Alaska Department of Transportation & Public Facilities

Post Earthquake Structural Inspection: A Case Study in Modern Seismic Design

Andrew Wells, PE

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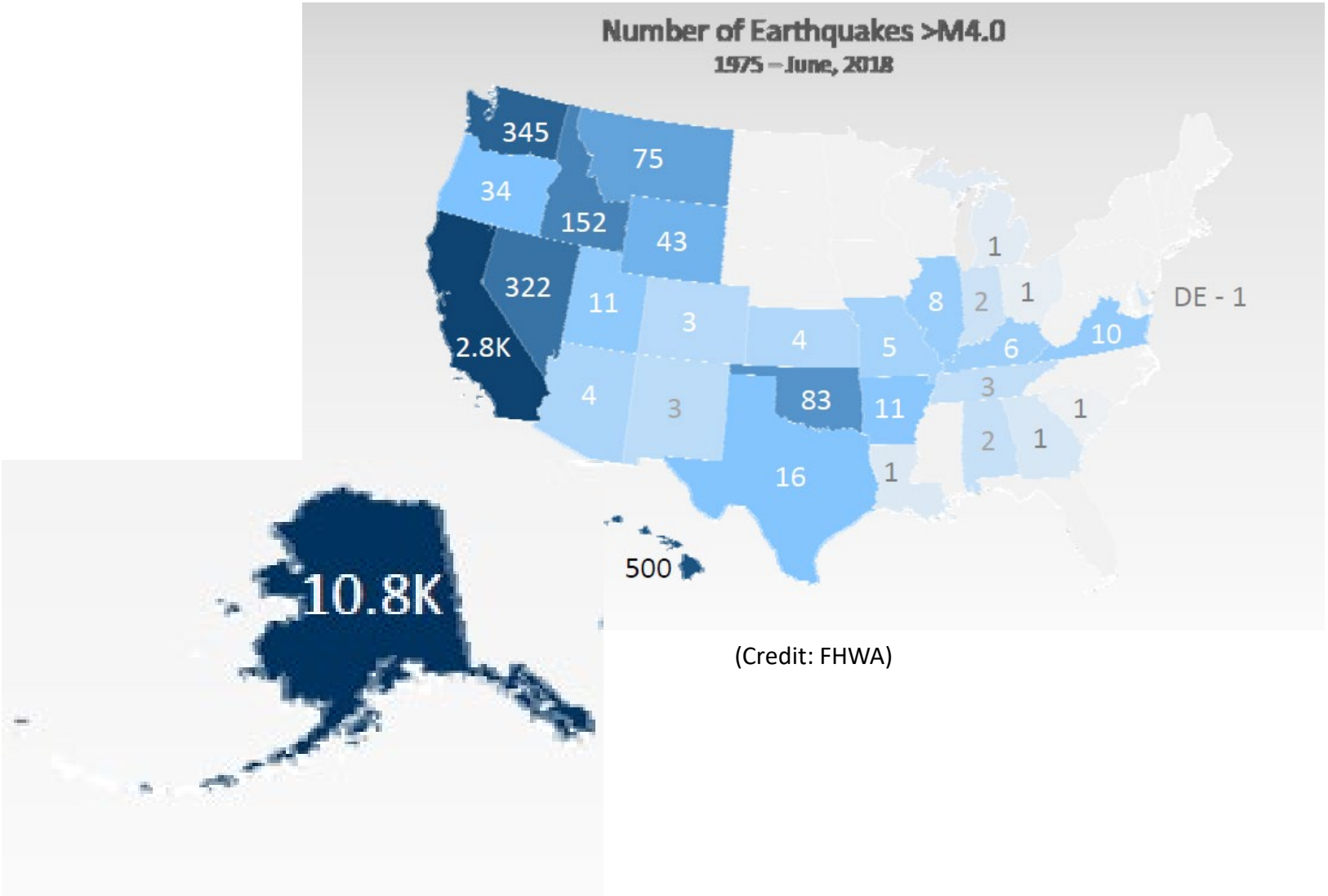
Presentation Outline

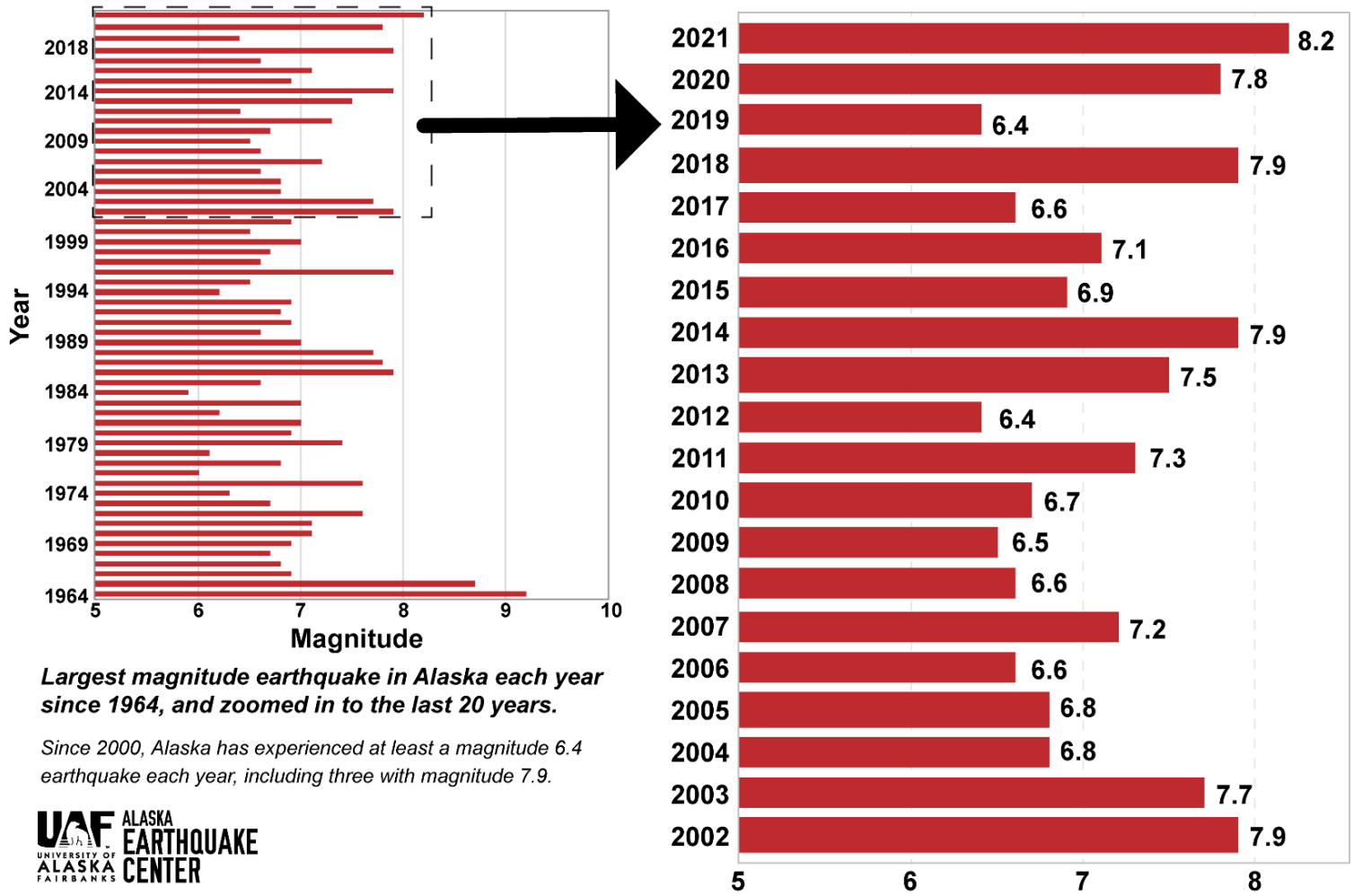
- Seismic history on the Aleutian Islands over the last century
- Overview of the seismic event
- Overview of the Alaska DOT&PF response
- Discussion of modern seismic design principles
- Compare two adjacent structures with disparate outcomes

Seismic History



(Credit: FHWA)

