
Behavior with and without Seismic Isolation



Characteristics of a Seismic Isolation System

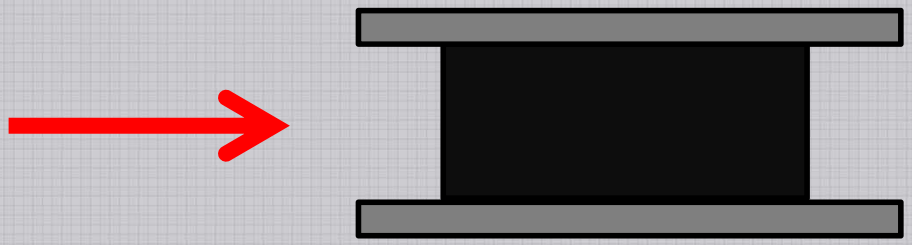
- Added flexibility increases period of vibration and reduces force response
- Energy dissipation (damping) controls forces and displacements
- Rigidity under service demands

Lead Rubber Bearing (LRB)



Requirements of Marine Seismic Isolation System

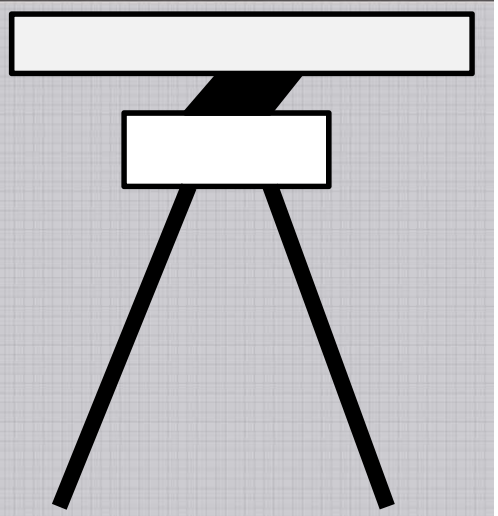
- Every element tested
- Resist desired earthquake undamaged
- Saltwater resistant

