Walnut Avenue Overpass

Warm Springs Extension, LTSS

By:
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BART’s Role

- BART – Bay Area Rapid Transit
  - Is the San Francisco Bay Area’s commuter rail system.
  - It serves Alameda, Contra Costa, San Francisco, and San Mateo counties.
  - It’s the 5th busiest heavy rail rapid transit system in the US.
  - Serves Approx. 400,000 daily riders.
  - https://www.bart.gov/

BART System Map

Bart’s Goal

- BART (Bay Area Rapid Transit) agency’s ultimate goal is to enhance regional mobility, generate new ridership by extending commuter service to multiple regions in the Bay area.

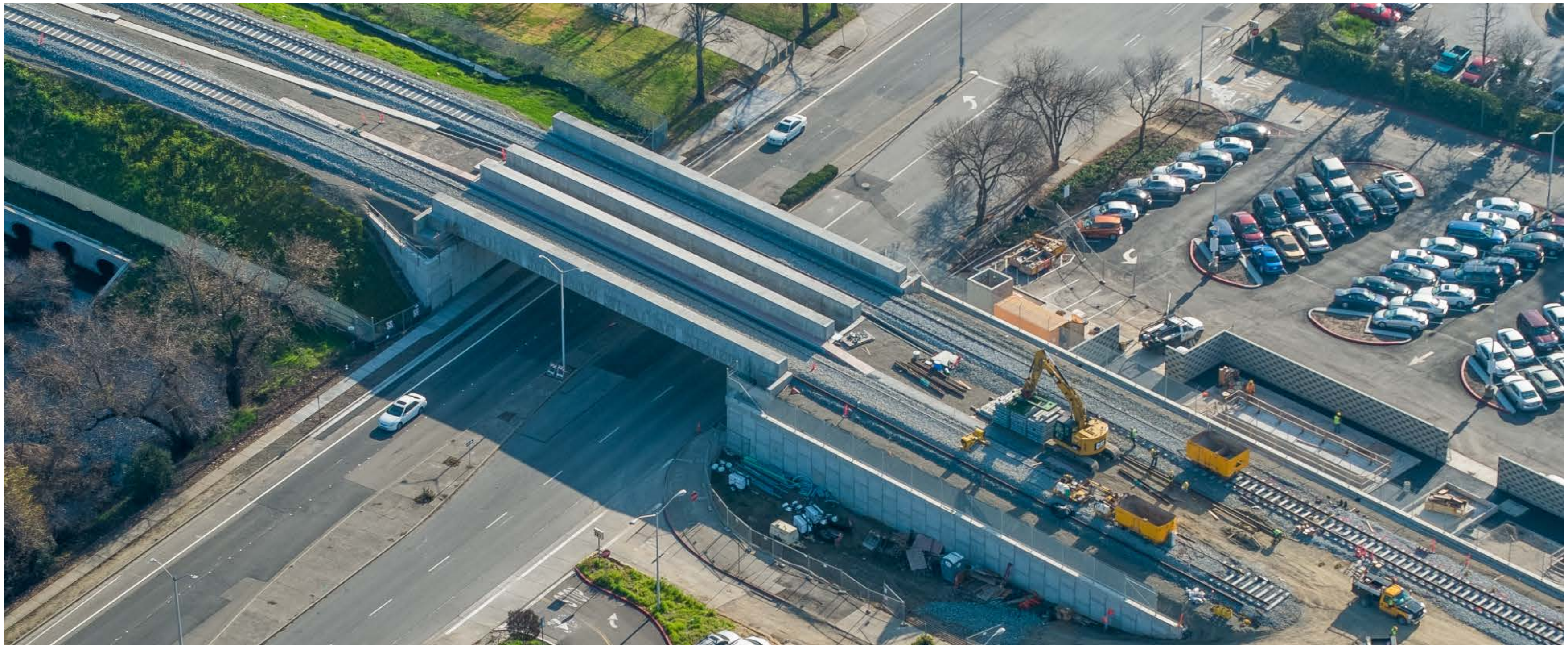
- Extending BART service to San Jose has been a long awaited goal and the Warm Springs Extension is part of this goal.

- Warm Springs Extension Line, Track, Station and Systems Project is a 5.4-mile extension from existing Fremont Station south to a new station in the Warm Springs District of the City of Fremont.

