Chile Earthquake and Tsunami of February 27th, 2010

ASCE/COPRI RECONNAISSANCE

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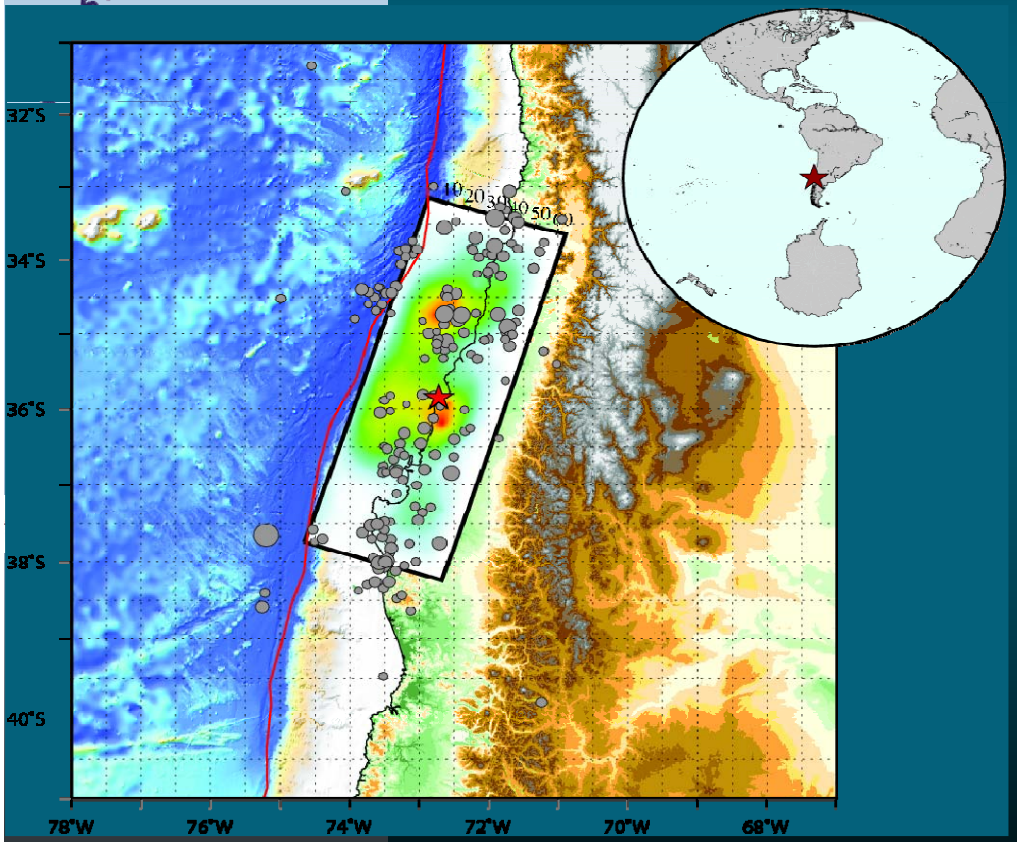
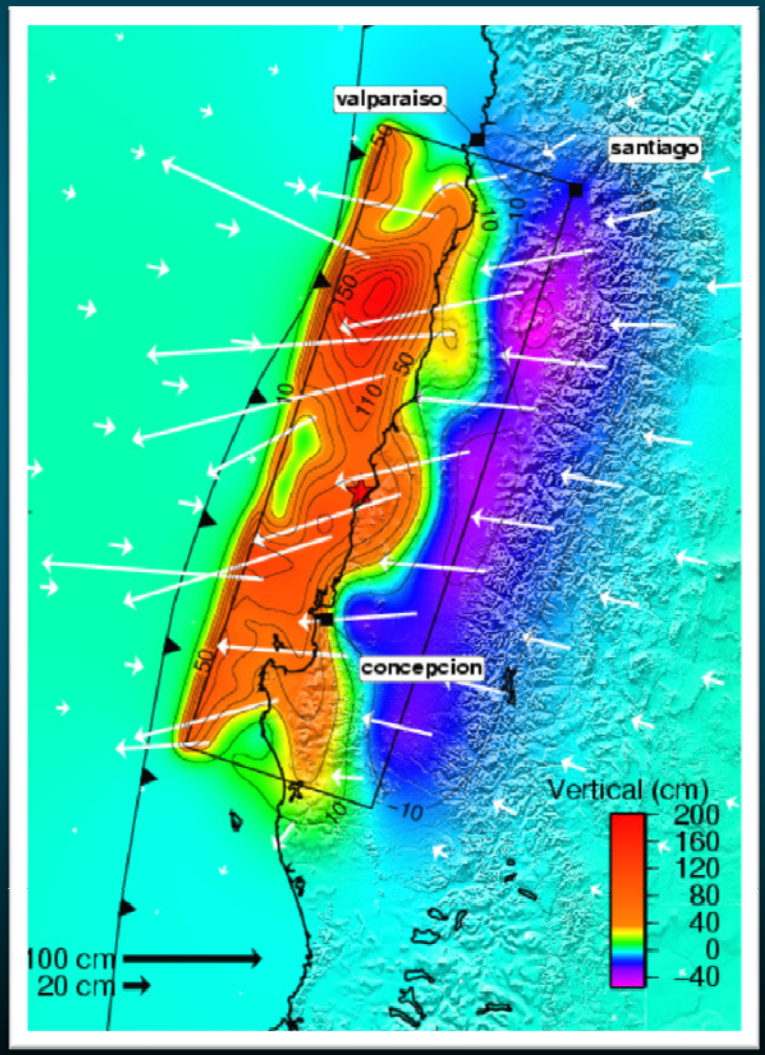
Quake