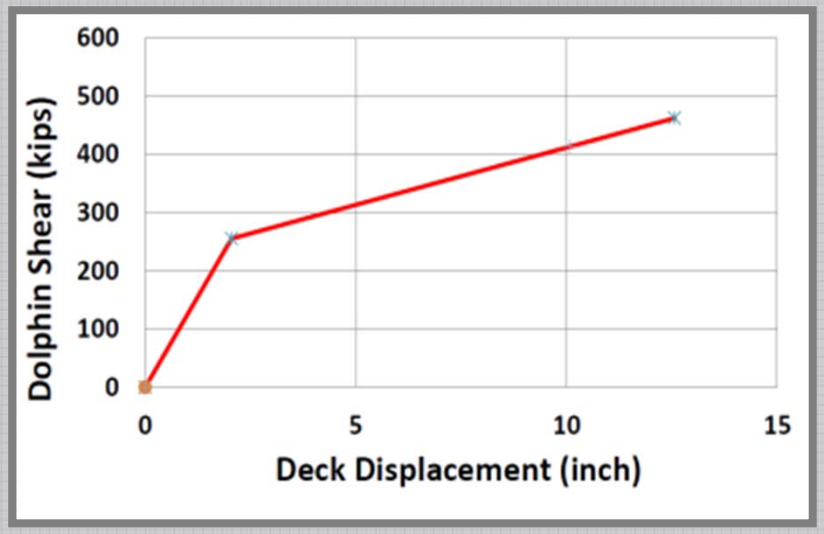


Lead-Rubber Bearing

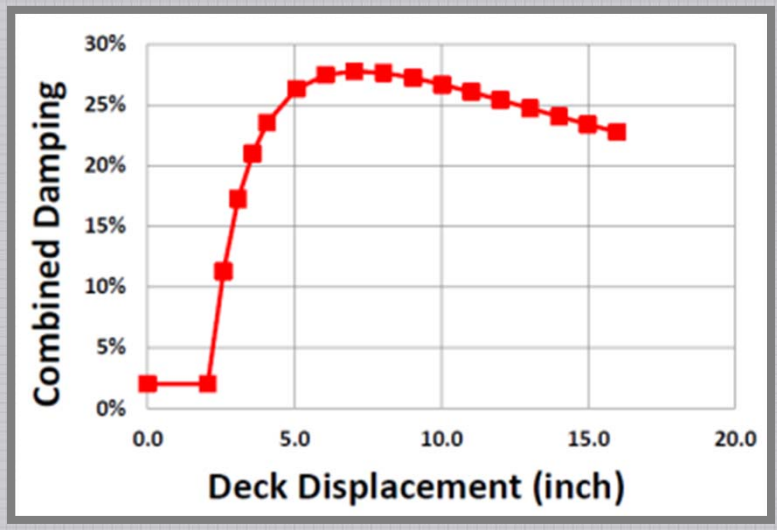
LRB Dolphin

- 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

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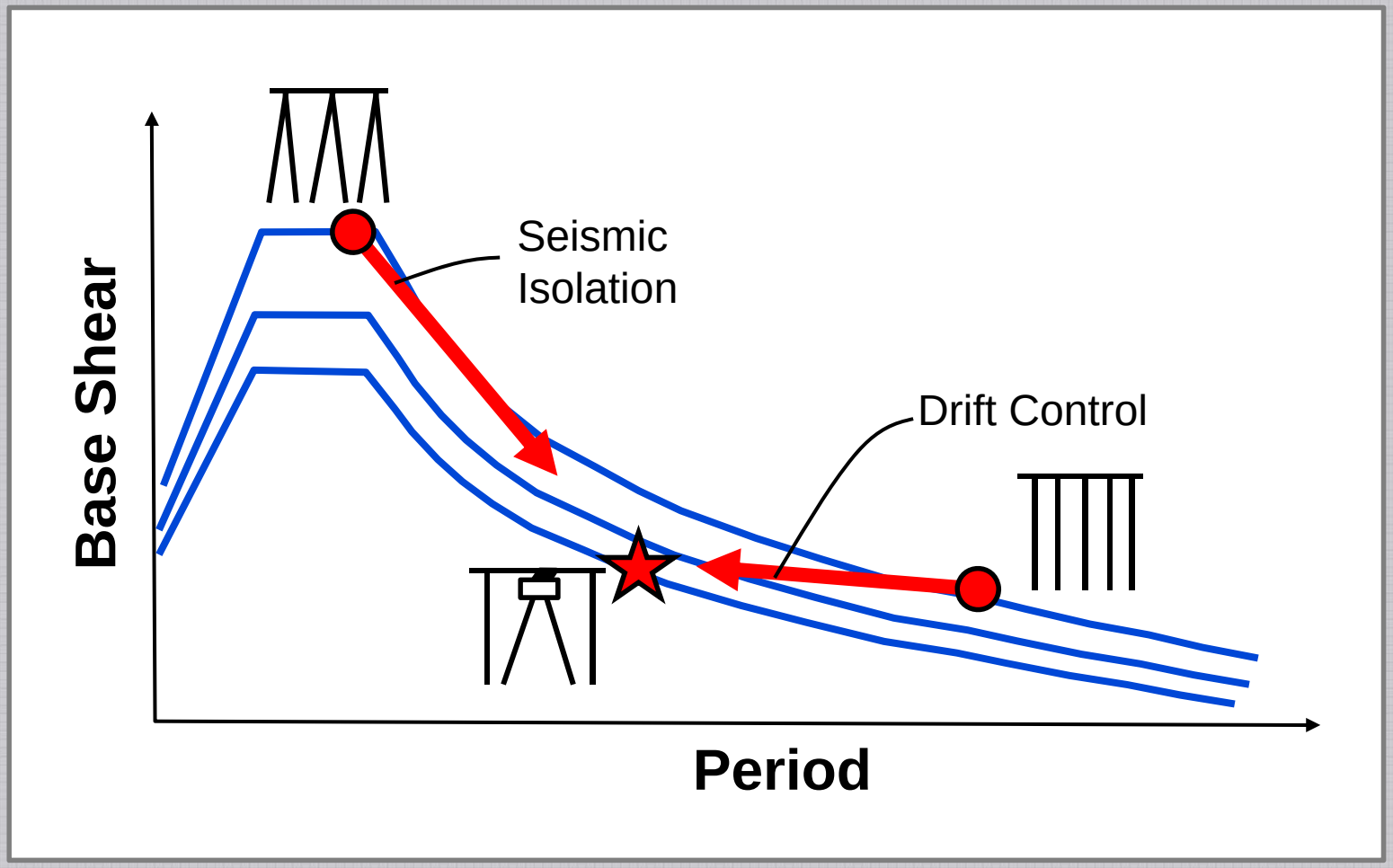
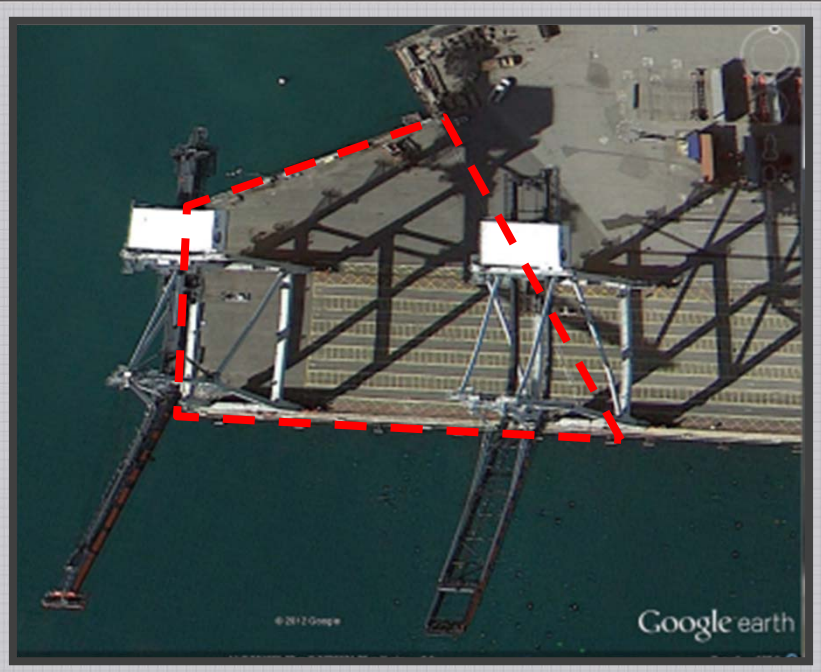
Uses of LRB Dolphins
“Seismic Isolation” and “Drift Control”