Walnut Avenue Overpass

- Low vertical clearance
- Fixed rail profile

Walnut Avenue Overpass



- Two girders
- Slight Skew

Walnut Avenue Overpass - Innovation

- Cast in Place Post-tensioned Concrete thru girder for rail transit (1st in CA)
- Straddles the Hayward Fault at the #2 Abutment (1st in CA)
- Supported by two Mechanically Stabilized Earth (MSE) abutments (1st in CA)

Walnut Avenue Overpass - OVERVIEW

- Seismic loading
- Superstructure design
- Substructure (MSE) design

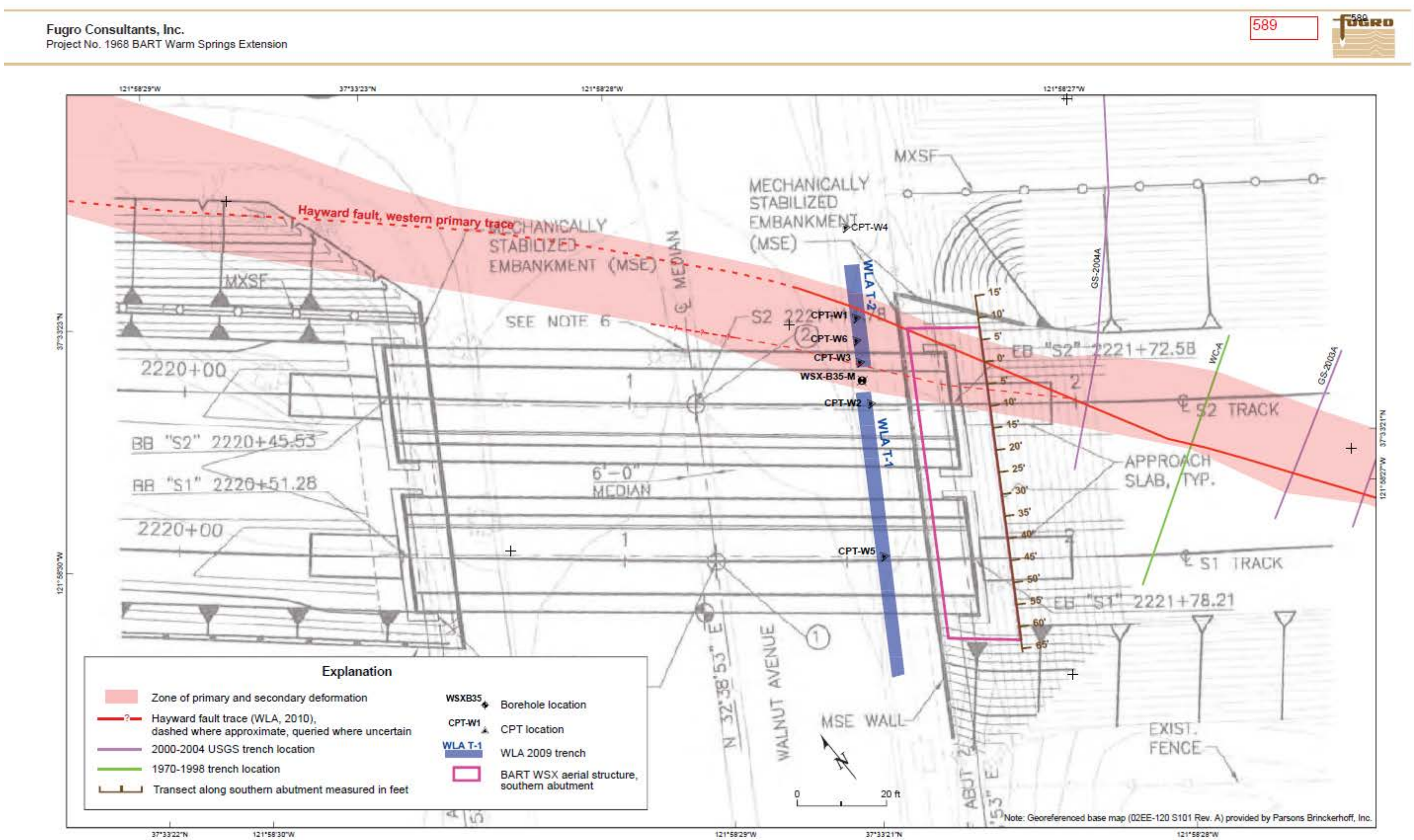
Seismic Loading

Hayward Fault Statistics:

- 31% probability of a large (Mw.6.8) earthquake between 2006 to 2035

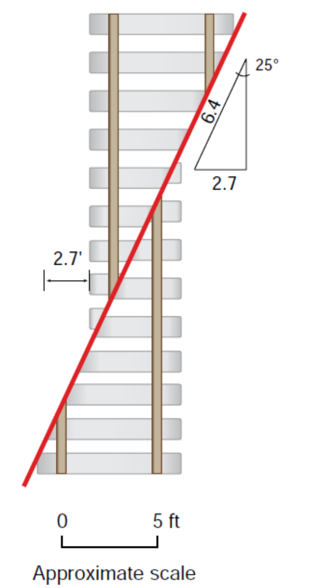
Seismic Loading

USGS Description: Right-Lateral strike-slip offset & East-Side-Down vertical displacement.