- February 27, 2010
- 8.8 Magnitude
- 120+ seconds shaking
- Plate uplift
- Tsunami
  - 35ft run-up typical in south
  - 100ft run-up in Tirua
  - Decks overtopped 1ft in nort
- Aftershocks up to 6.9 M

Chile Earthquake Fault Rupture





Chile Earthquake (February 27, 2010)

- More than 500 people lost lives
- Destroyed more than 500,000 homes
- Displaced over 1,000,000 people
- Estimated damage is more than $20-$30 Billion (US), equivalent to 10-15% of Chile's GDP

Earthquake Reconnaissance

- Chile
  - April 10 to 17, 2010
  - Organized by ASCE Coasts Oceans Ports and Rivers Institute (COPRI)
  - 8 Marine & Coastal Engineering Professionals
    - Structural (Wharves, MOTs, Bridges)
    - Coastal (Tsunami, Coasts)
    - Geotechnical (Marine Structures)

Objectives

- Assess and learn from the performance of port infrastructure including:
  - Waterfront structures and Foundation systems
  - Handling equipments and Utilities
- Assess and learn from the effects of the earthquake and subsequent tsunami
- Identify infrastructure that performed as intended and the ones that performed poorly

Site Investigations

1. Talcahuano
2. San Vicente Port
3. San Vicente Gas Terminal
4. Dichato
5. Port of Lirquen
6. Port of Coronel
7. Isla Santa Maria
8. Punta Tumbes
9. Valparaiso Port
10. San Antonio Port

Observations

- Damage related to Tsunami
- Damage due to earthquake shaking – Inertia and kinematic loading
- Damage due to lateral spreading, slope failure, liquefaction, land vertical movement
- Indirect damage due to power failure, vessels, cranes, etc….

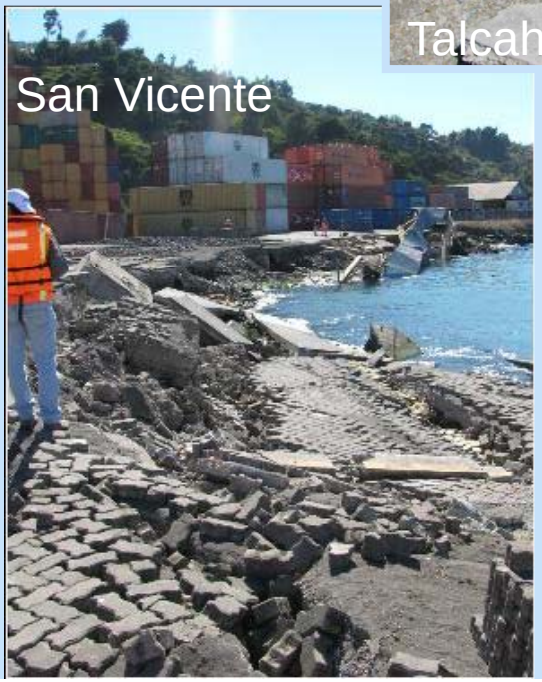
Observations
Soil Slope Failures

Observations: Loss of Dikes/ Sheetpiles/ Retaining Walls


Coronel


Talcahuano


Talcahuano


San Vicente

- Loss of dike/sheetpile/retaining wall results in loss of backlands
- Tsunami removes evidence (if any) of liquefaction

