Operability Retrofits for BART's North Oakland Aerial Guideways

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2013 Western Bridge Engineers Seminar

- BART System
- BART's Earthquake Safety Program
- Vulnerability Study and Seismic Performance Criteria
- Retrofit Design
- Retrofit Construction

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BART System

5 Lines

104 Miles

- 37 Miles on Underground Track
- 23 Miles on Aerial Track
- 44 Miles on Surface Track

4-County Service Area

- Alameda (19 Stations)
- Contra Costa (10 Stations)
- San Francisco (8 Stations)
- San Mateo (6 Stations)

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BART System

- 360,000 Passengers Daily Peak
- Without BART, translates to an Additional 60 to 80 Minutes Commute Delay along the Hwy 24 Corridor and Other Roadways
- Public Investment Conservatively Valued at $15 Billion

Earthquake Safety Program Voter Approved !

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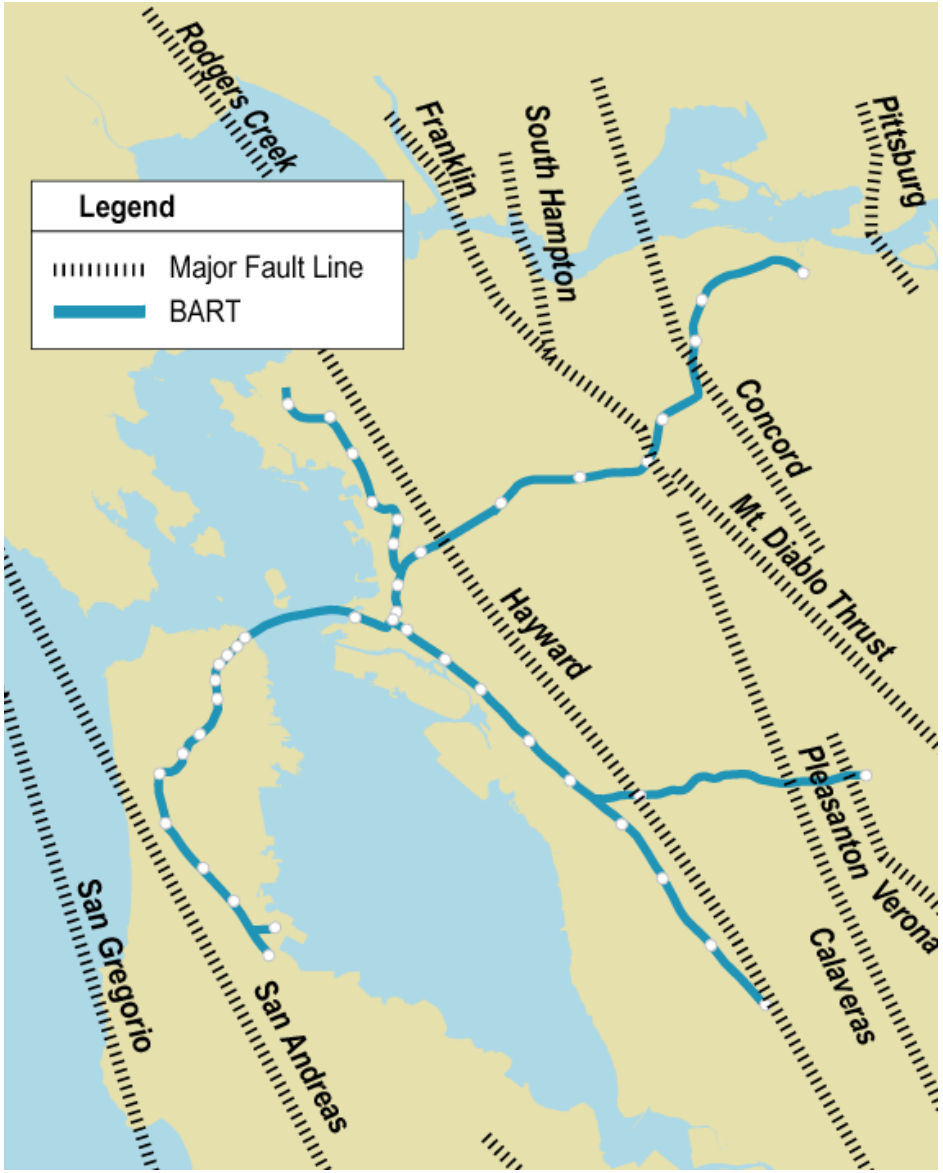
Bay Area Earthquake Hazard



- Hayward Fault Parallel to BART/ Crosses BART
- **1868** Last Major Rupture of Southern Hayward Fault (130- to170-Year Return Cycle)

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Vulnerability Study

- Assessed the BART system's vulnerability to large earthquakes.

- Assessed how a seismically-upgraded system might perform after similar earthquakes.

- Assessed the benefits and costs of various levels of retrofit.

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Vulnerability Study Findings

Potential Life Safety Issues

- Transbay Tube – Critical Link in System
- Aerial Guideways – Located Throughout System
- Stations

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Seismic Performance Criteria

Safety Performance Level – protect life safety by preventing a collapse limit state per Caltrans MTD 20-1. Maintain structure vertical load capacity following the Design Basis earthquake. Rocking and damage is allowed, but no collapse.

Operability Performance Level – limit structure damage so train operations can continue following the Lower Level Design Basis Earthquake [LDBE]. No pile damage and limited rocking of spread footings

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Core System Operability, Systemwide Safety

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Ground Motions

- Design Basis Event (DBE)
  - Transbay Tube: Greater of Deterministic m + 1.0 σ or Probabilistic 1,000 year return period
  - Other Structures: Greater of Deterministic m + ½ σ or Probabilistic 500 year return period

- Lower Design Basis Event (LDBE)
  - Transbay Tube: Greater of Deterministic m + ½ σ or Probabilistic 500 year return period
  - Other Structures: Deterministic median ground motions

Seismic Analysis

Structure Models – displacement demand and capacity is determined in a generalized controlled deflection of the structure

Analysis – Caltrans Rocking Analysis Priestly SSRPO-91/03

Displacement Demand – conforms to CBDS, BDA, MTD, & SDC v 1.3

Displacement Capacity – non-linear push over analysis – concrete or steel strain limits