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)

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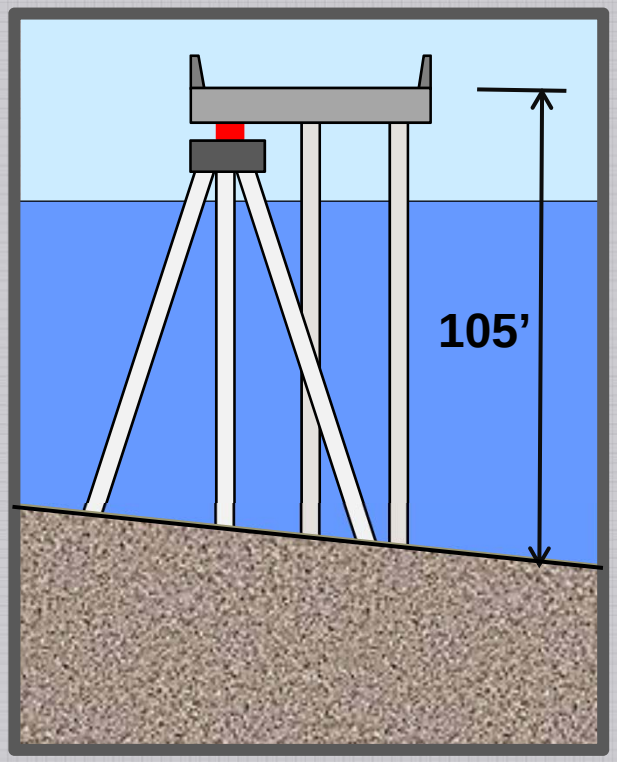
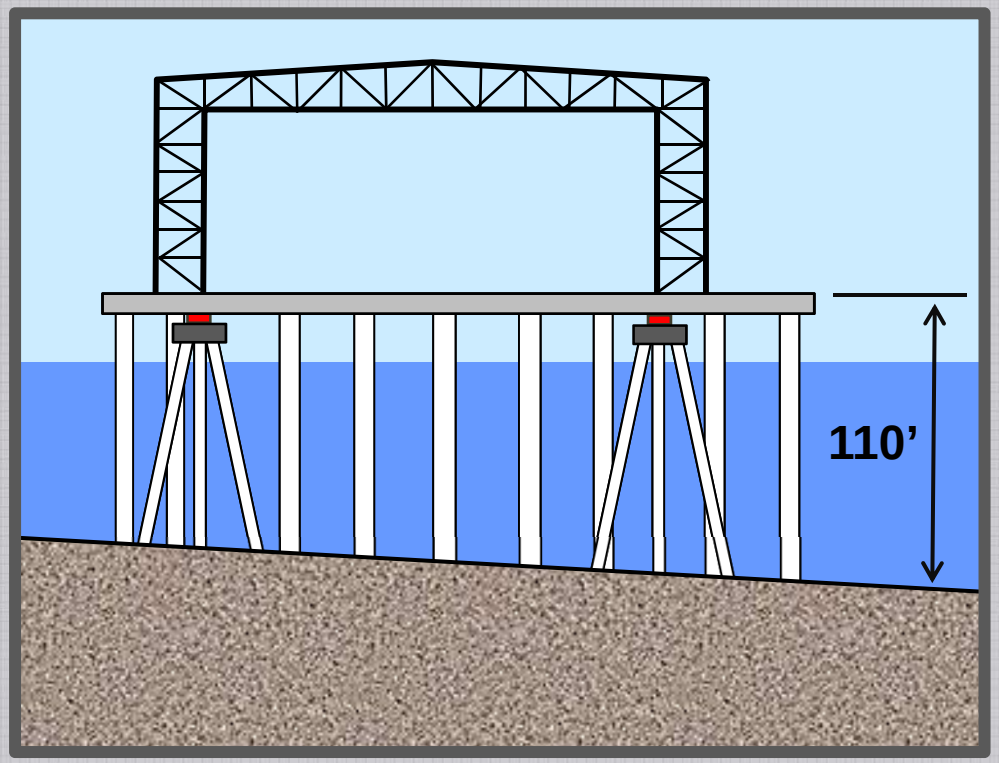
Use of Seismic Isolation on Piers by BergerABAM