Observations
Soil Slope Failures

- Dry Season – It could have been worse!

Observations
Concrete Pier / Wharf

San Vicente Port

Prevention First 2010

Twenty years of Prevention 1990 - 2010

CALIFORNIA STATE LANDS COMMISSION

MARINE FACILITIES DIVISION

ASCE COPRI

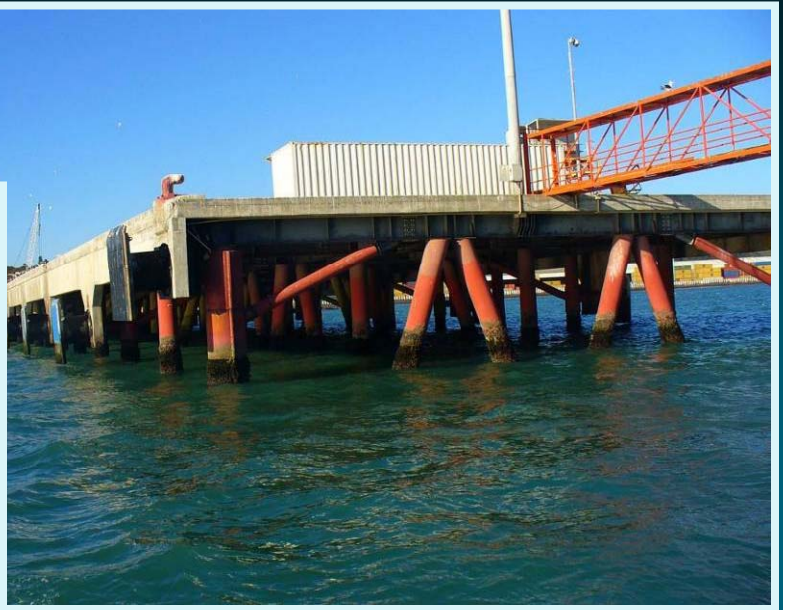
Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