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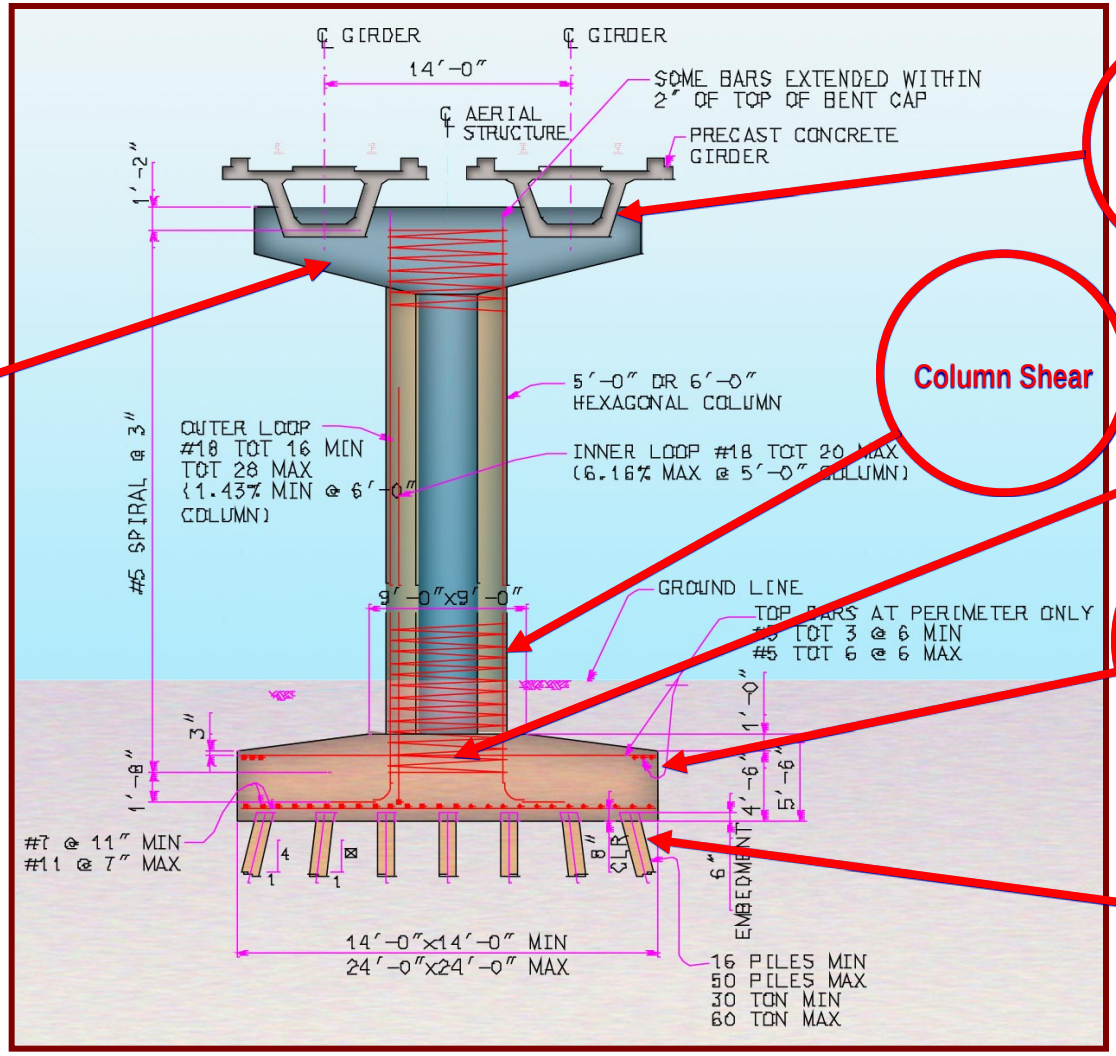
As-Built Seismic Deficiencies



Bent Cap

Shear Key

Column Shear

Column to Footing Joint Shear

Footing Top Mat & Shear R/F

Pile & Pile to Pile Cap Connection

As-Built Seismic Deficiencies

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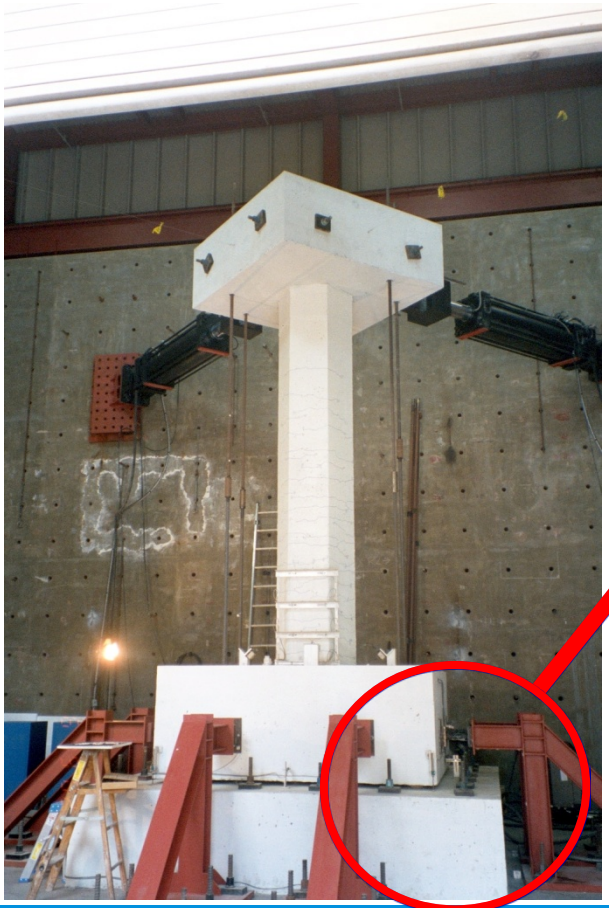
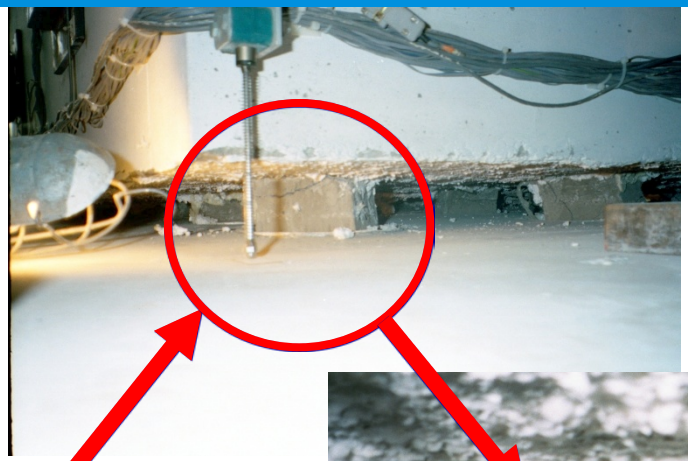
As-Built Seismic Deficiencies