Seismic History



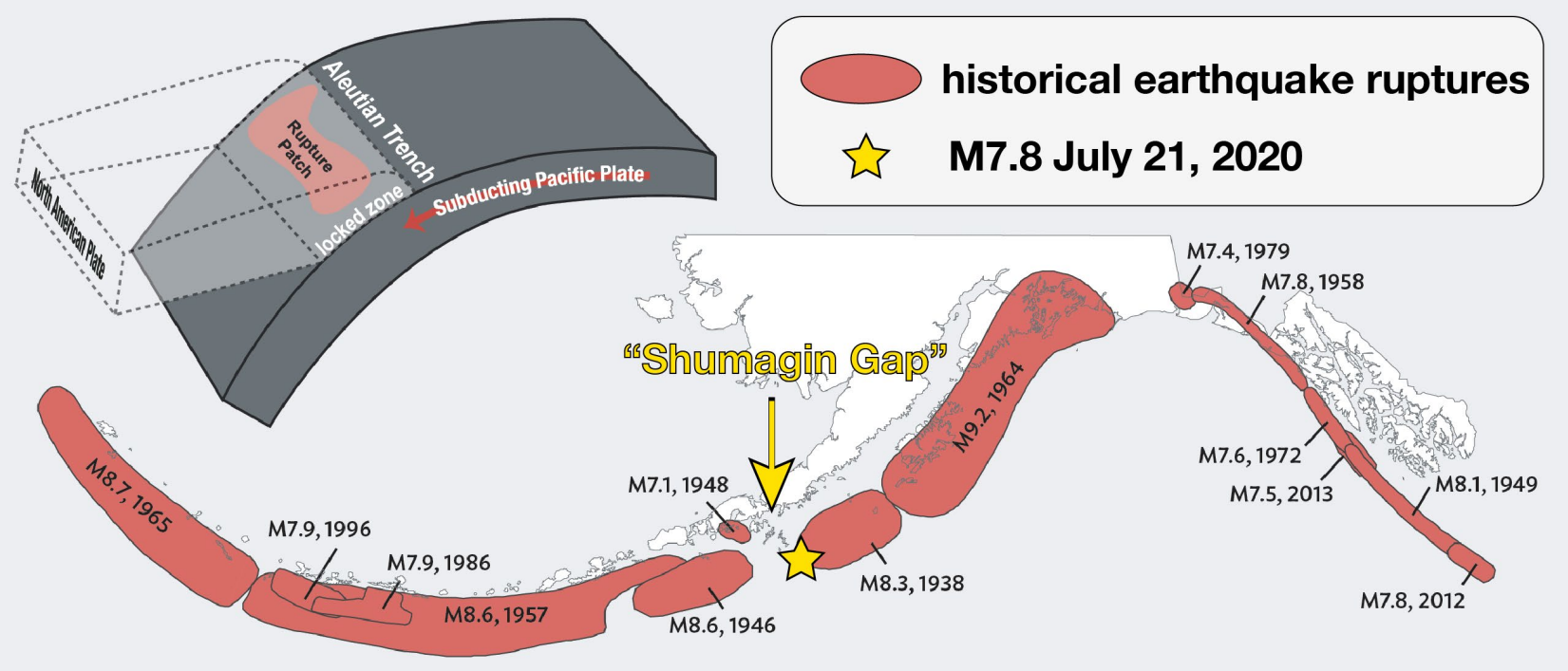
Largest magnitude earthquake in Alaska each year since 1964, and zoomed in to the last 20 years.

Since 2000, Alaska has experienced at least a magnitude 6.4 earthquake each year, including three with magnitude 7.9.

UAF UNIVERSITY OF ALASKA FAIRBANKS ALASKA EARTHQUAKE CENTER

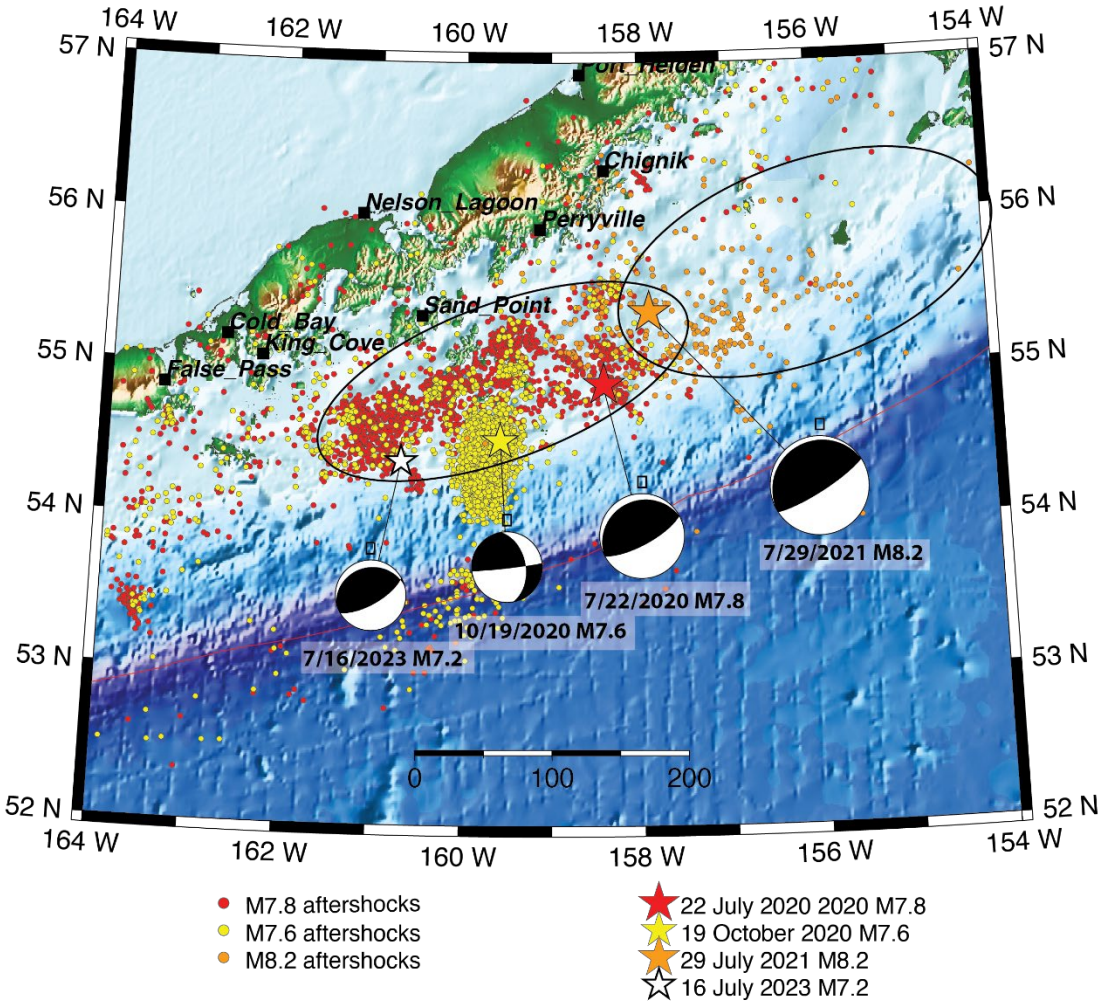
Seismic History

- Since 1938 eight earthquakes M7.1-M9.4 ruptured 1,800 mi. along the Aleutian Subduction zone between the North American and Pacific Plates
- A 75 mi. section known as the Shumagin Gap remained unruptured until July 2020



(Credit: Alaska Earthquake Center)

Seismic History



(Credit: Alaska Earthquake Center)