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





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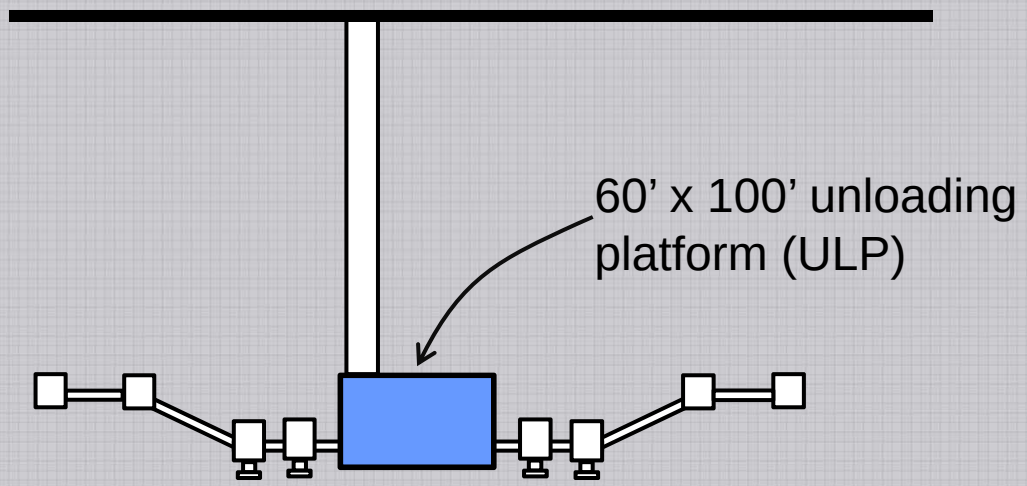
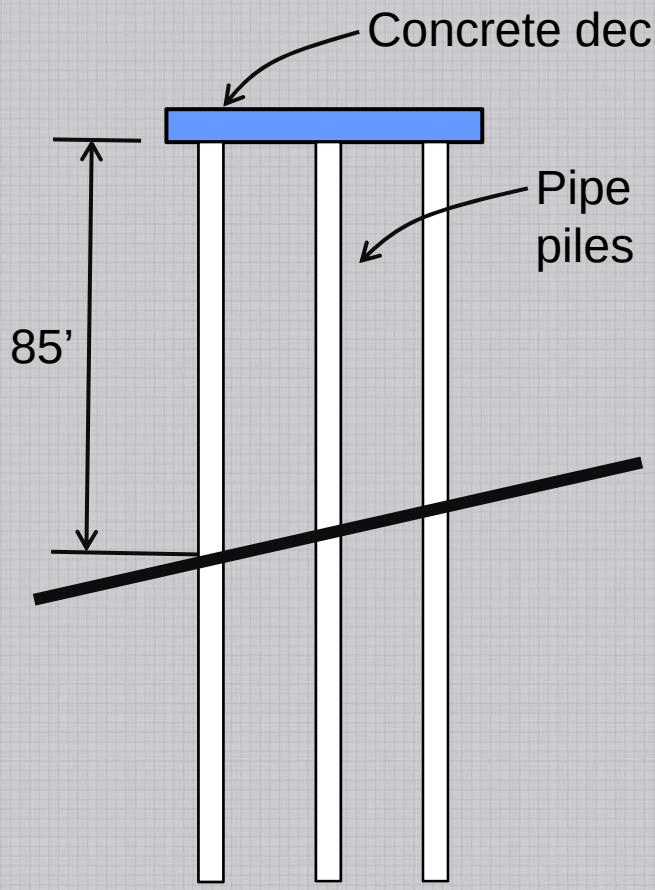
MOT Case Study

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



MOT Plan



Section

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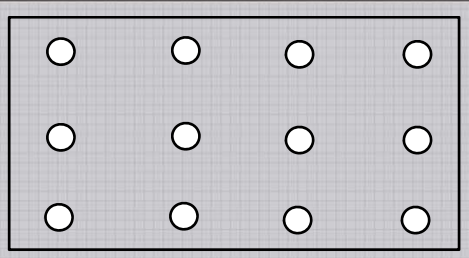
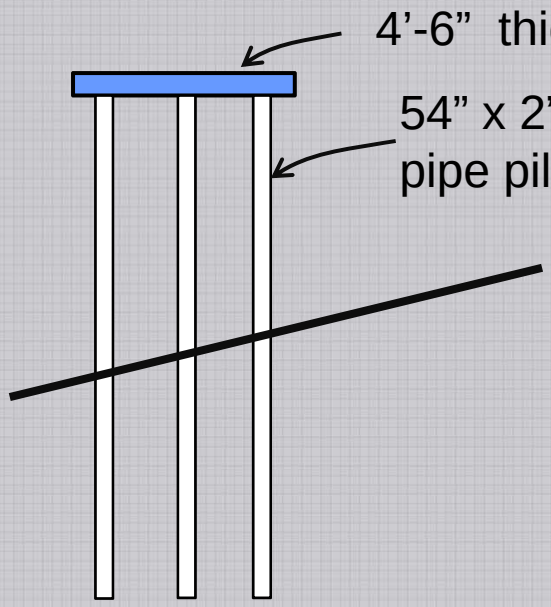
Solution Using 54” Diameter Plumb Piles