Site Map of the BART WSX Overpass Struture along Walnut Avenue

FIGURE 2



D) Median + 1 σ displacement
D_{16} = 6.4 feet

WSC Warm Springs Constructors

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Seismic Loading

CHALLENGES

- During a fault rupture event we could count on:
  - Horizontal displacements up to 6.4 ft
  - Vertical Displacement up to 1.3 ft (~16 inches)
- Fault Creep: Fault is constantly moving at an approximate rate of 0.2 inches/year.
- BART's design policy:

  "To ensure safety and to provide post-earthquake operability by limiting strains, deflections and damage such that they are capable of being returned to service within a reasonable amount of time….with only minor repairs or shoring."

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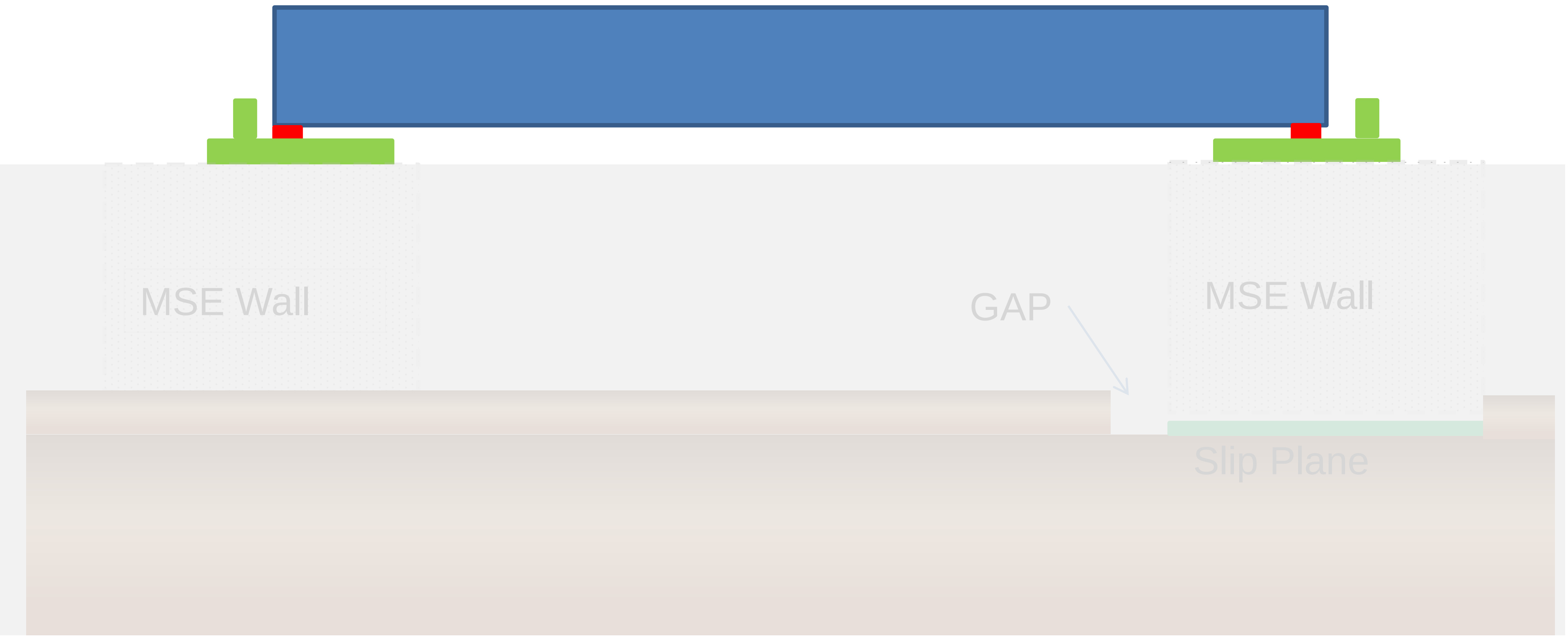
Seismic Loading - Design

How to design away our challenge

- How to simplify the analysis
    - Highly predictable Design
- Minimize the number of variables within the design of the bridges components
    - Load Path, Load Path, Load Path.