Event Overview

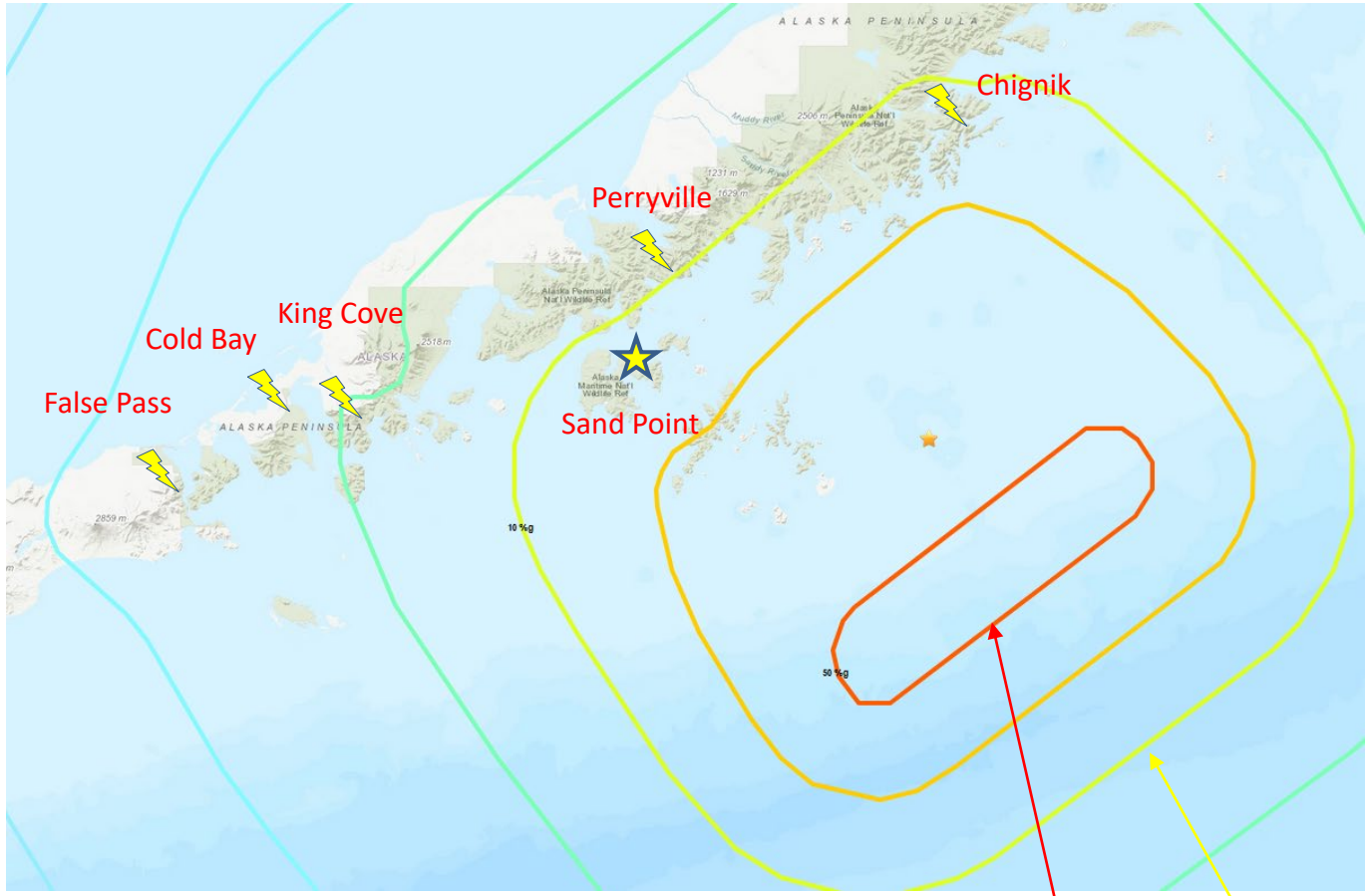
4:44am Wednesday, July 22, 2020

- Magnitude 7.8
- Depth = 28.0 km (17.4 miles)

16 structures in 6 communities affected

- 10 Bridges
- 6 Docks/Ferry Terminals

Population Impacted ~2,000



(Photo Credit: USGS)

Event Overview

Bridges:

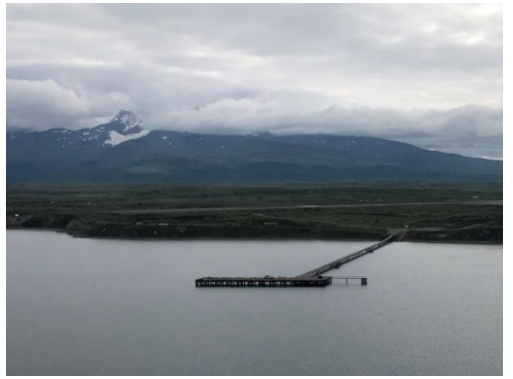
- Mostly single-span, steel or timber superstructure with timber deck on spread footings
- 1 steel ACROW Bridge truss
- 1 multi-span, timber superstructure with timber deck on steel piles
- 1 multi-span, precast decked bulb-T on RCFP piles

Humbolt Slough
(Sand Point, AK)

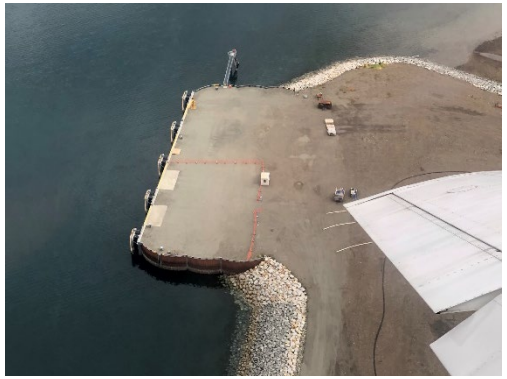
Event Overview

Ferry Terminals:

- 2 steel sheet pile bulkheads
- 2 steel pile docks with concrete slab decks
- 1 steel pile dock with a timber deck
- 1 RCFP pile dock with concrete deck



Cold Bay Dock



Chignik Dock

Sand Point City Dock

Sand Point City Dock II

King Cove City Dock

False Pass City Dock

Alaska DOT&PF Response

Event: 4:44am Wednesday, July 22

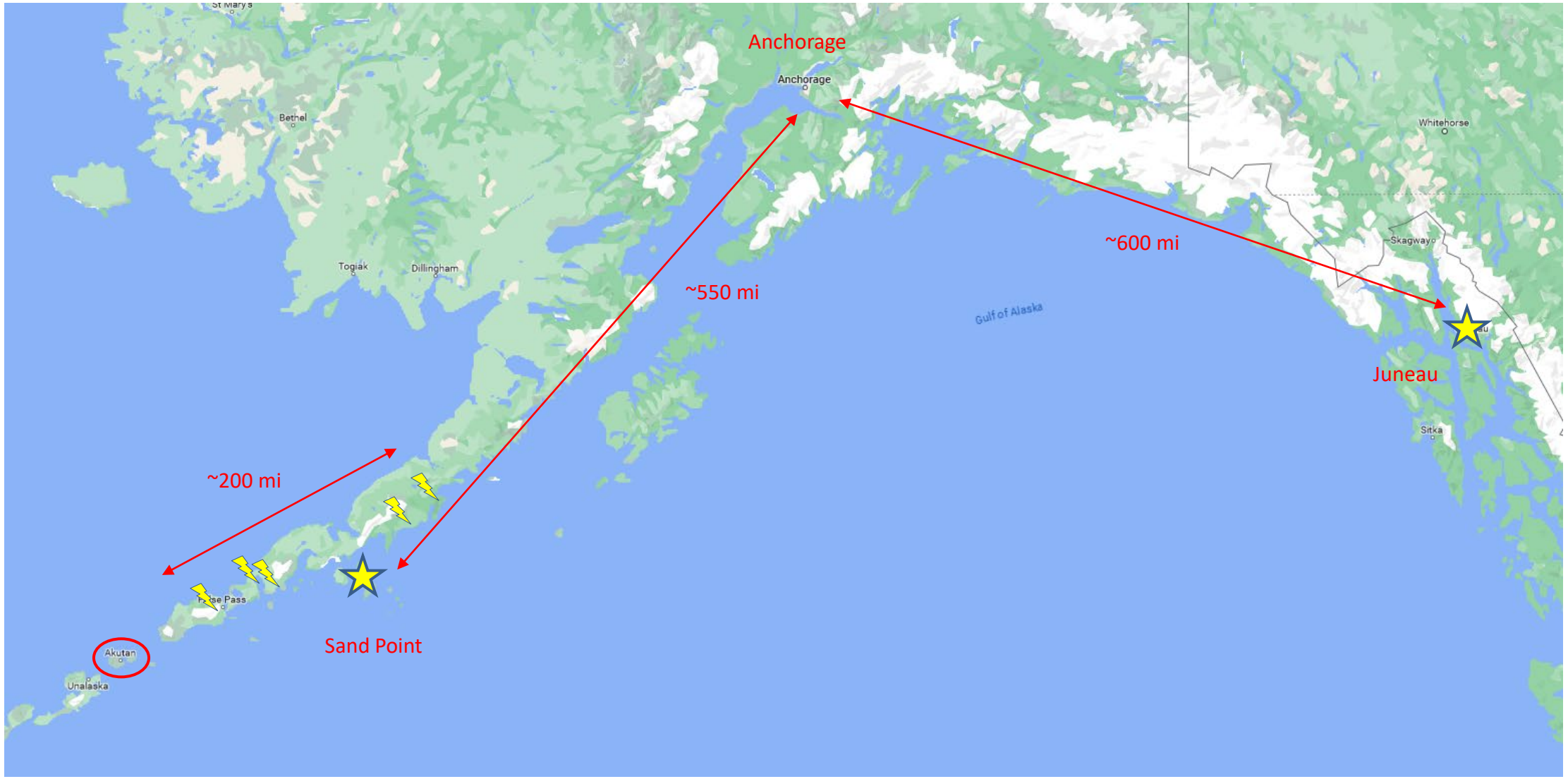
Team Assembled: Thursday

- Bridge Design
- Southcoast Marine Design
- Southcoast Geotechnical Engineer

Mobilized to ANC: Friday afternoon (via AK Airlines)

Mobilized to SP: Saturday morning (via local airline)

Alaska DOT&PF Response



(google maps)