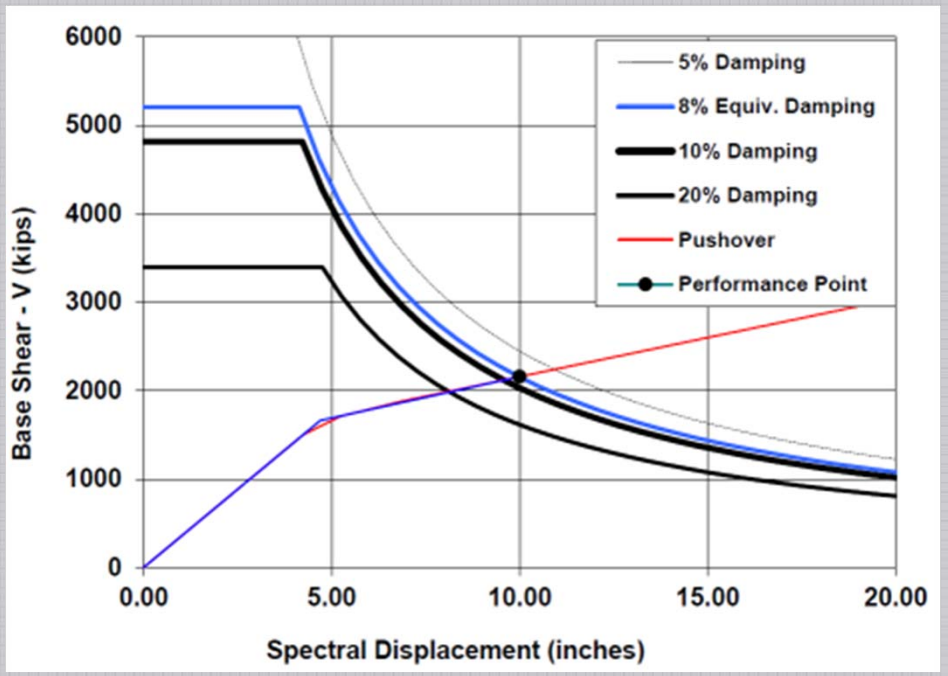


Pile Plan



Section

- Mass = 4700 kips
- Displacement = 10 inches
- V= 2100 kips
- Damping 8%
- Steel weight in piles = 2,000,000 lbs
- **Approx. Cost = $4 million**



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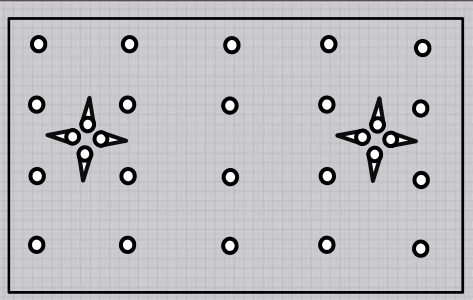
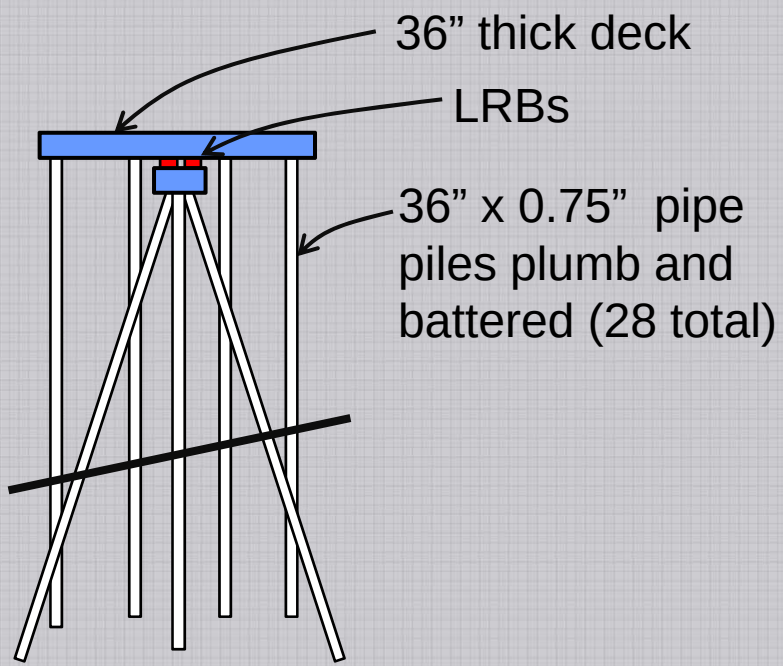
Solution Using 36” Piles and LRBs for Drift Control