Halcrow

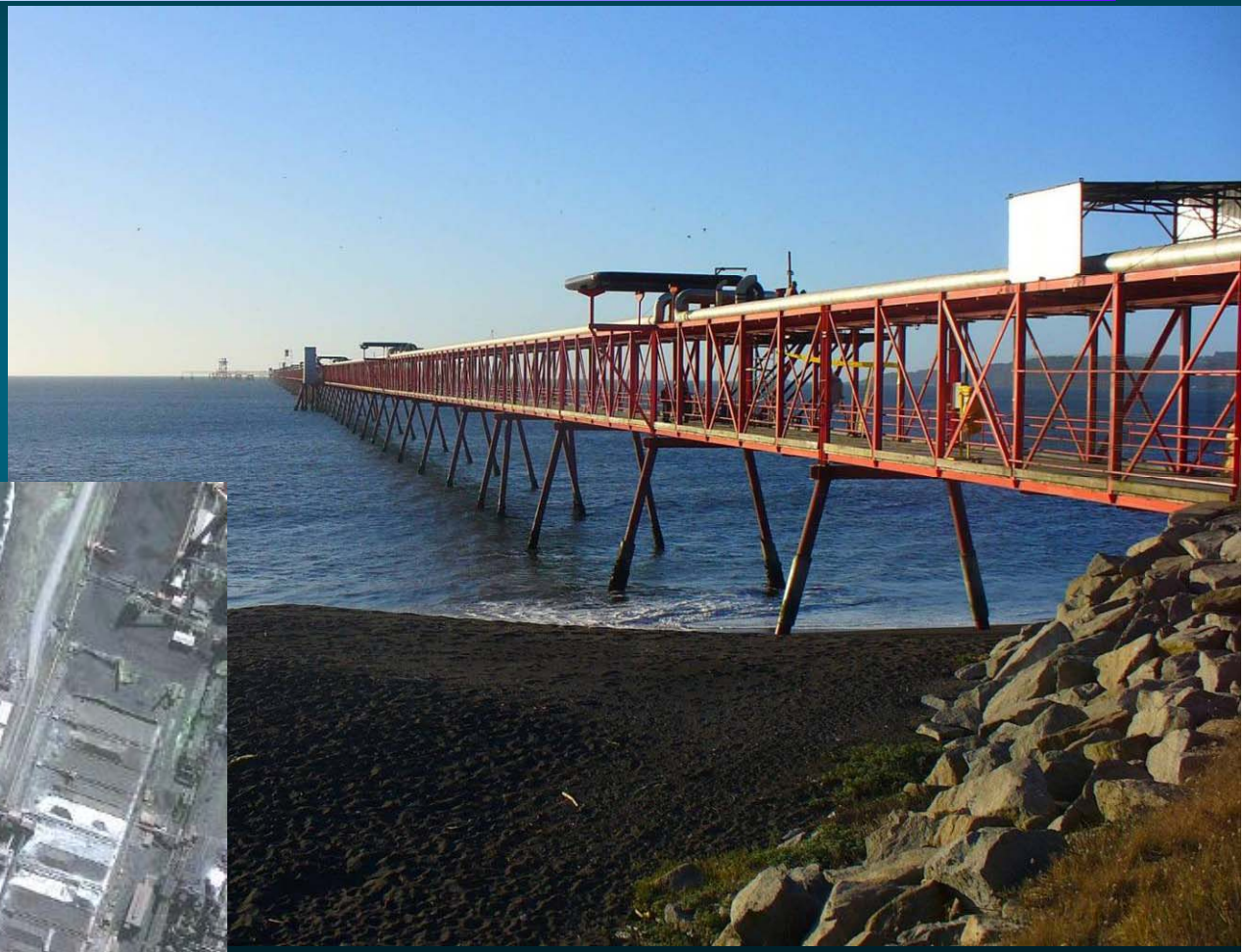
moffatt & nichol

Observations
Steel Pier / Wharf

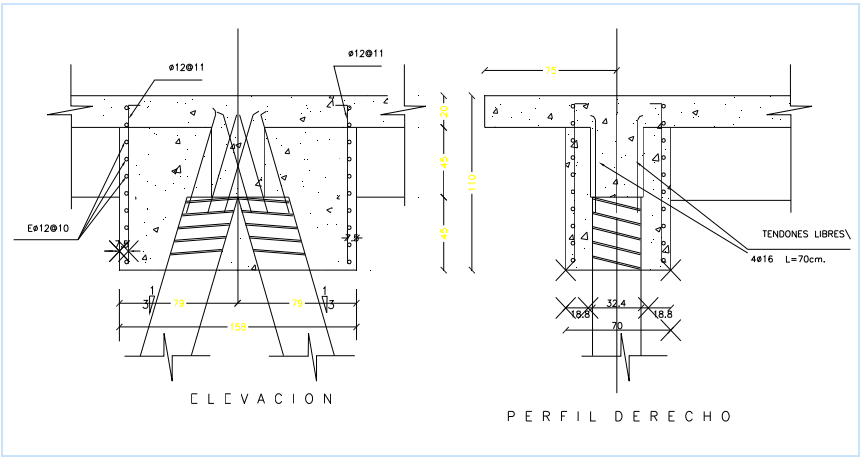
Port of Coronel



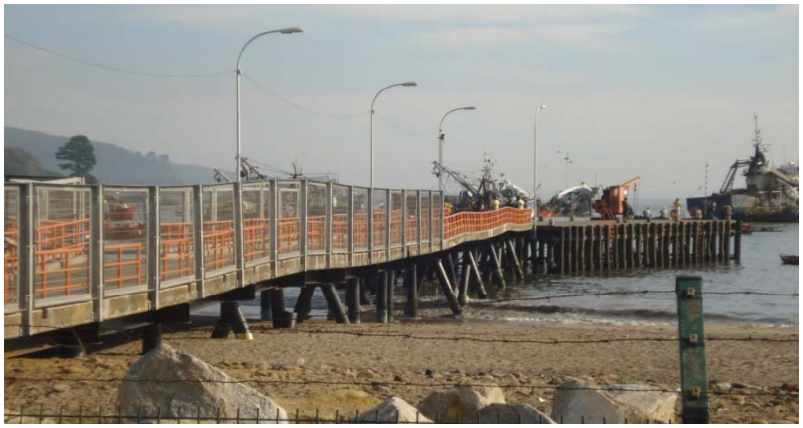
San Vincente Gas Terminal

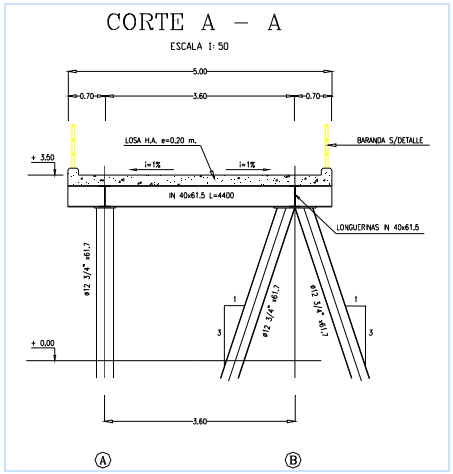


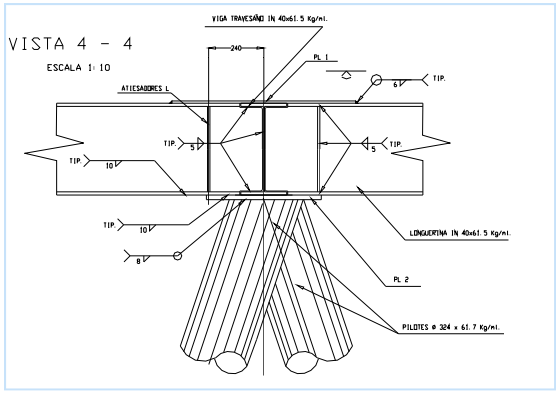
MUELLE LO ROJAS - CORONEL



MUELLE LOTA BAJO







Observations