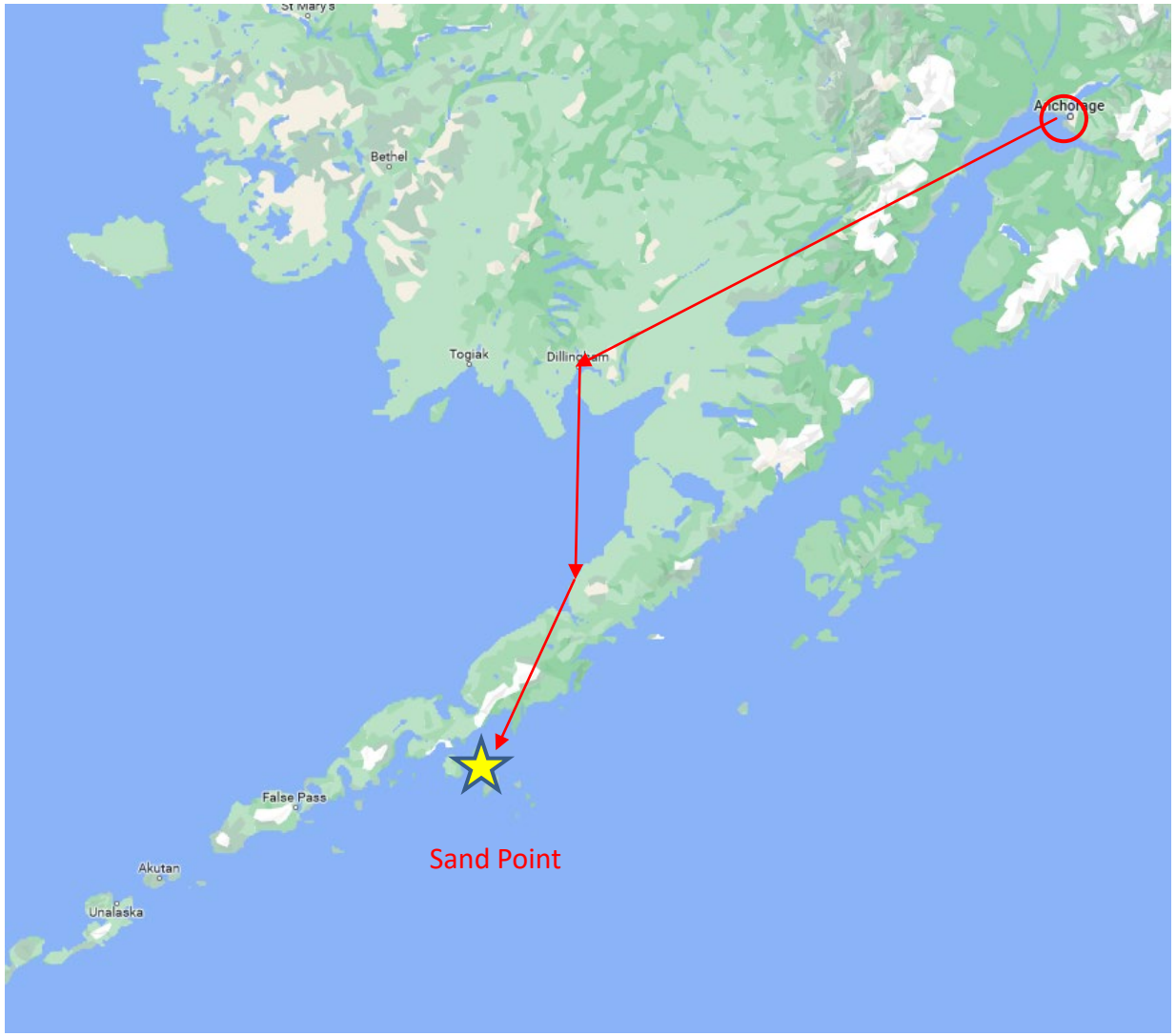
Alaska DOT&PF Response

Day 1: Saturday

Fly from ANC to SDP

Inspection:

- Sand Point City Dock II
- Old Sand Point City Dock



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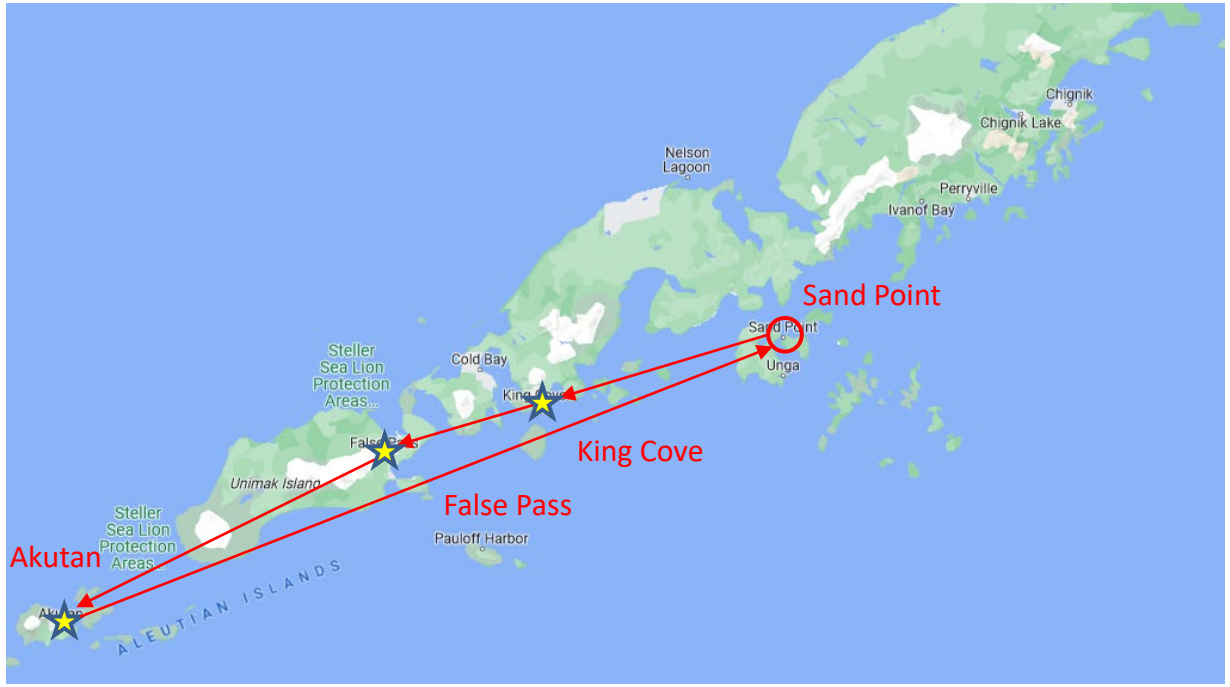
Day 2: King Cove / False Pass / Akutan

Inspection:

- King Cove City Dock
- King Cove Access Bridge
- King Cove Lagoon Bridge

- False Pass City Dock
- Unagman Creek Bridge
- Breach Bridge

- Akutan City Dock



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King Cove Lagoon

Alaska DOT&PF Response

Akutan City Dock

Alaska DOT&PF Response

Day 3: Chignik / Perryville / Cold Bay

Inspection:

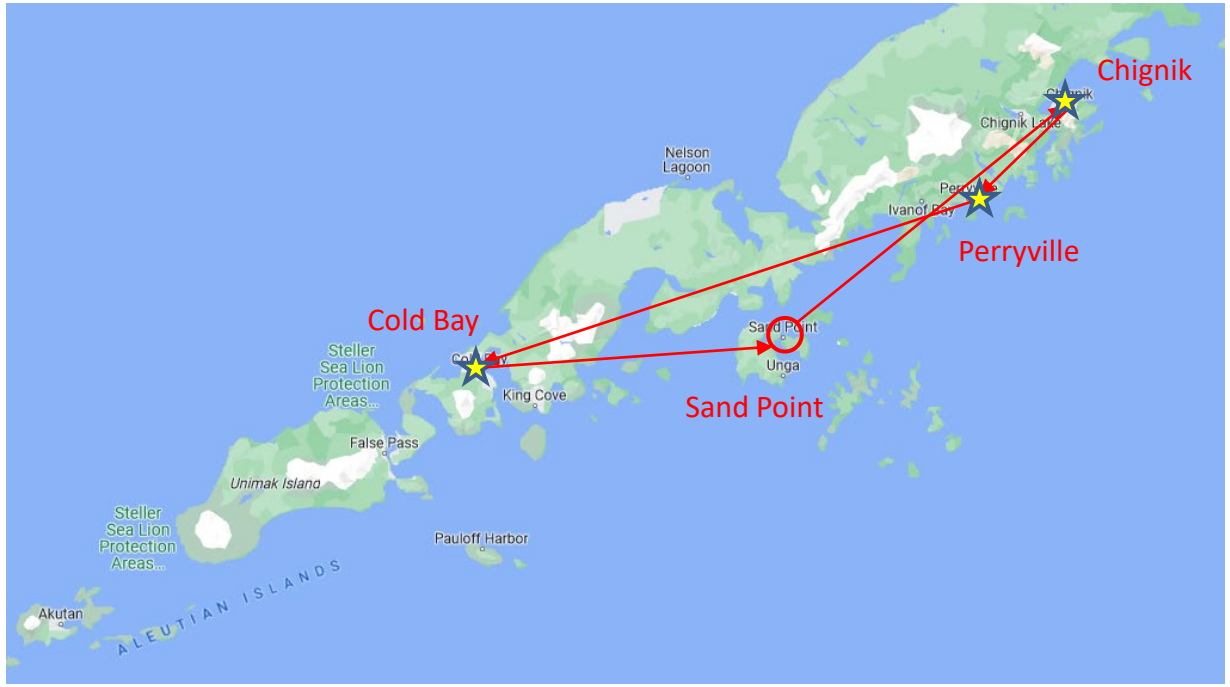
- Chignik City Dock
- Chignik Creek
- Indian Creek