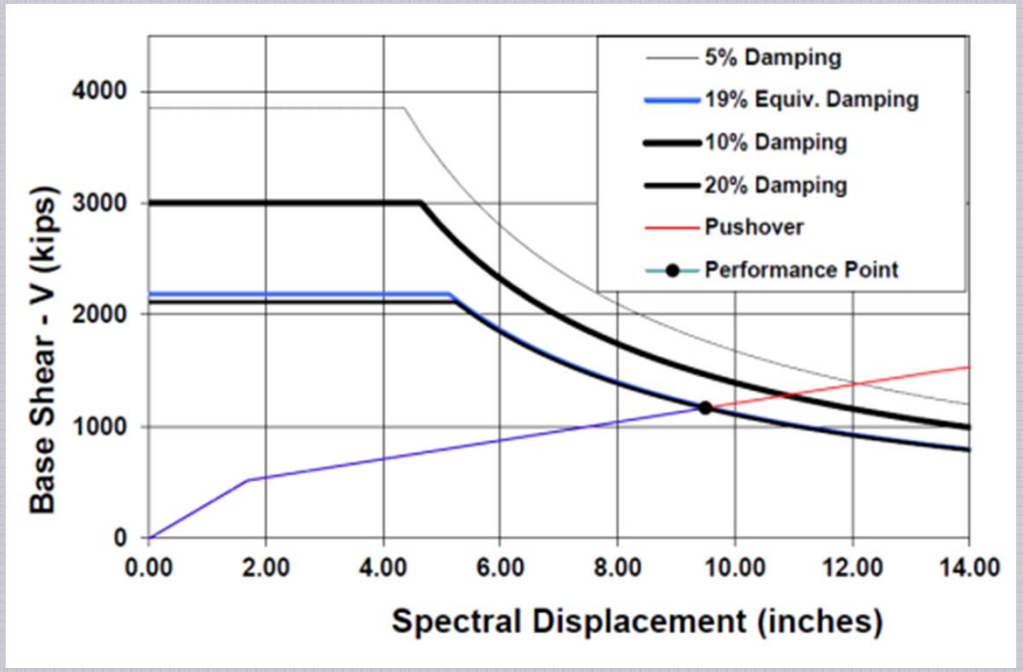


Pile Plan



Section

- 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**



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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**

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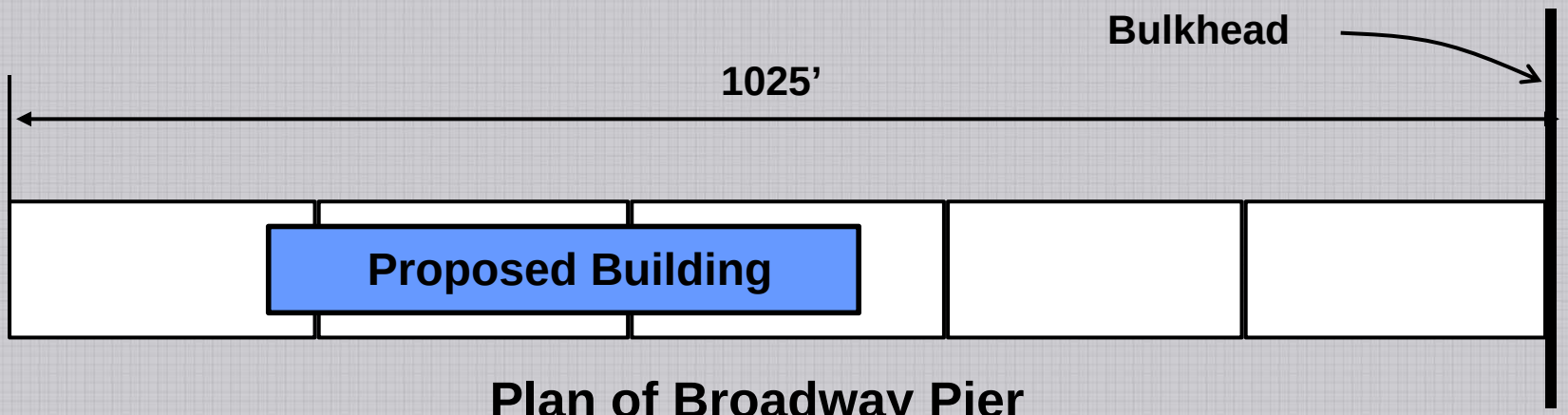
Broadway Pier Seismic Upgrade – San Diego, CA