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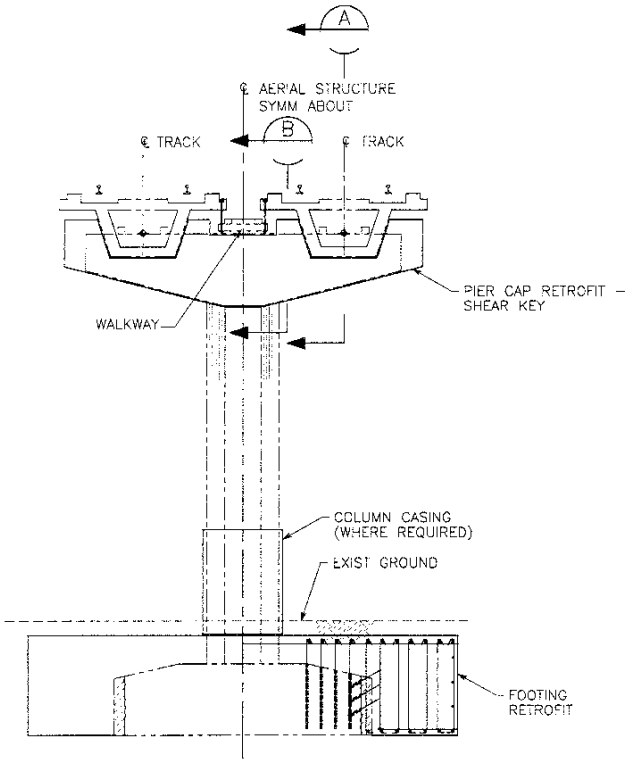
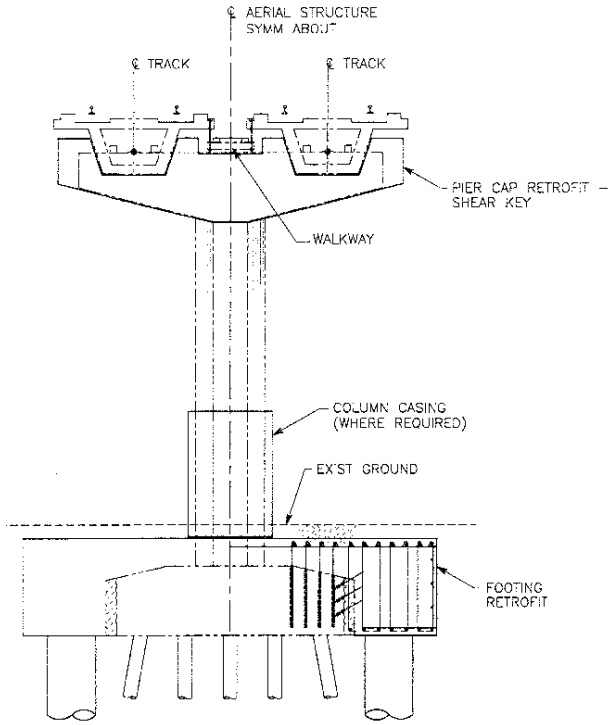
Typical Operability Retrofits



Spread Footings



Pile Foundations

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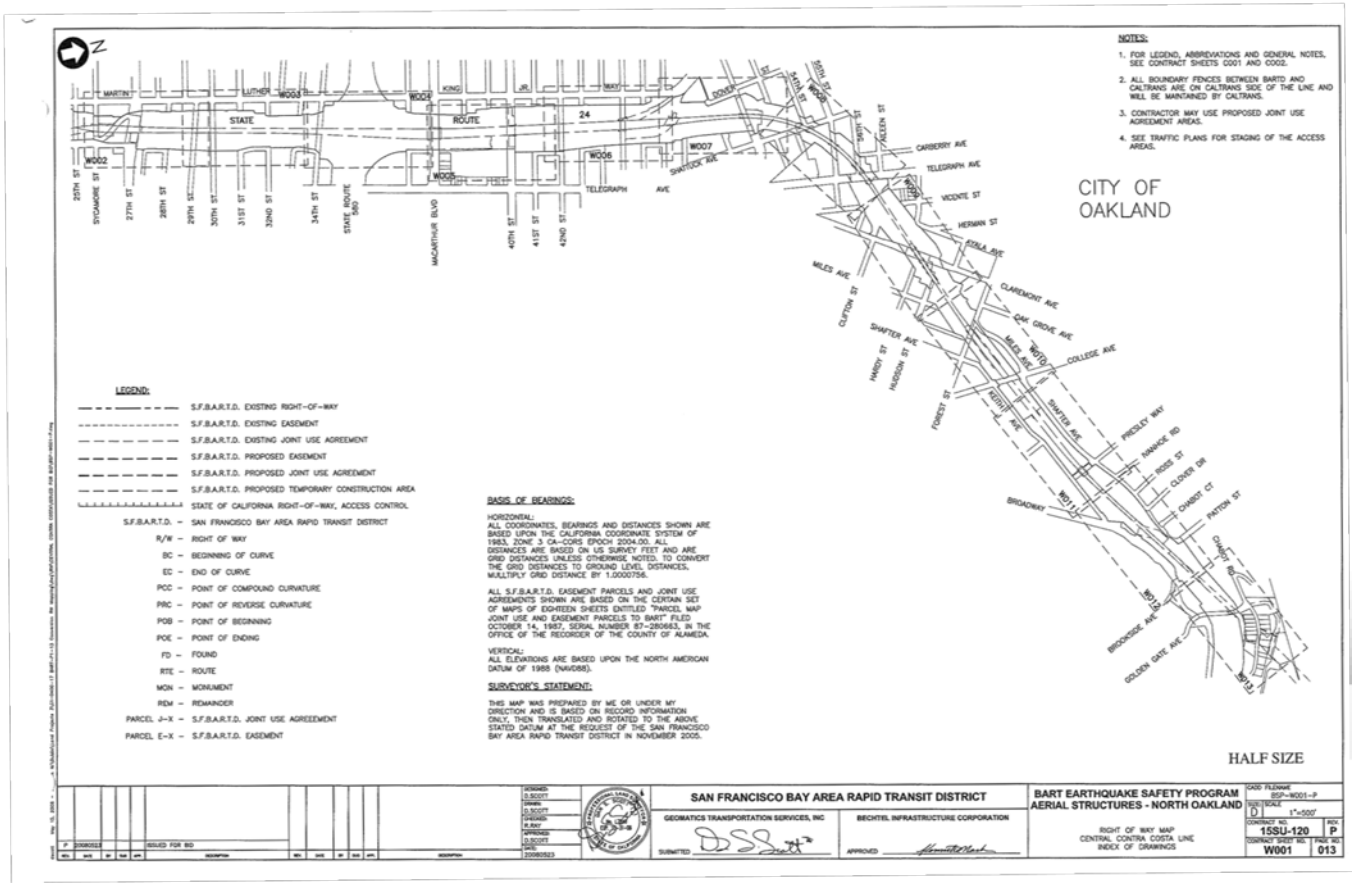