- Perryville Creek

- Cold Bay Dock

(M6.1 Aftershock while in Chignik)

→ Re-inspected Sand Point Docks



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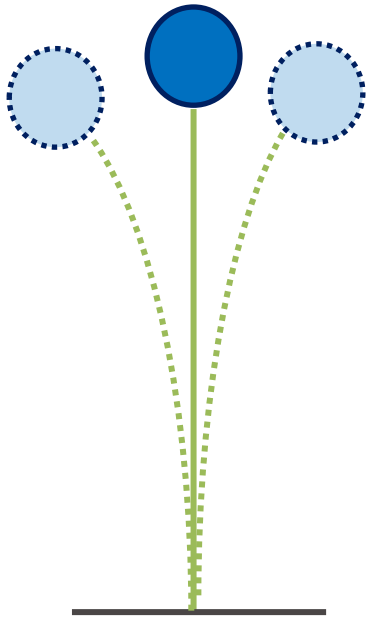
Perryville Creek

Seismic Design Principles



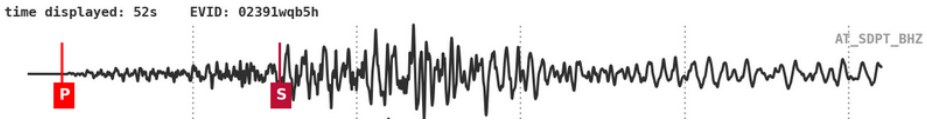
Natural Period of Vibration (T_n)

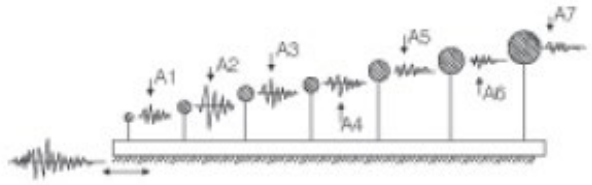
$$T_n = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{m}{EI}}$$

Seismic Design Principles

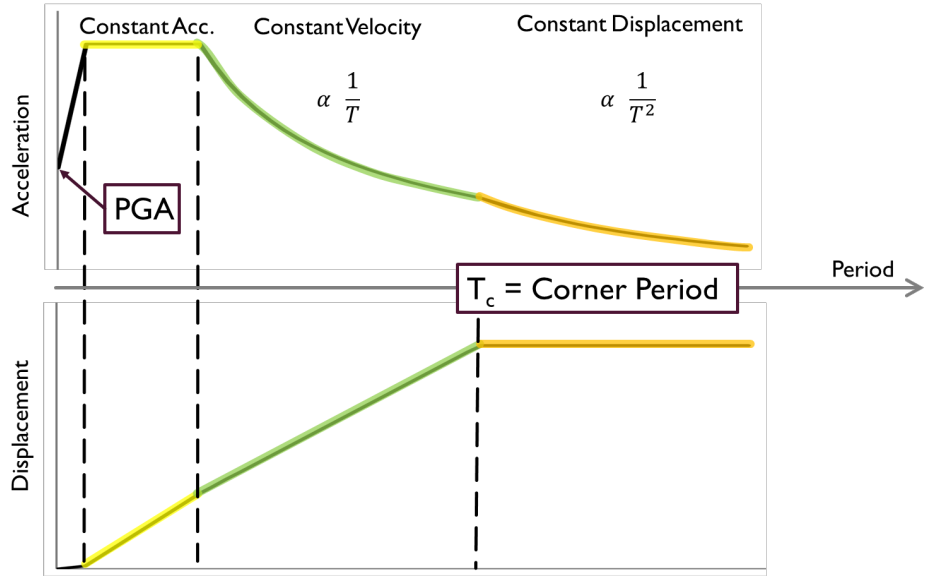
- Seismic motion is typically represented as an acceleration with respect to period
  - How we collect data (accelerometers)
  - Force based methods:

    F = m x a

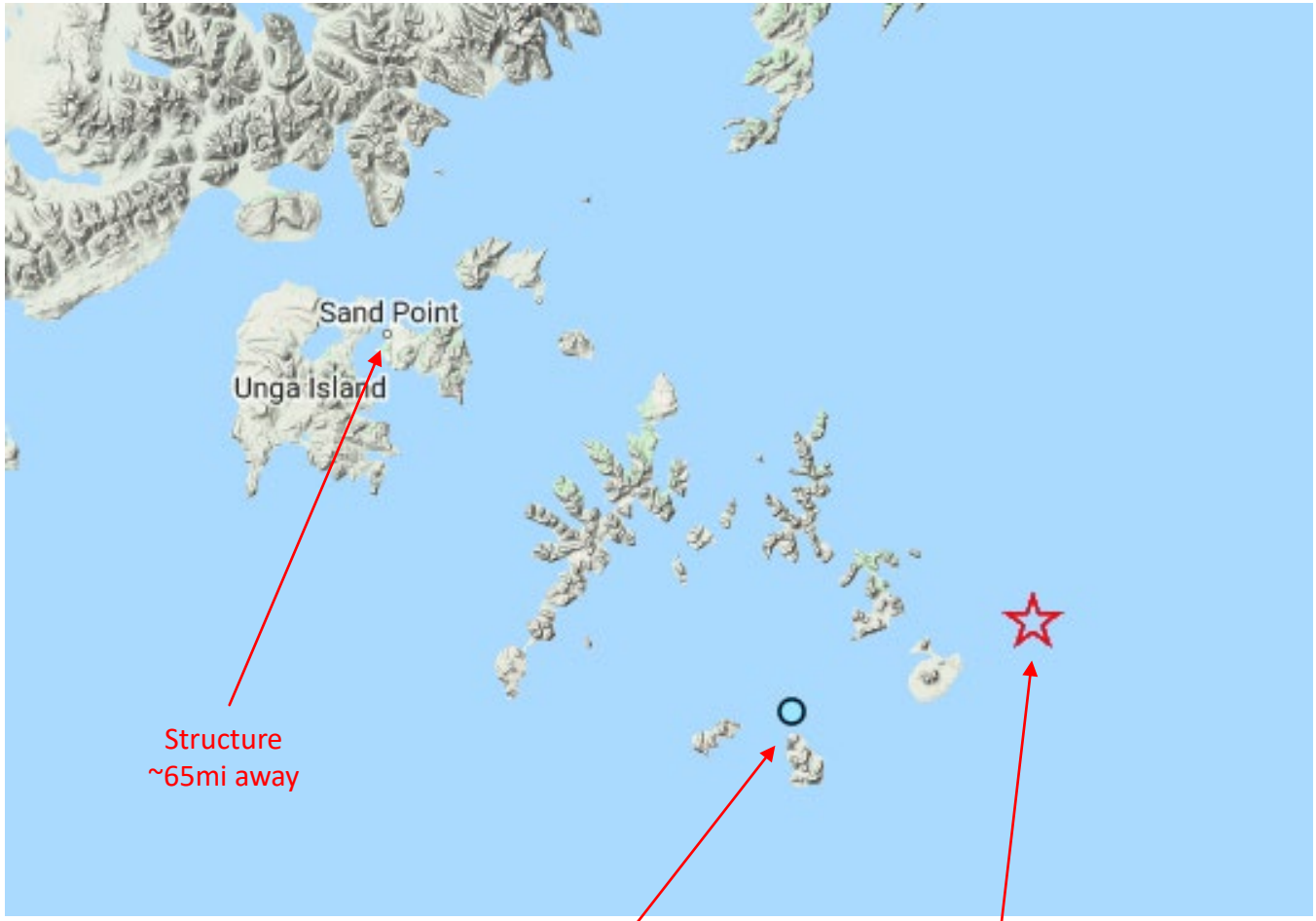


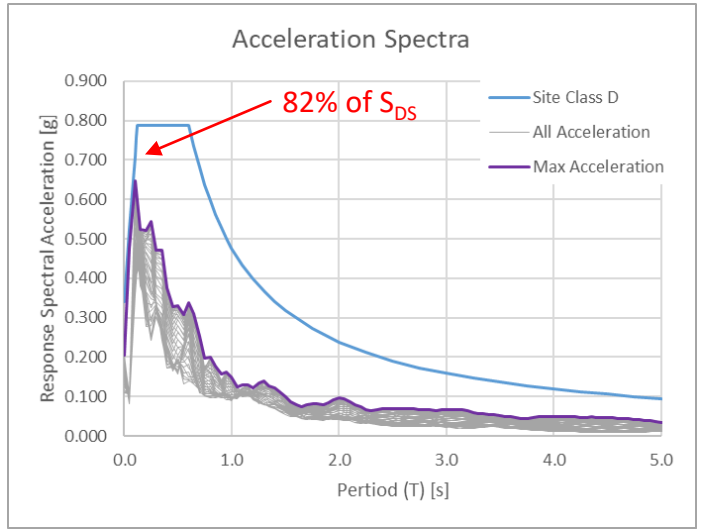


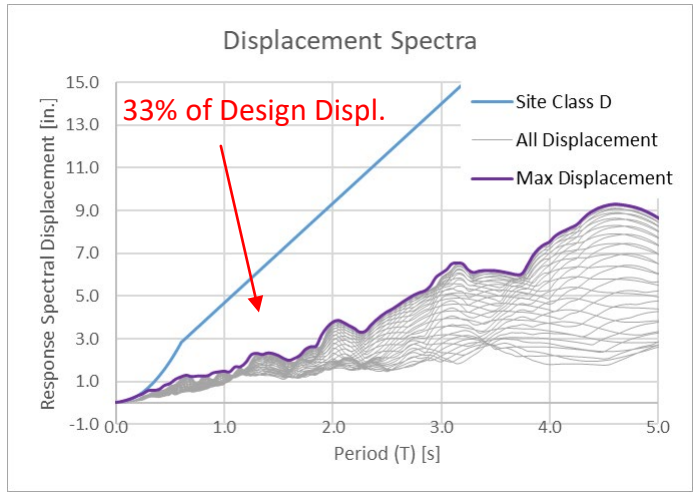
- Acceleration can be integrated to determine the induced displacement.
- Because the displacement is tied to the natural period, it is a fundamental property of the design seismic event.
- Displacement is directly relevant to structural performance during a seismic event.
- It is also a variable that can be assessed directly and can be treated as a limit state.



Seismic Design Principles







Seismic Design Principles

- In a design level seismic event, some portion of the bridge is going to become plastic and potentially fail if not designed properly
  - As engineers, we determine what elements will become plastic by intentionally designing ductile “fuses” in the system that will plasticize, but not fracture in order to protect more vital portions of the structure that we want to remain elastic.
  - Therefore we are “capacity protecting” the non-fusible elements to prevent collapse.

→ We are designing a predictable mechanism that requires failure to occur at a location that is best suited to accommodate seismic demands

Comparison of Structures

- Two adjacent docks. One built in 1983 and the other in 2019.

Breakwater

Soil Cracking in Breakwater

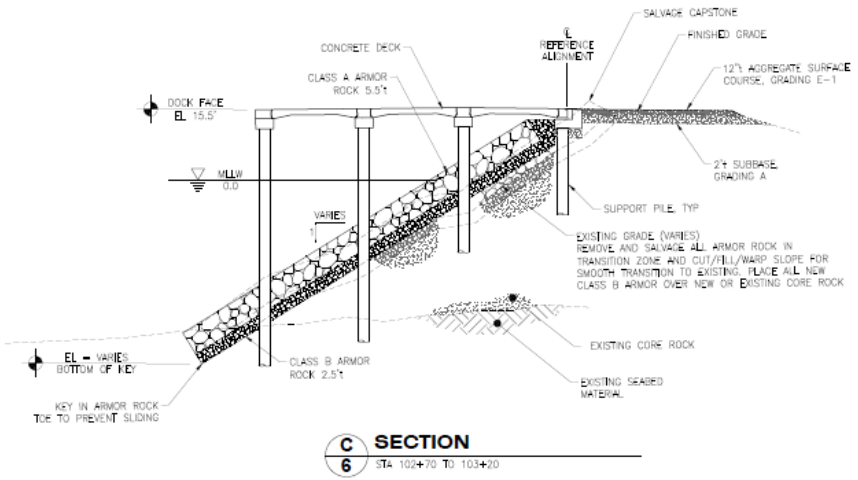
Old Dock

New Dock

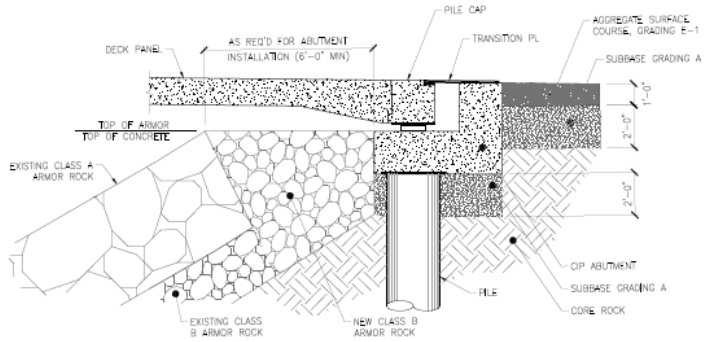
(Photo Credit: Google Earth)

Comparison of Structures

Sand Point City Dock II (2019)