Kinematic Loading

Port of Coronel

Observations
Cranes and Base Isolated Pier

Port Lirquen

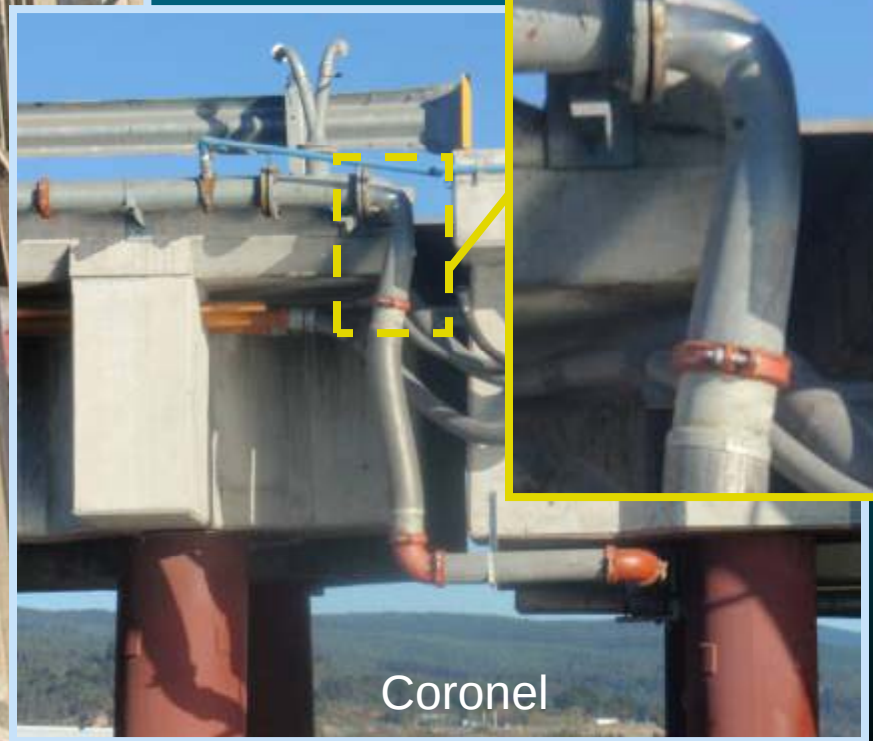
Valparaiso Port

Based Isolated Bi

- Designed and constructed (including isolators) in Chile
- No damage seen or measured (not instrumented)
- Grane at base isolated structure hit by vessel
- Possibly due to interaction during earthquake