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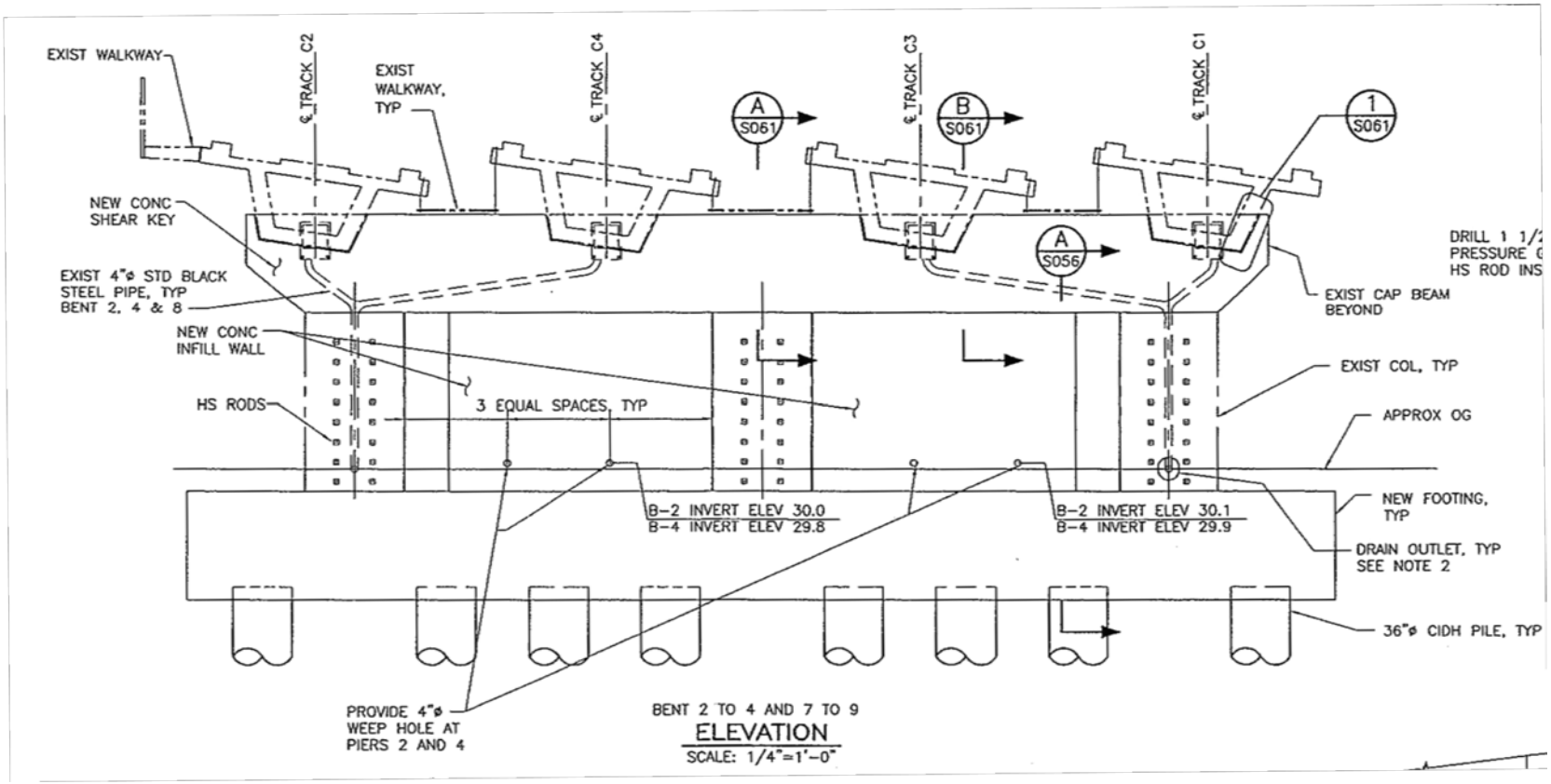

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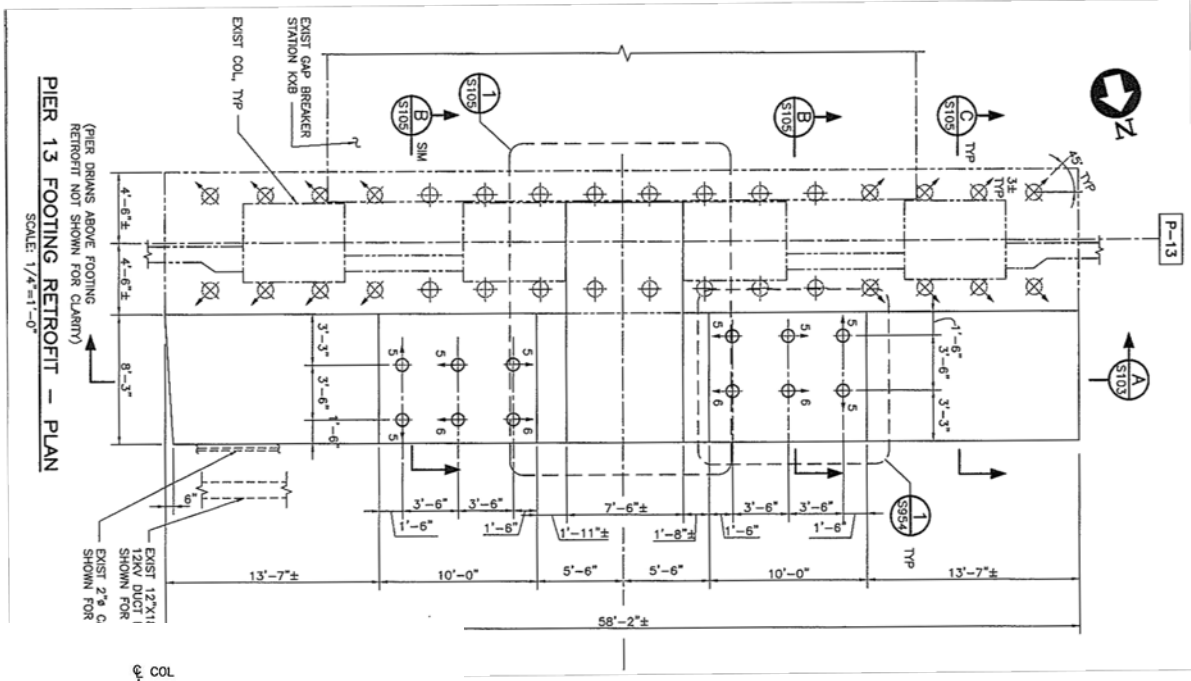