Superstructure - Design



Superstructure - Design

APPROACH/IMPLEMENTATION TO MITIGATE FAULT RUPTURE EFFECTS

- **SUPERSTRUCTURE**
  - Anticipated the loss of one bearing at south abutment. Girders are designed for resulting:
    - Shear
    - Torsion
  - The girders are supported on wide-seat abutment spread footings.
    - Transverse Post Tensioned spread footing
  - Shallow foundations preferred over deep foundations
    - Minimizes unpredictable behavior

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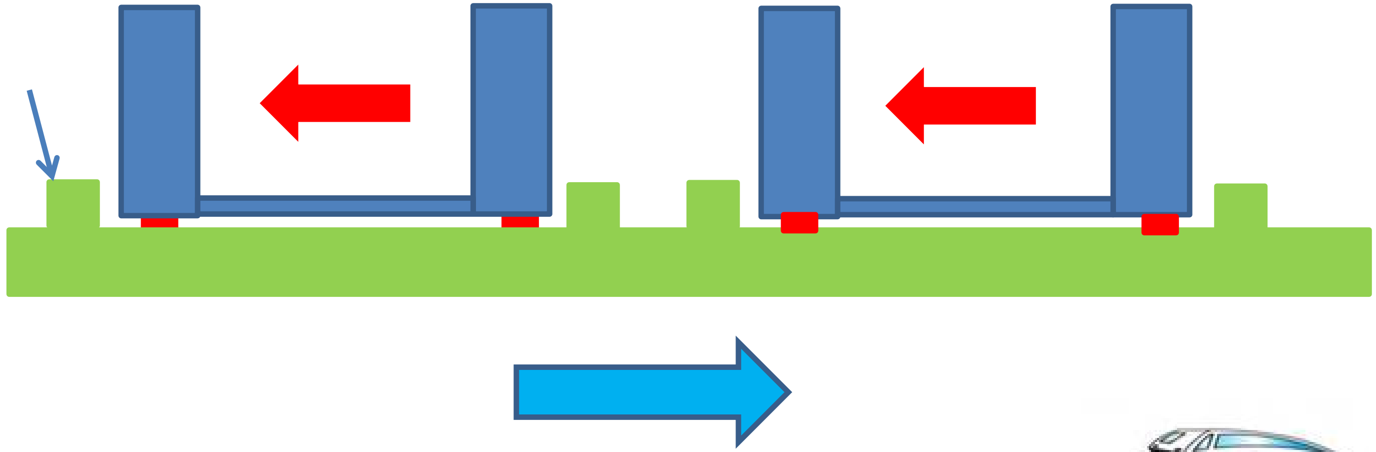
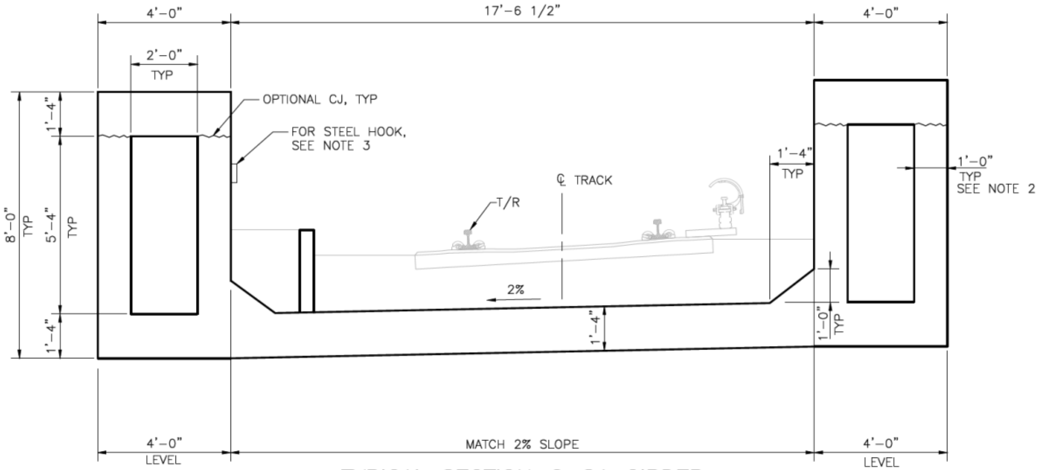
Superstructure - Design