Observations
Piping

- Performed well, no ruptured piping found, even where pounding or anchorage loss



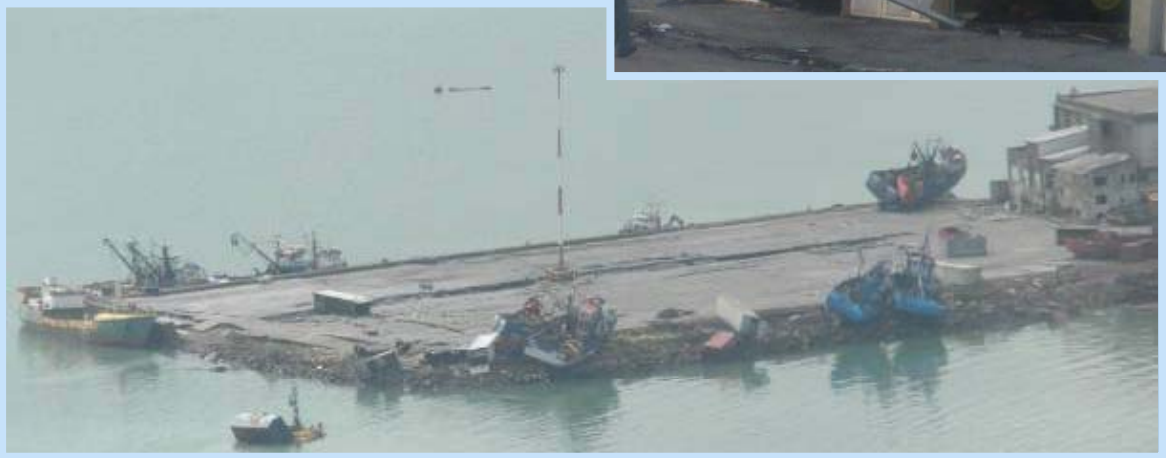
Observations Tanks

- Outside scope of trip, can't help but look

Observations
Tsunami – Impact Damage

- Much of the damage is from debris impact

Talcahuano

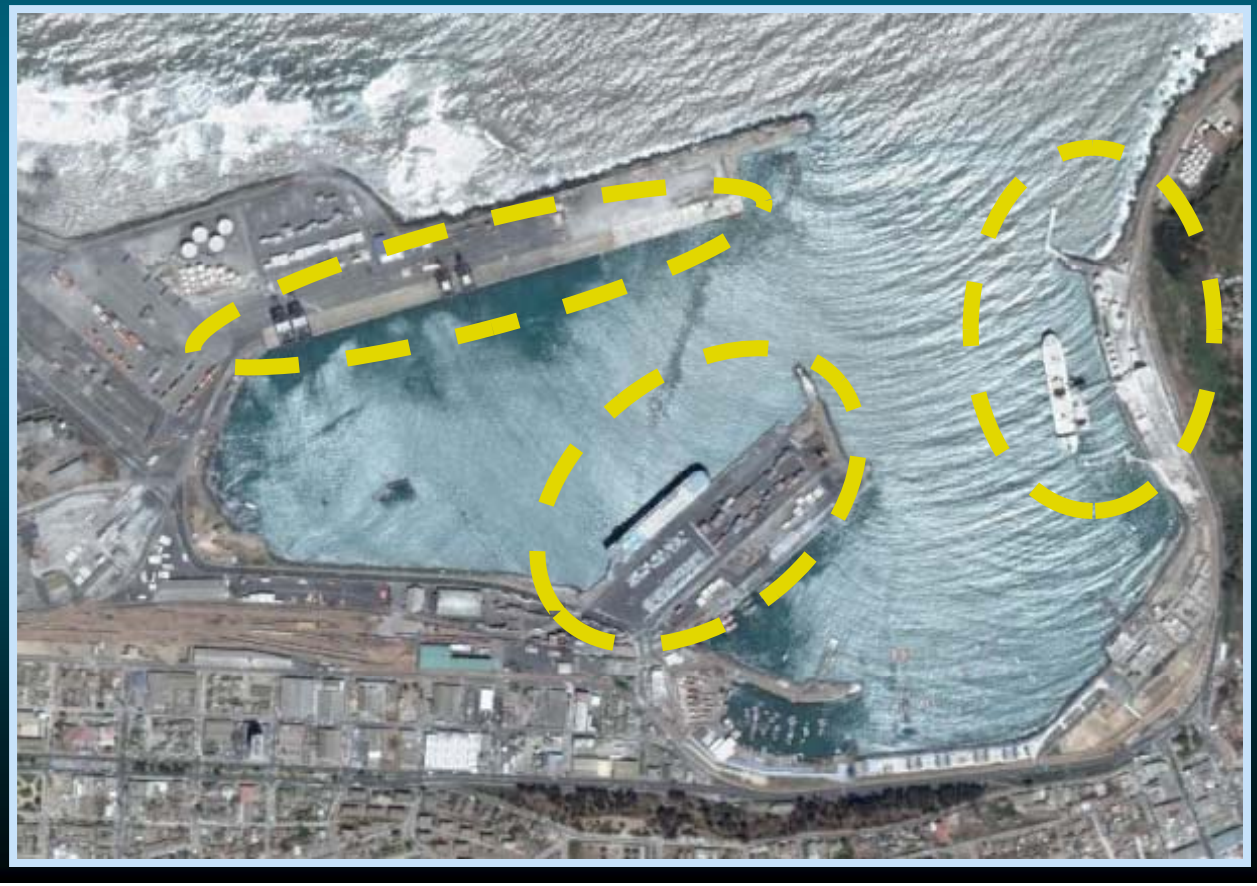


Observations
Tsunami – Vessel Theft

- Breaks lines, carries away vessel

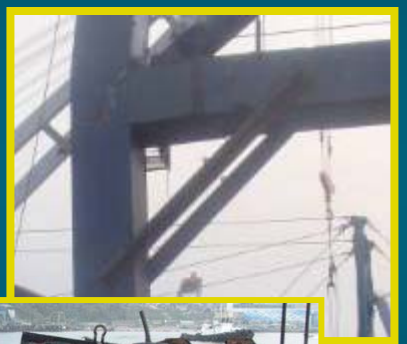
Observations
Tsunami – Vessel Escape

- San Antonio – 7 of 9 berths filled at earthquake
- 1.5 hours later all vessels had escaped



Observations
Cranes – Vessel Escape

- During earthquake power lost
- Cranes left inside vessels or w/ hanging containers
- Vessel escapes – catches container / crane and damages it



Observations
Bollards – Vessel Escape

- Do not use quick release hooks in Chile (costs)
- Most bollards performed well, but San Antonio lost 3

San Antonio

Lessons Learned

- **Port** Structures built to current **Building** code performed well
- Loss Retaining Walls → Loss Backlands
- Soil Movement impacts:
  - Structural Performance
  - Post-EQ Operability
- Cranes lose power → damaged by escaping vessel
- Operations **MUST** work around damage
- Debris impact causes majority of tsunami damage
  - **Rapid evacuation of vessels** reduces port damage significantly

Tsunami Recommendations

- Have
  - **EXISTING** vessel evacuation plan
  - Risk assessments to determine tsunami zone
  - Audible warning systems and signage
  - Plans for **VERTICAL** evacuation
- Design foundations for scour in tsunami zone
- Low lying buildings need flowthrough, anchorage, and low importance
- **<u>Keep critical equipment away from lowlands</u>**

Earthquake Recommendations

- Chile **NATIONAL** instrumentation program
- Consider soil movement in structural design
- Use anchored retaining structures, consolidated ground, in-depth geotechnical studies
- Quick release hooks at moorings **OR** balanced design for bollards
- Keep in mind post event resource limitations
  - Need steel plates, aggregate fill, etc.
  - Need engineers, inspectors, and regulators on board and best prepared

Questions?