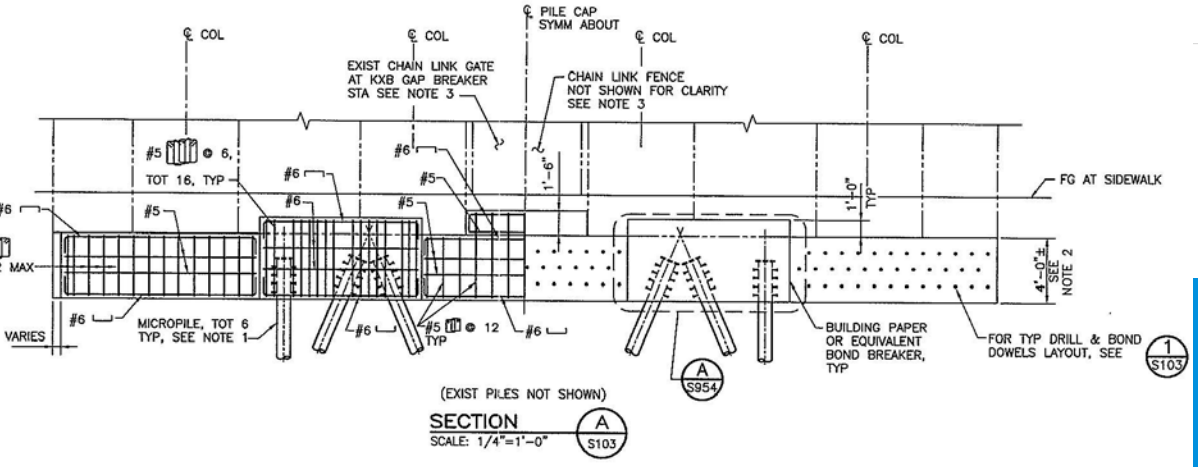

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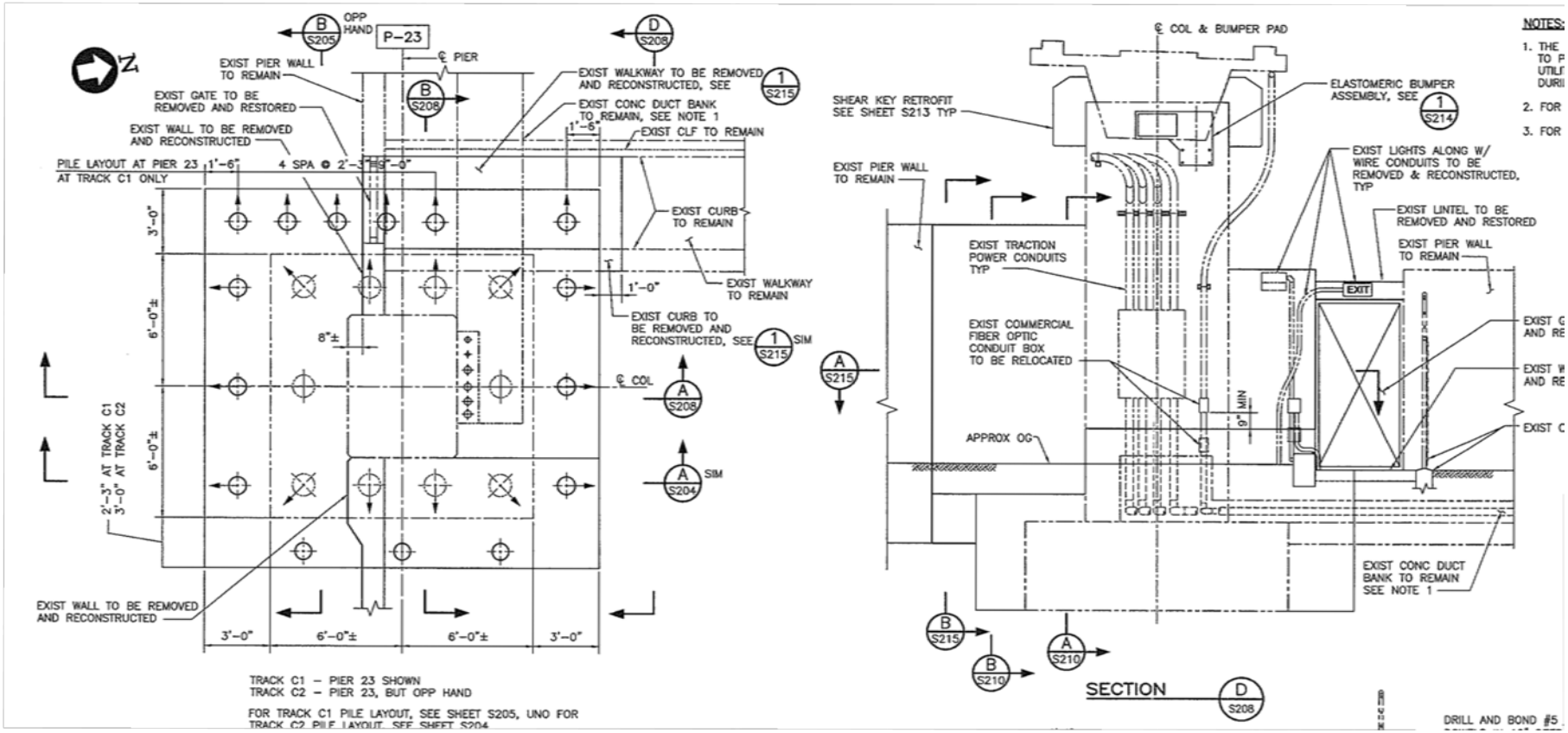

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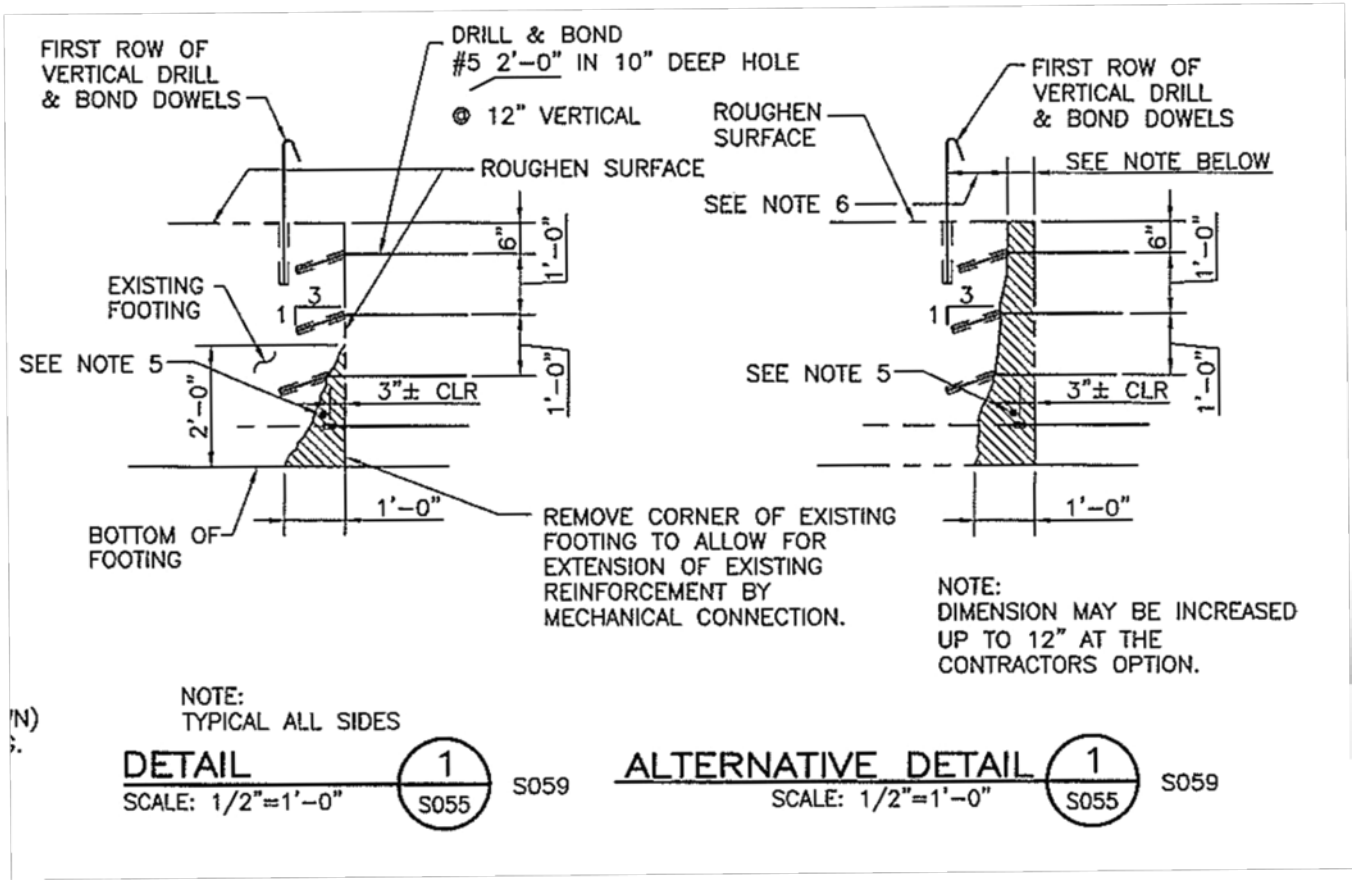