- Longitudinal

- Transverse

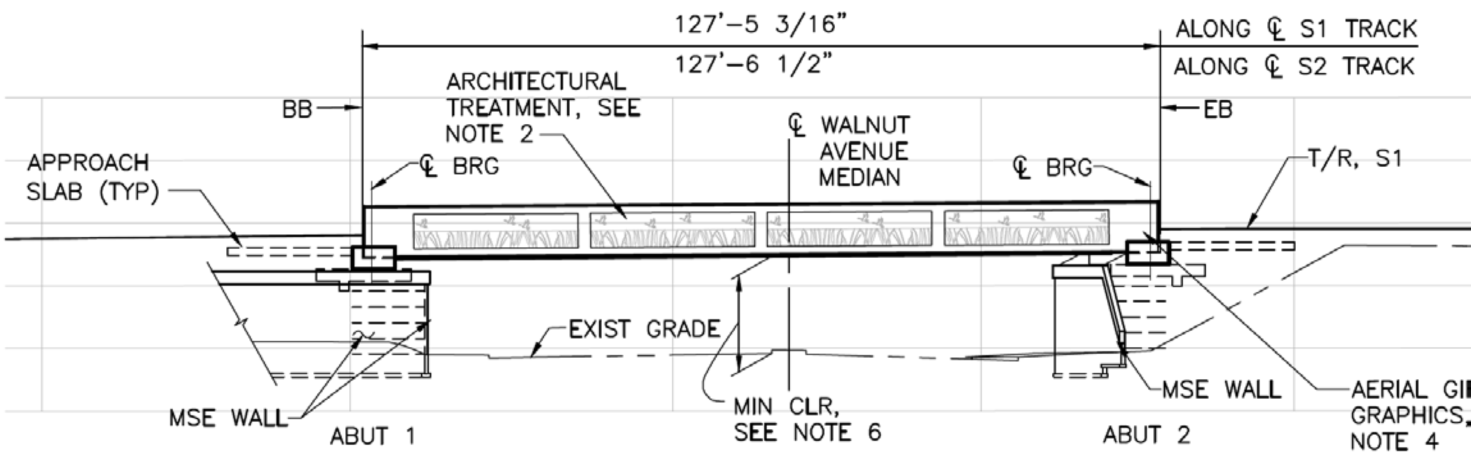


Superstructure - Design



TYPICAL SECTION @ S1 GIRDER

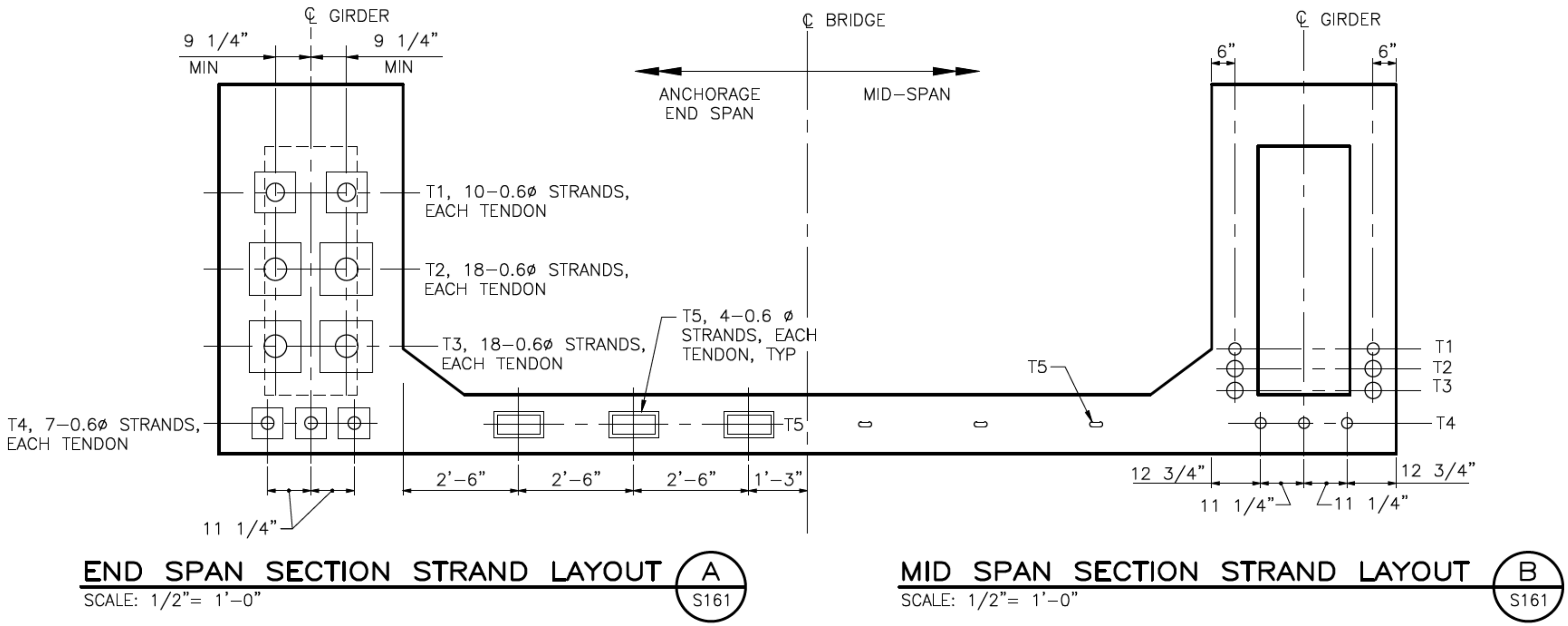
Girder Depth: 8'-0"
Span length: 127'-6"
P_{jack}: 10,888 kips
Clear distance (interior face to face): 17'-6 1/2"
Slab thickness: 1'-4"
Designed for Zero tension