- 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

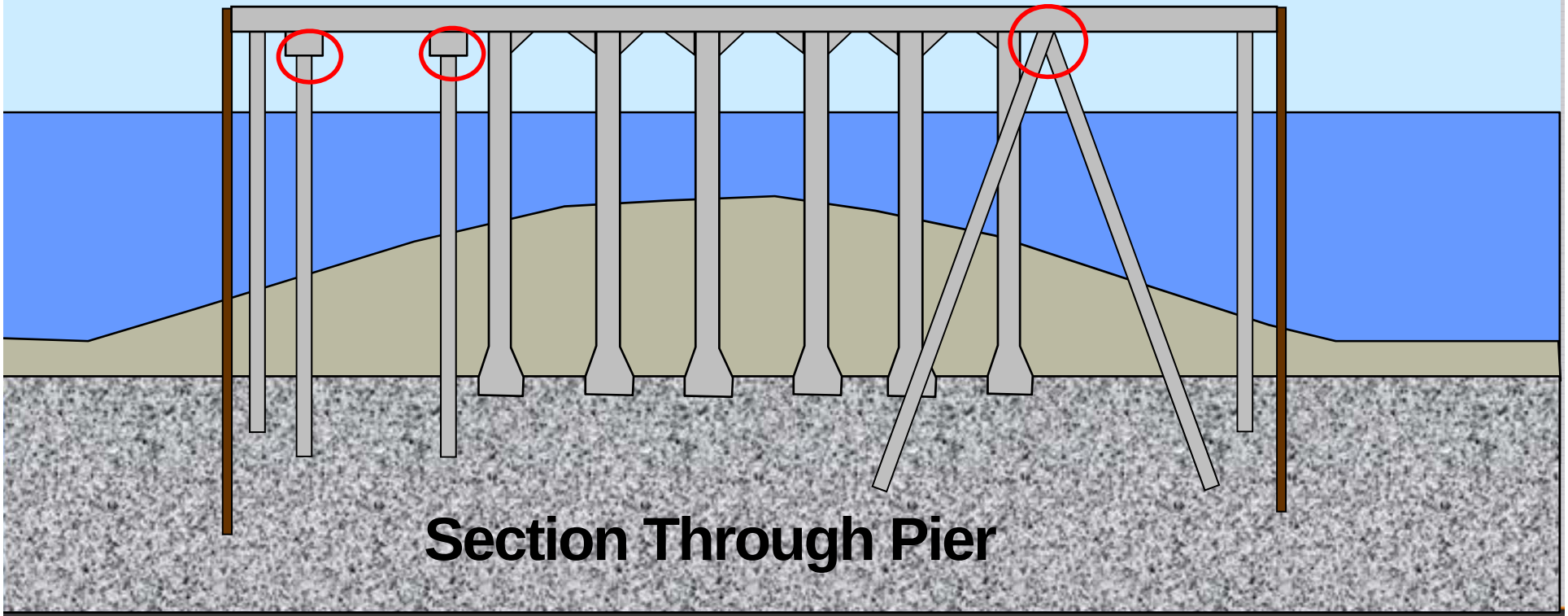
- Client wants new building on an aging pier
- Pier had seismic deficiencies – did not meet CBC
- No permit for new piles
- Project completion date fixed
- Limited budget