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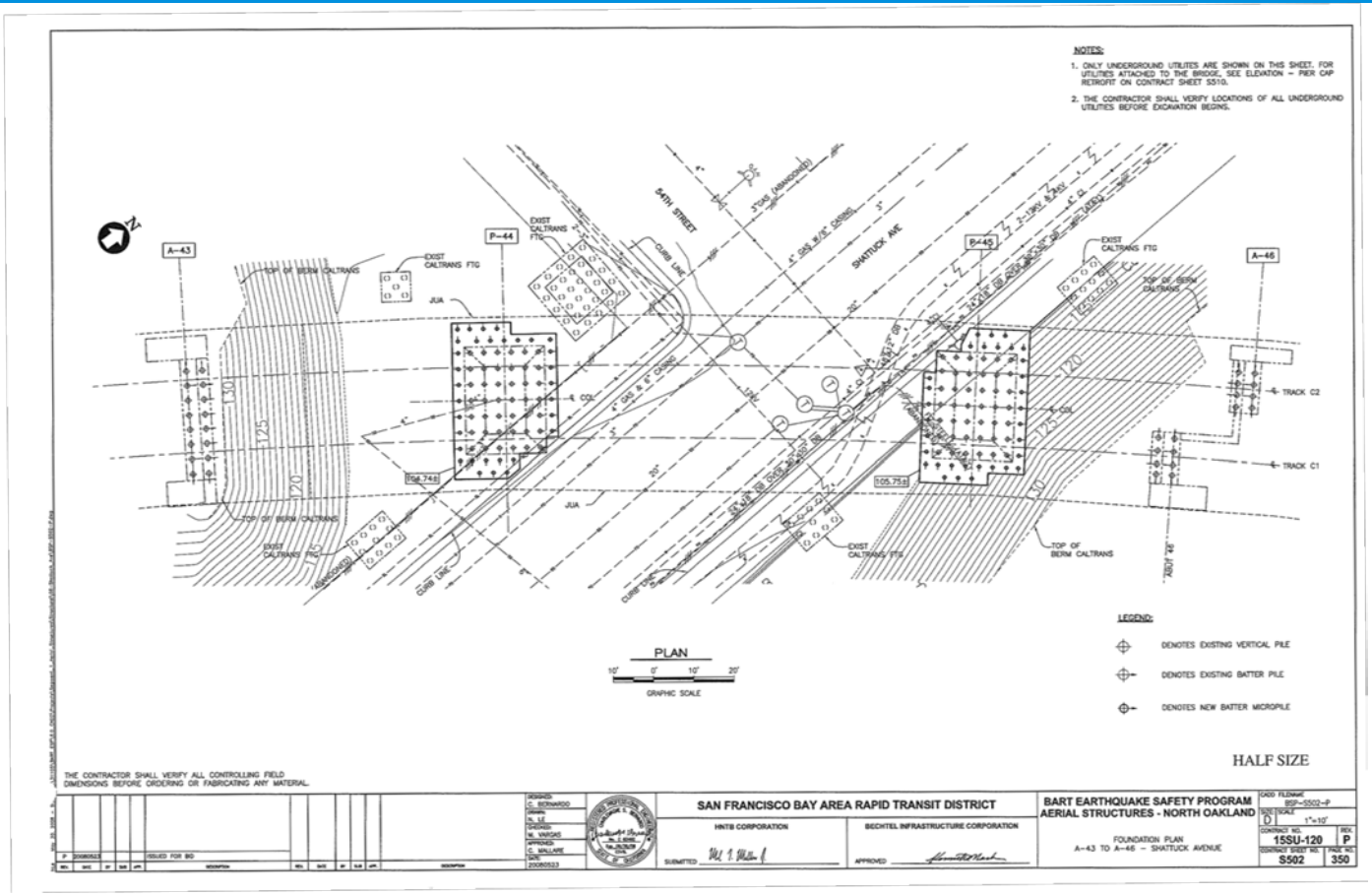

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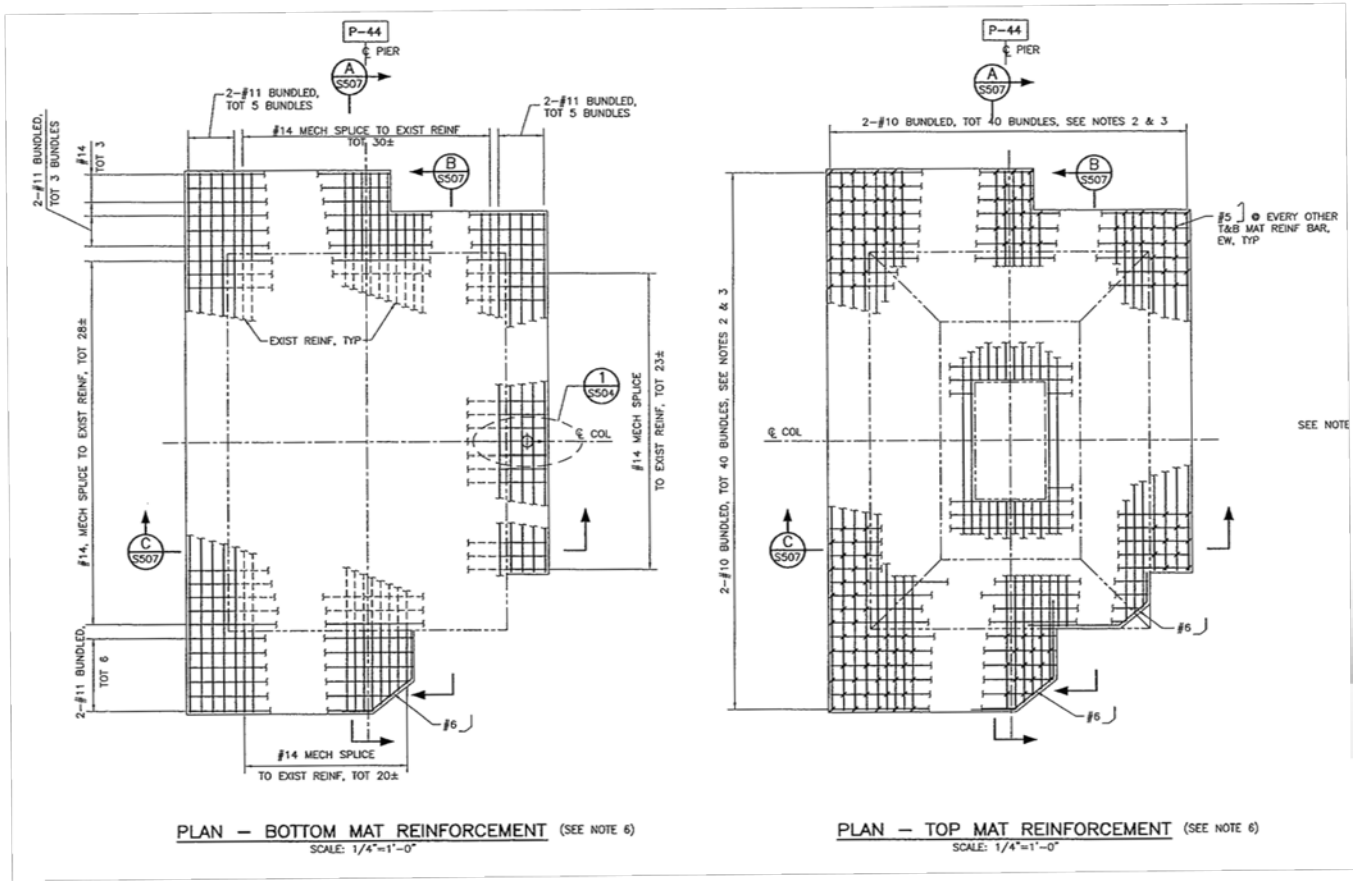