ELEVATION
SCALE: 1"=20'

Superstructure - Design

Post Tensioning



PRESTRESSING TABLE

	X_1(in)	X_2(in)	X_3(in)	JACKING FORCE PER STRAND (KIPS)	NOTES
T1	68.50"	37.11"	26.61"	43.94	10-0.6ø STRANDS EACH TENDON (TOTAL 4)
T2	48.72"	29.04"	22.47"	43.94	18-0.6ø STRANDS EACH TENDON (TOTAL 4)
T3	28.72"	19.72"	16.72"	43.94	18-0.6ø STRANDS EACH TENDON (TOTAL 4)
T4	8.36"	8.36"	8.36"	43.94	7-0.6ø STRANDS EACH TENDON (TOTAL 6)
T5	8"	8"	8"	43.94	4-0.6ø STRANDS EACH TENDON (TOTAL 6)

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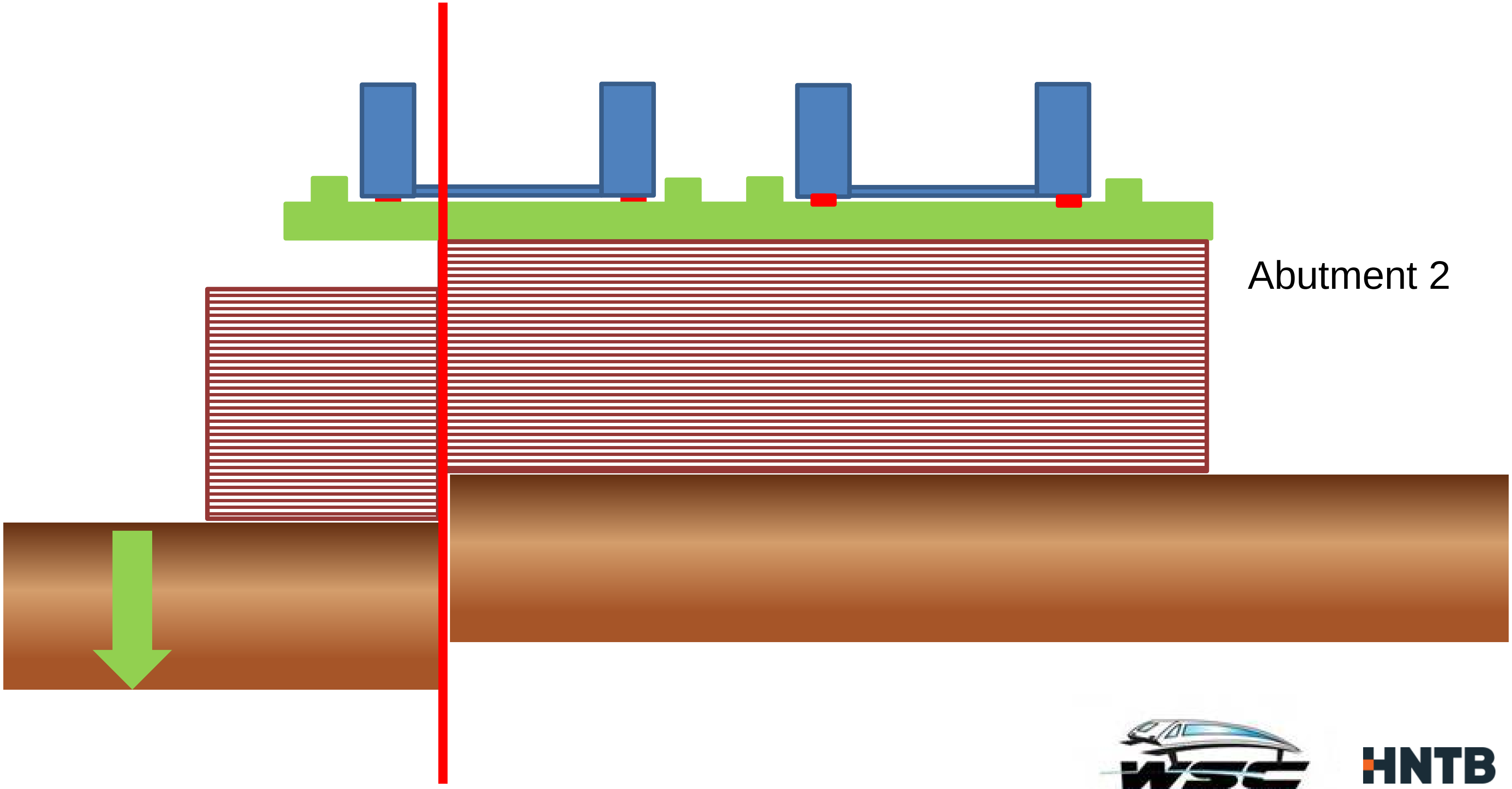
Superstructure – Design