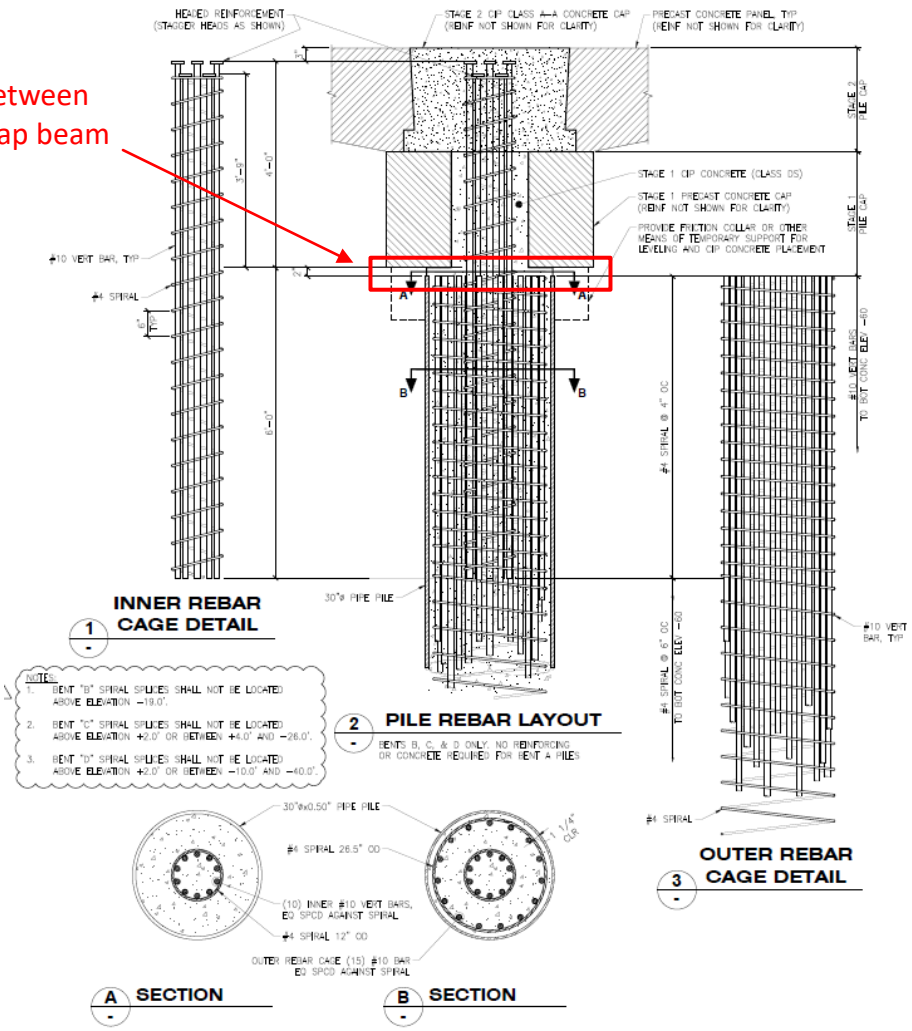


C 6 SECTION
STA 102+70 TO 103+20



D 6 SECTION - DETAIL

2" gap between pipe and cap beam



1 - INNER REBAR CAGE DETAIL

2 - PILE REBAR LAYOUT
BENTS B, C, & D ONLY. NO REINFORCING OR CONCRETE REQUIRED FOR BENT A PILES

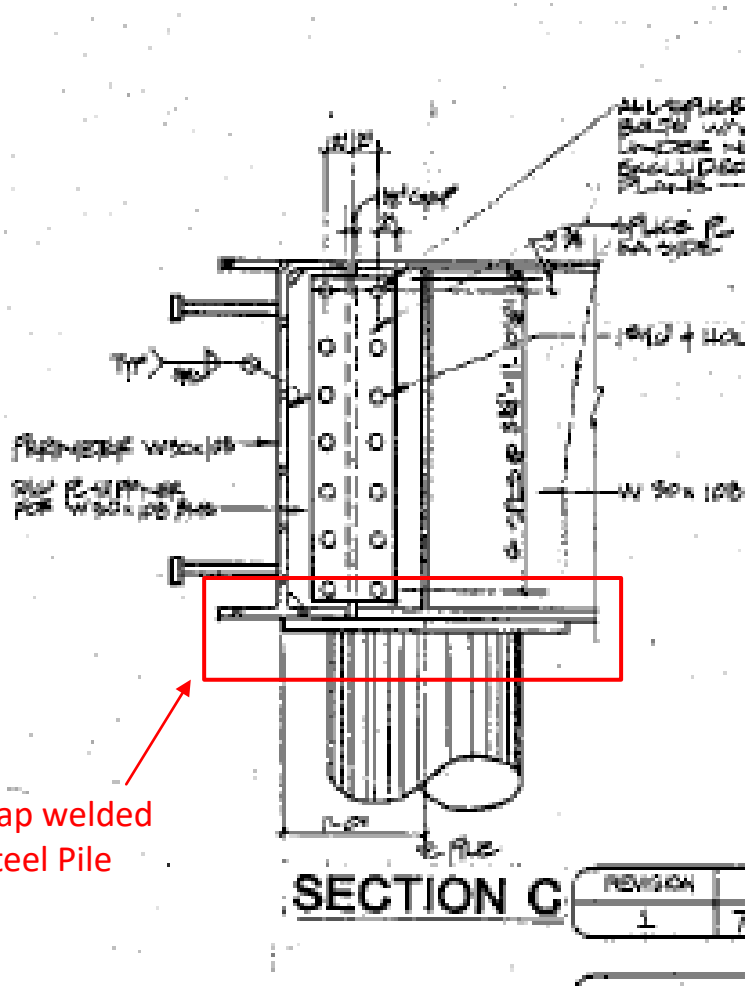
3 - OUTER REBAR CAGE DETAIL

A - SECTION

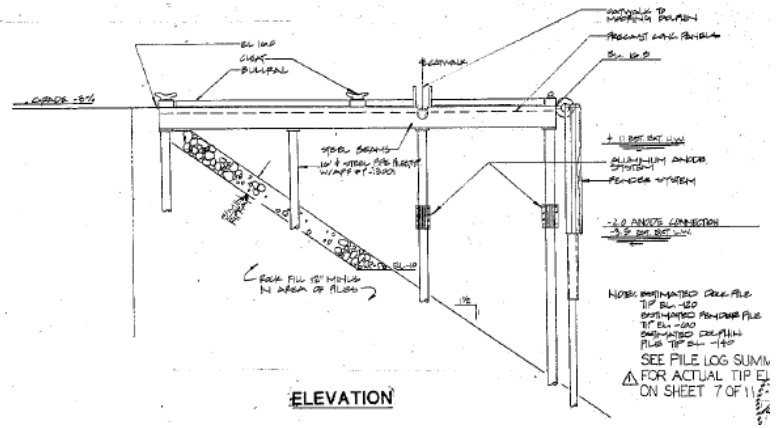
B - SECTION

Comparison of Structures

Sand Point City Dock (1983)



Steel Cap welded to Steel Pile



Comparison of Structures

Sand Point City Dock II (2019)

Comparison of Structures

Comparison of Structures

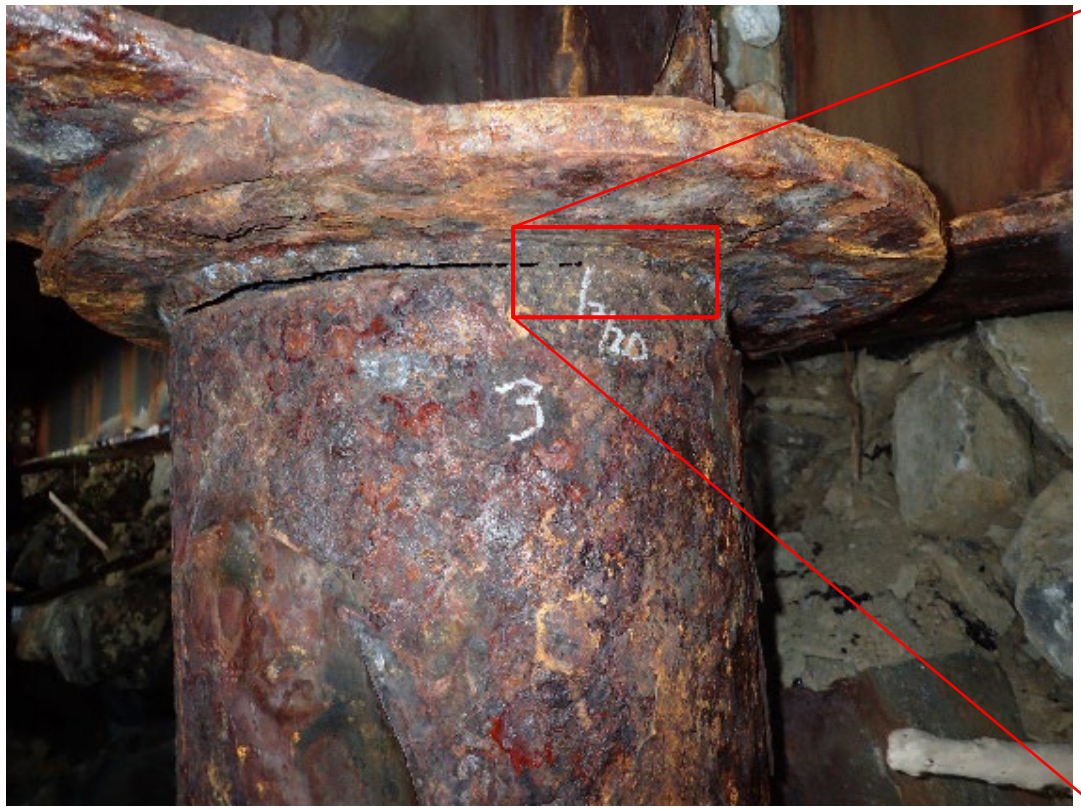
Sand Point City Dock (1983)

Comparison of Structures

Crack at the Pile Weld

Crack at the Girder to Base Plate Weld

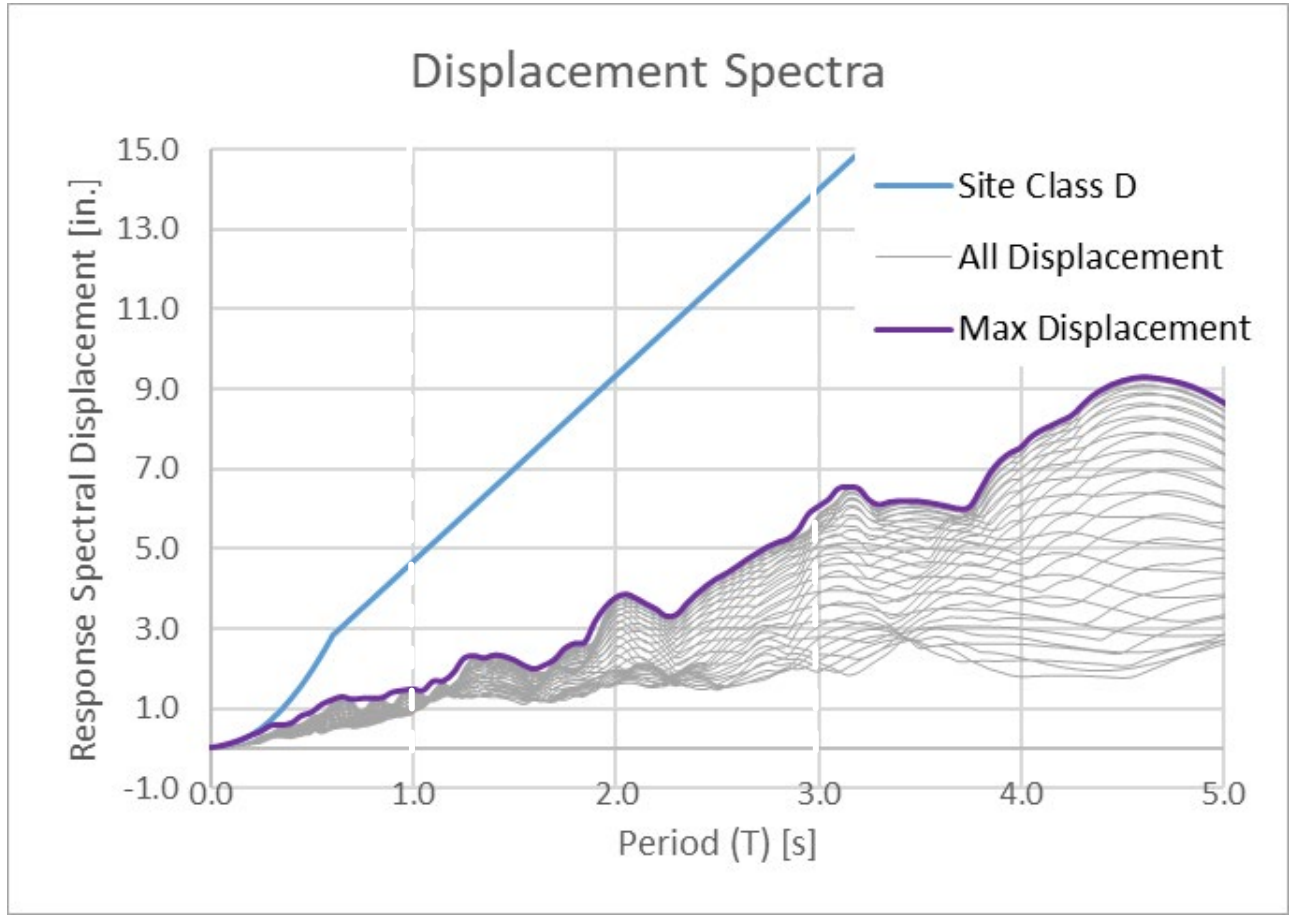
Comparison of Structures



First Inspection

After M6.1 Aftershock

Comparison of Structures



Intended Response

Unintended Response

Lesson Learned? Design ductile details with fuses to accommodate seismic displacements.