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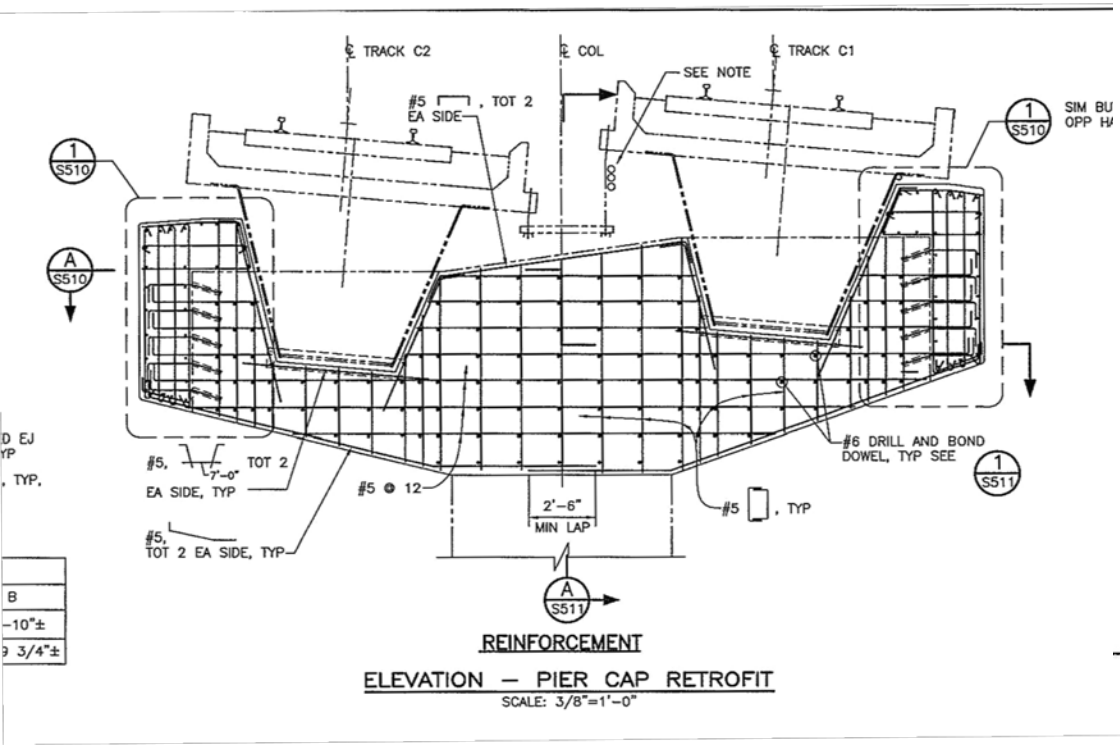