FAULT RUPTURE

- Girder Design
- Spread Footing Model

Superstructure – Vertical Fault Rupture

- ABUTMENT 2 – Vertical Rupture - Displacement = 1.3 ft (16 inches)



Superstructure – Vertical Fault Rupture

Torsion

Blodgett Graphic – Torsional Response. Balancing on opposite corners

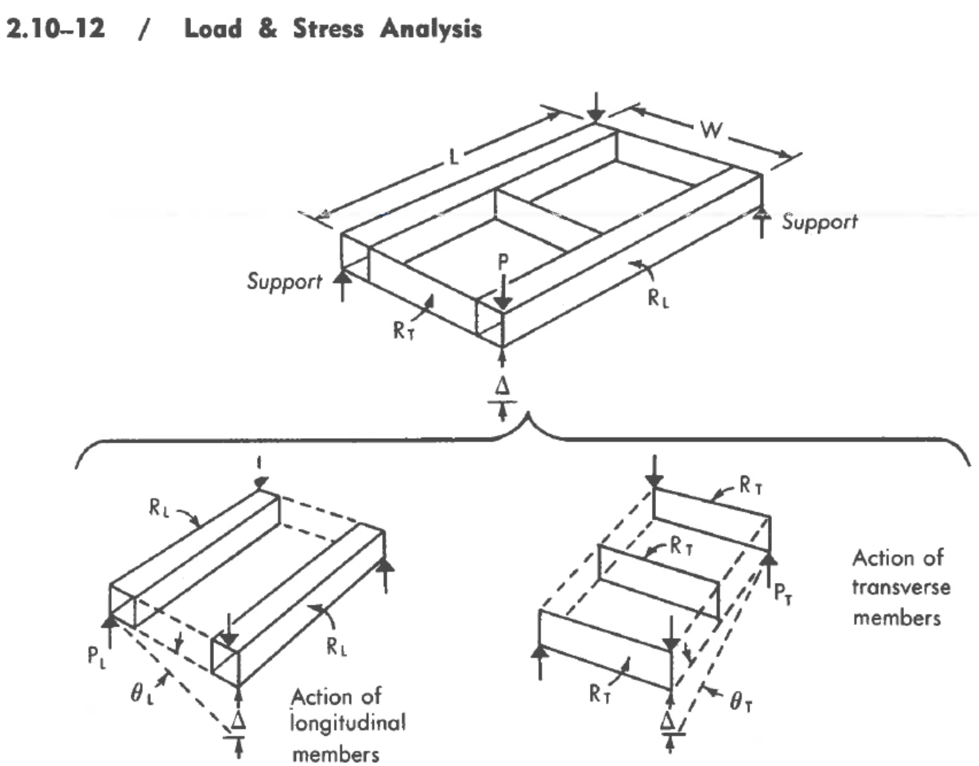
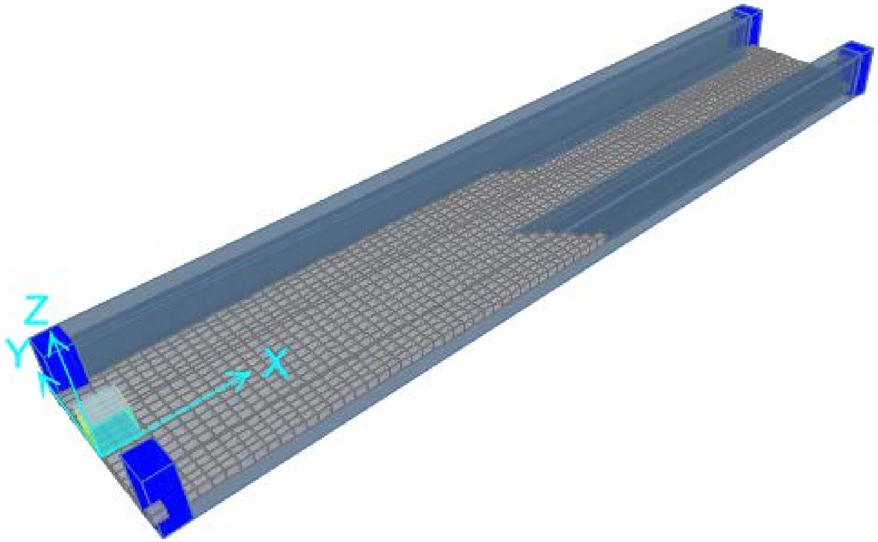
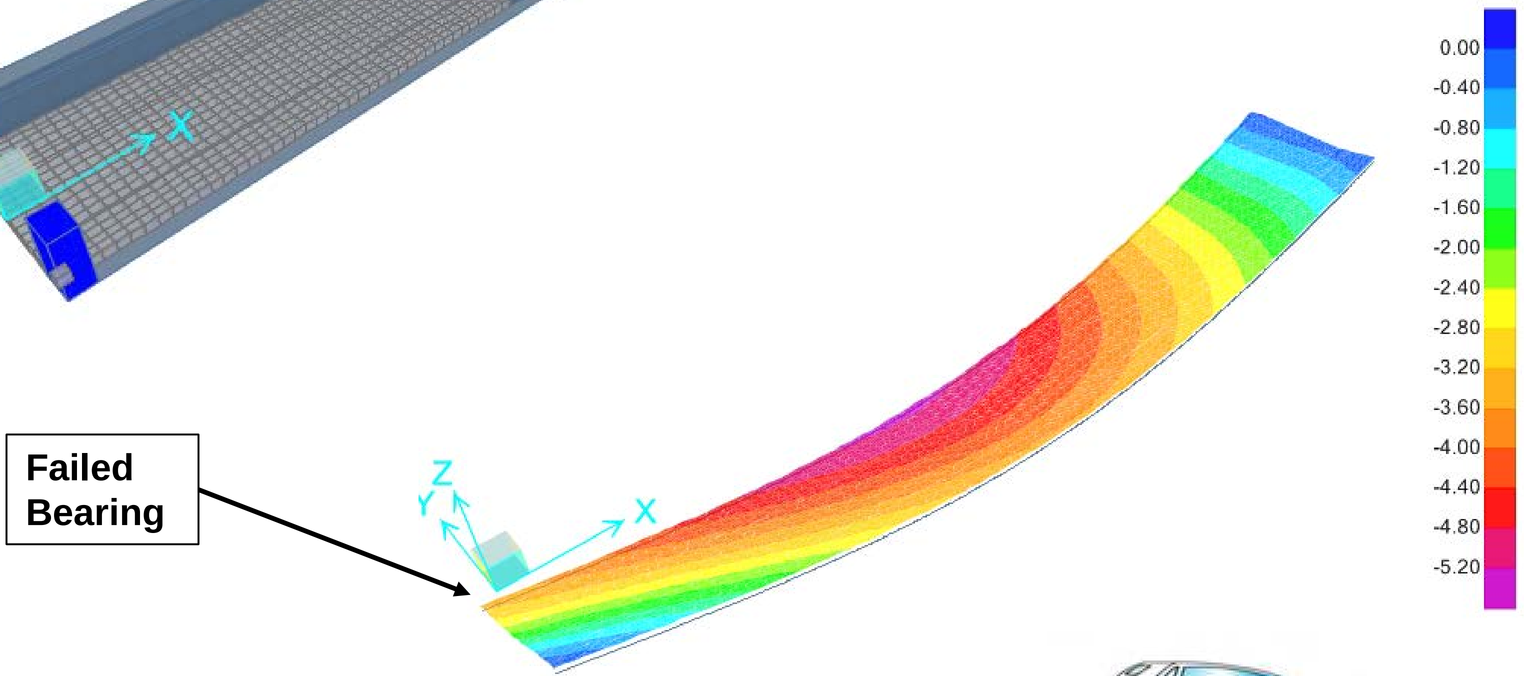


