Operability Retrofits for BART's North Oakland Aerial Guideways

BART EARTHQUAKE SAFETY PROGRAM
BART System

BART’s Earthquake Safety Program

Vulnerability Study and Seismic Performance Criteria

Retrofit Design

Retrofit Construction
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)
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!
Hayward Fault Parallel to BART/ Crosses BART

1868 Last Major Rupture of Southern Hayward Fault (130- to 170-Year Return Cycle)
• 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.
Vulnerability Study Findings

Potential Life Safety Issues

- Transbay Tube – Critical Link in System
- Aerial Guideways – Located Throughout System
- Stations
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.
Core System Operability, Systemwide Safety
Ground Motions

- **Design Basis Event (DBE)**
  - Transbay Tube: Greater of Deterministic $m + 1.0 \sigma$ or Probabilistic 1,000 year return period
  - Other Structures: Greater of Deterministic $m + \frac{1}{2} \sigma$ or Probabilistic 500 year return period

- **Lower Design Basis Event (LDBE)**
  - Transbay Tube: Greater of Deterministic $m + \frac{1}{2} \sigma$ or Probabilistic 500 year return period
  - Other Structures: Deterministic median ground motions
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
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
As-Built Seismic Deficiencies
As-Built Seismic Deficiencies
Typical Operability Retrofits

Spread Footings

Pile Foundations
North Oakland Aerial Guideways
North Oakland Aerial Guideways

**Diagram:**
- **First Row of Vertical Drill & Bond Dowels**
- **Drill & Bond #5 2'-0" in 10" Deep Hole**
- **12" Vertical**
- **Roughen Surface**
- **See Note 6**
- **Existing Footing**
- **See Note 5**
- **Bottom of Footing**
- **Remove Corner of Existing Footing to Allow for Extension of Existing Reinforcement by Mechanical Connection.**
- **Note:** Dimension may be increased up to 12" at the contractor's option.

**Details & Scales:**
- **Detail Scale:** 1/2" = 1'-0"
- **Alternative Detail Scale:** 1/2" = 1'-0"
North Oakland Aerial Guideways
North Oakland Aerial Guideways

REINFORCEMENT
ELEVATION - PIER CAP RETROFIT
SCALE: 3/8"=1'-0"
North Oakland Aerial Guideways
North Oakland Aerial Guideways
North Oakland Aerial Guideways
North Oakland Aerial Guideways
North Oakland Aerial Guideways