Questions?

Seismic Design Principles

Force Based Approach

1. Develop model
2. Input design spectra
3. Perform modal analysis
4. Design members based on forces from the analysis

Assumption:

- Forces are correct (or can be accurately scaled using reduction factors)

Disadvantage:

- If you are wrong about the magnitude and/or distribution of forces, the structure could fail prematurely at an undesirable location

  → Potentially non-ductile failure

Displacement Based Approach

1. Develop model
2. Input design spectra
3. Perform modal analysis
4. Select a location(s) in the structure whose plasticization will not result in structural failure.

   → Plastic Hinge (or fuse)
5. Design the plastic hinge based on displacements from analysis.
6. Design all other components to remain elastic when the fuse blows.

   → Other components are not designed based on the seismic input, only the fuse capacity

   → Capacity Protection

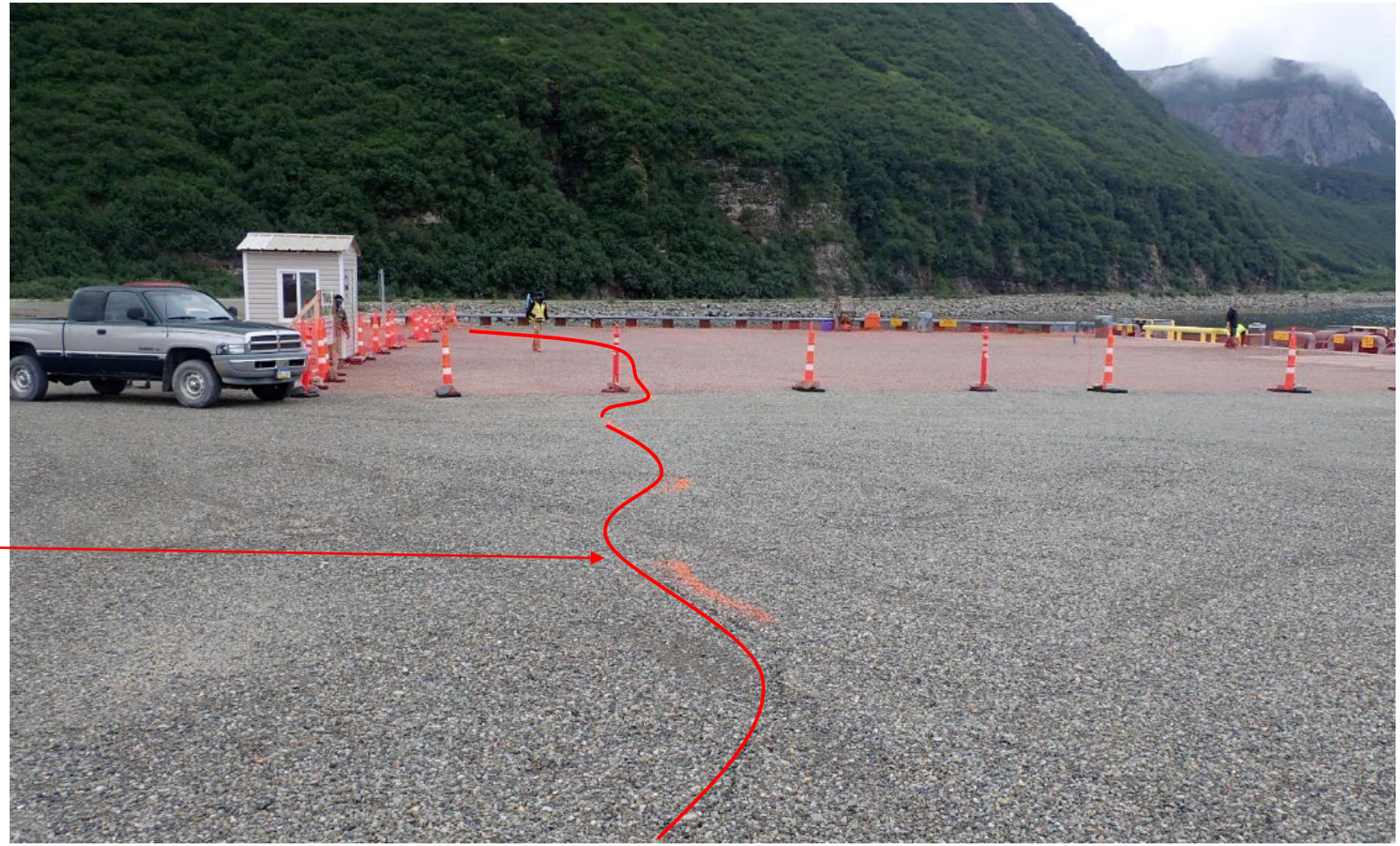
Advantages:

- Designing a predictable mechanism
- Requiring failure to occur at a location that is best suited to accommodate seismic inputs

  → Ductile failure mechanism guaranteed!

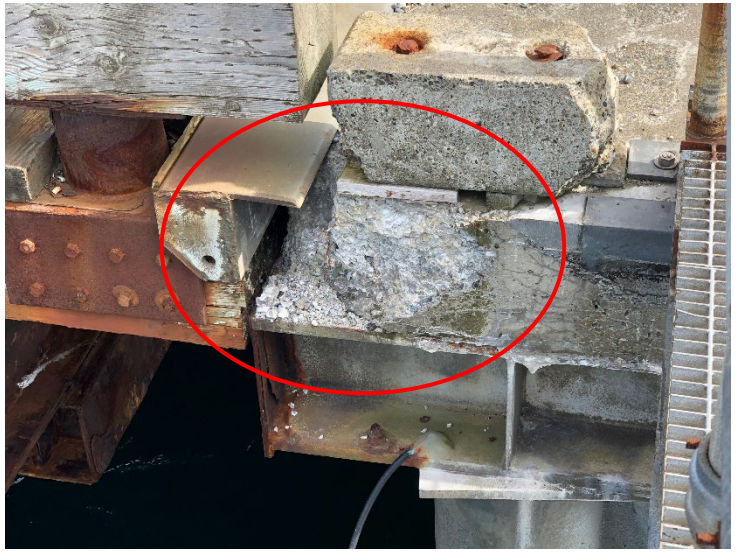
Day 3: Chignik Dock

Soil Cracking at Tie-Backs



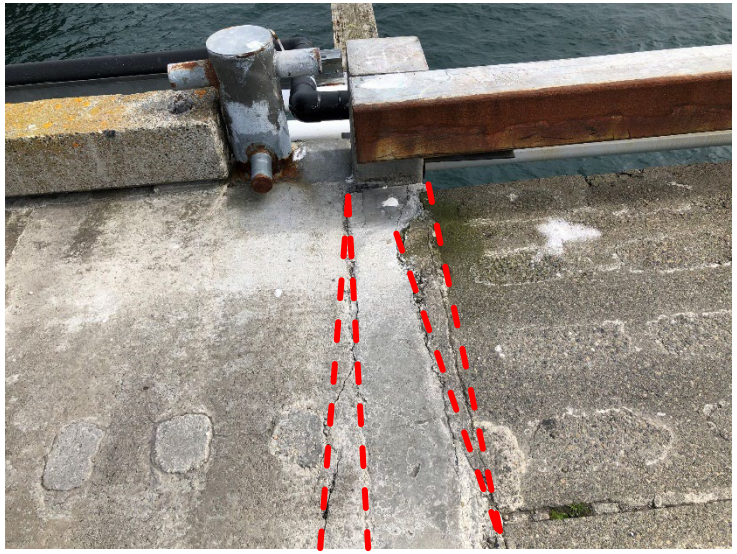
Alaska DOT&PF Response

Day 3: Cold Bay Dock



New Dock / Old Dock Joint (LT)

New Dock / Old Dock Joint (RT)



Old Dock / Causeway Joint