Plan of Broadway Pier

Seismic Deficiencies

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



Section Through Pier

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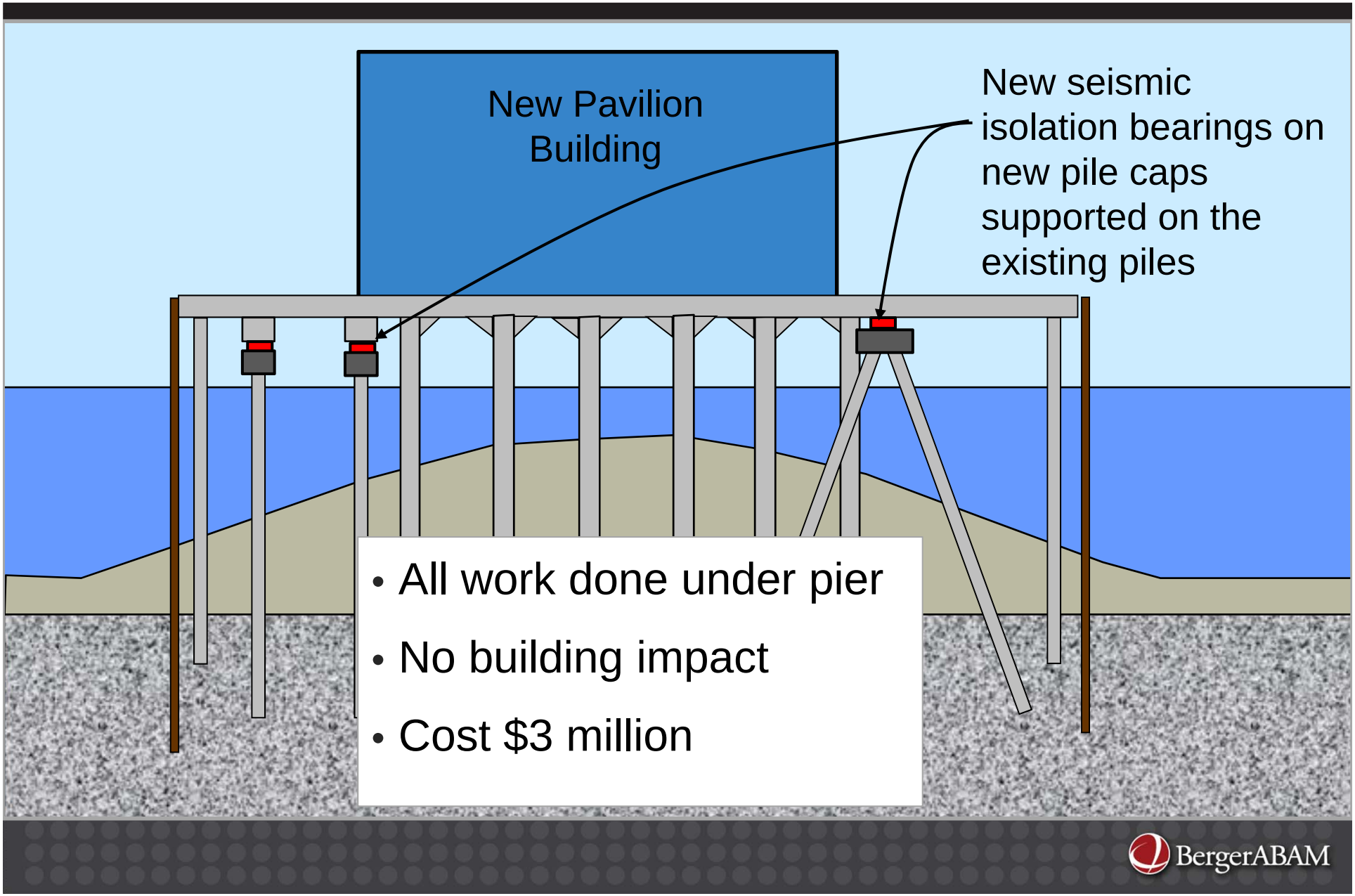
Solution


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
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Construction Step 1

- Install falsework
- Remove pile cover
- Install stage 1 pile cap

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Construction – Step 2

- Install pipe shoring
- Cut-off existing piles
- Anchor reinforcement

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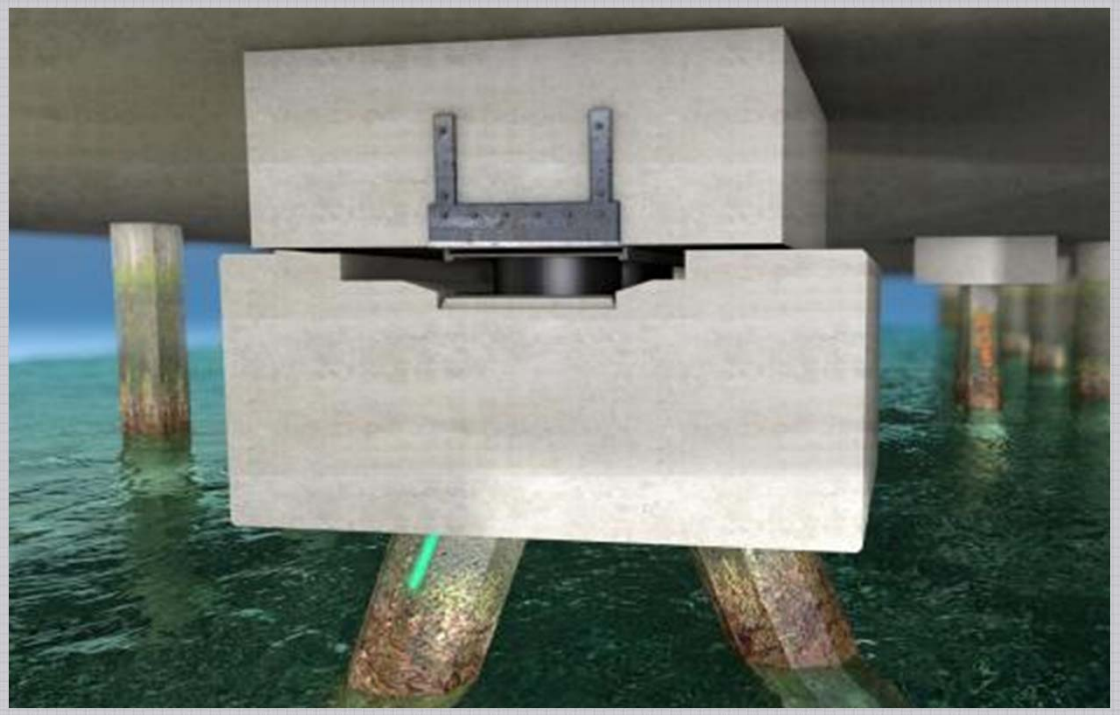
Construction – Step 3



- 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?