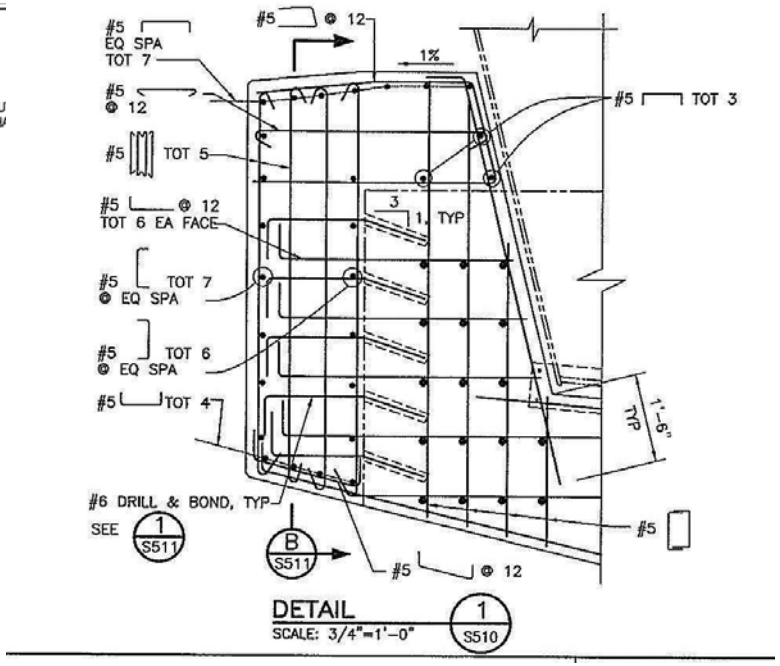

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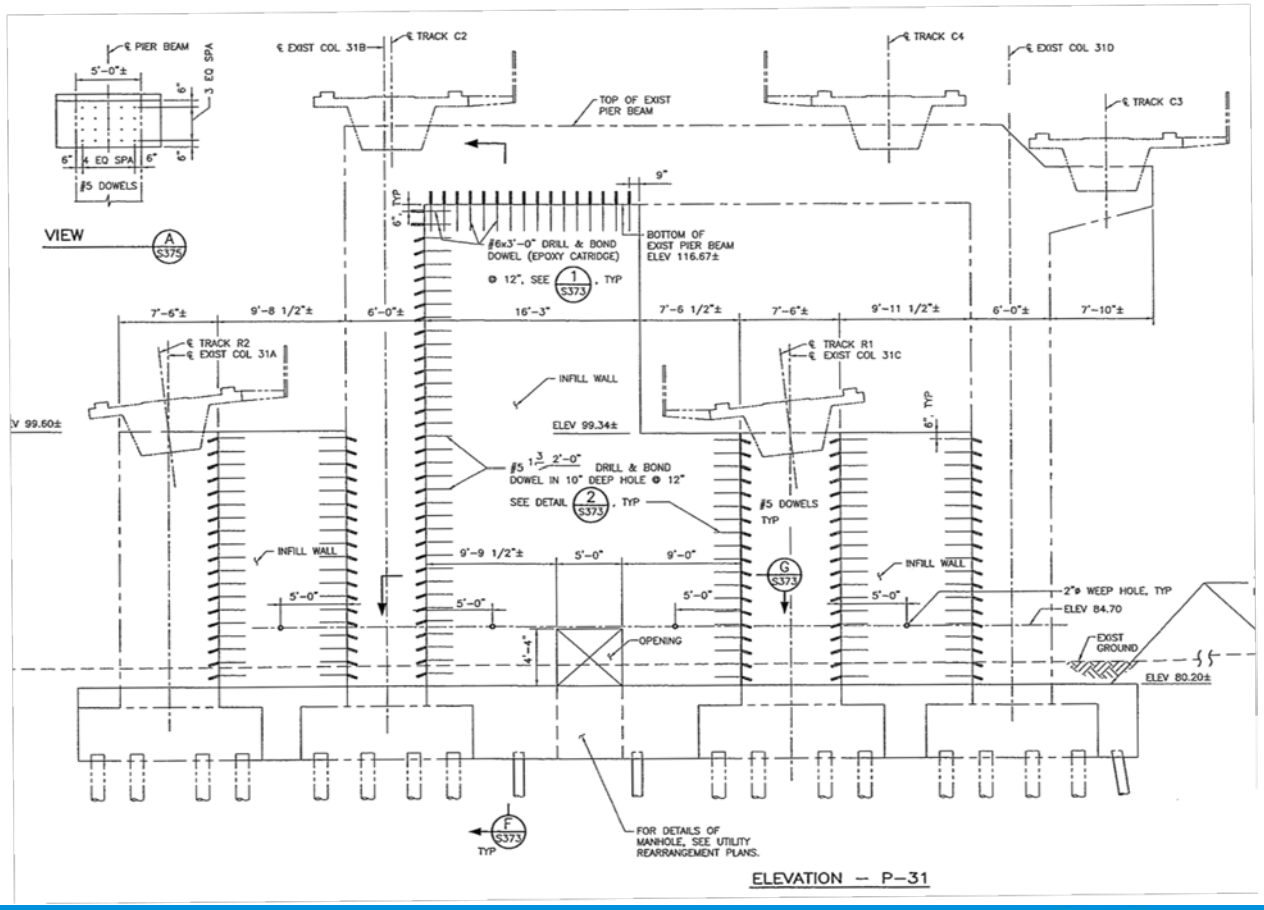

ELEVATION — P-31

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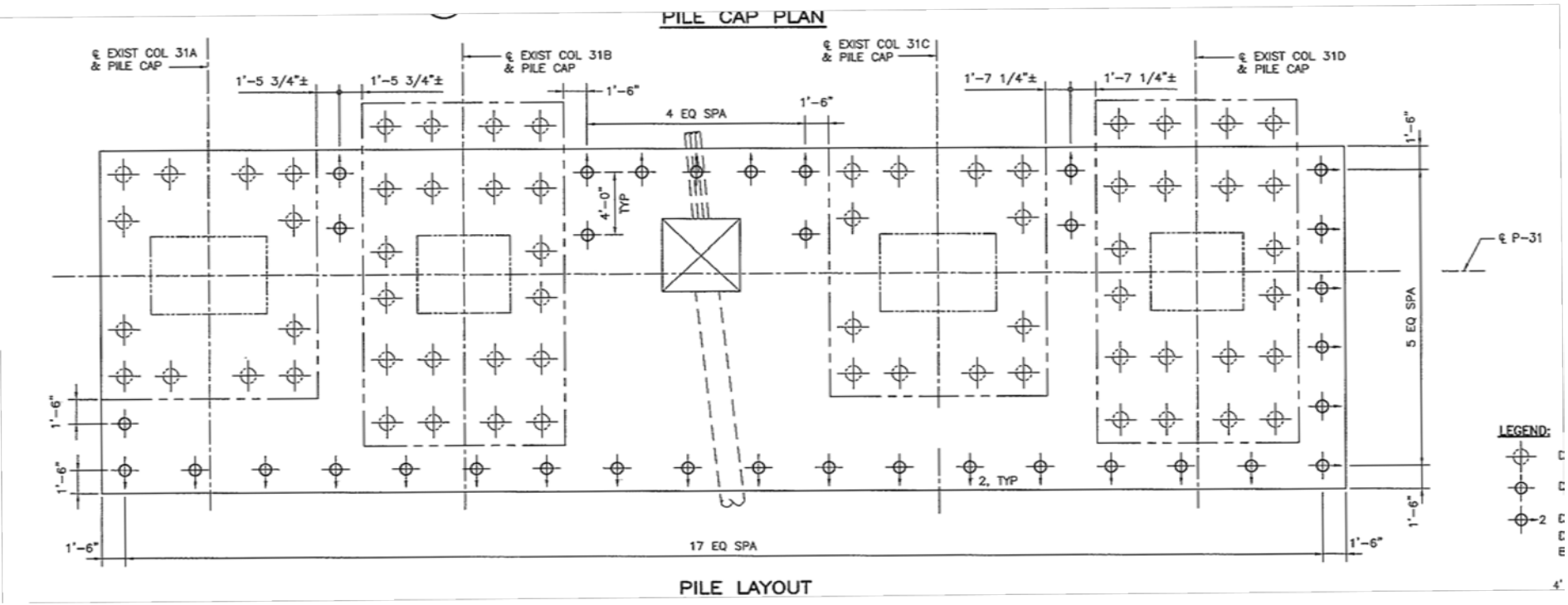

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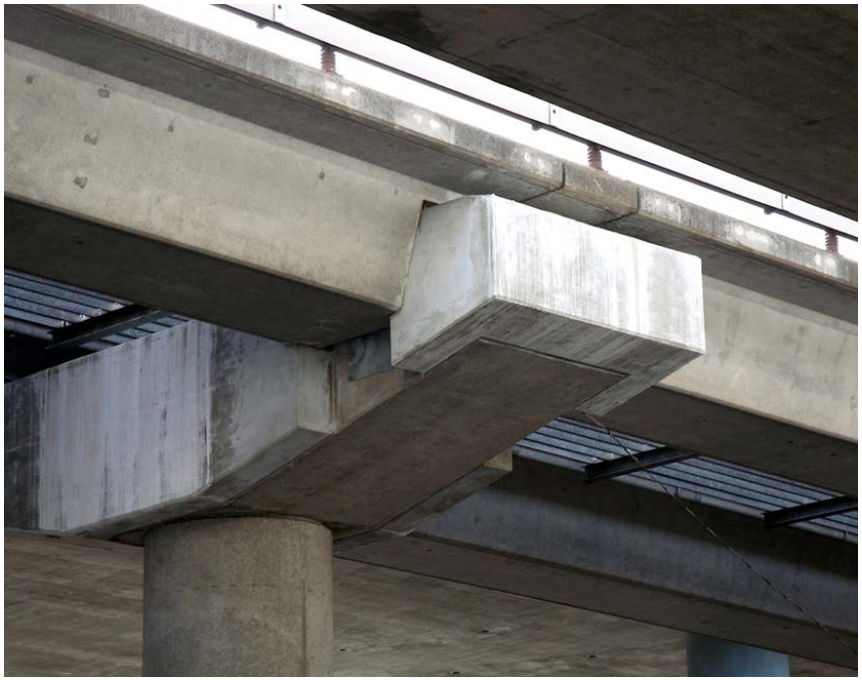

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