FIGURE 20

Superstructure – Vertical Fault Rupture

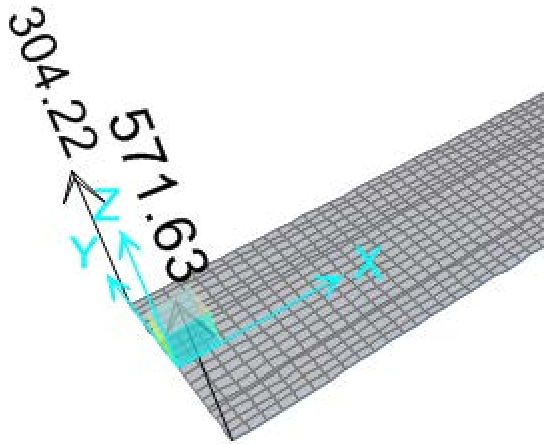
Bearing failure – superstructure deflection

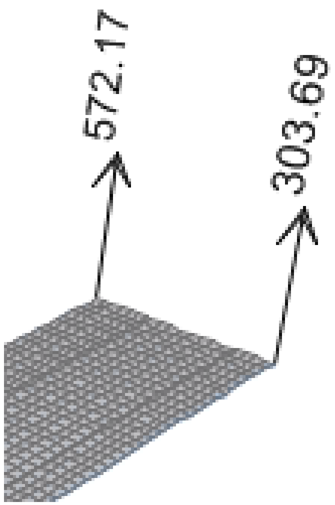




Superstructure – Vertical Fault Rupture

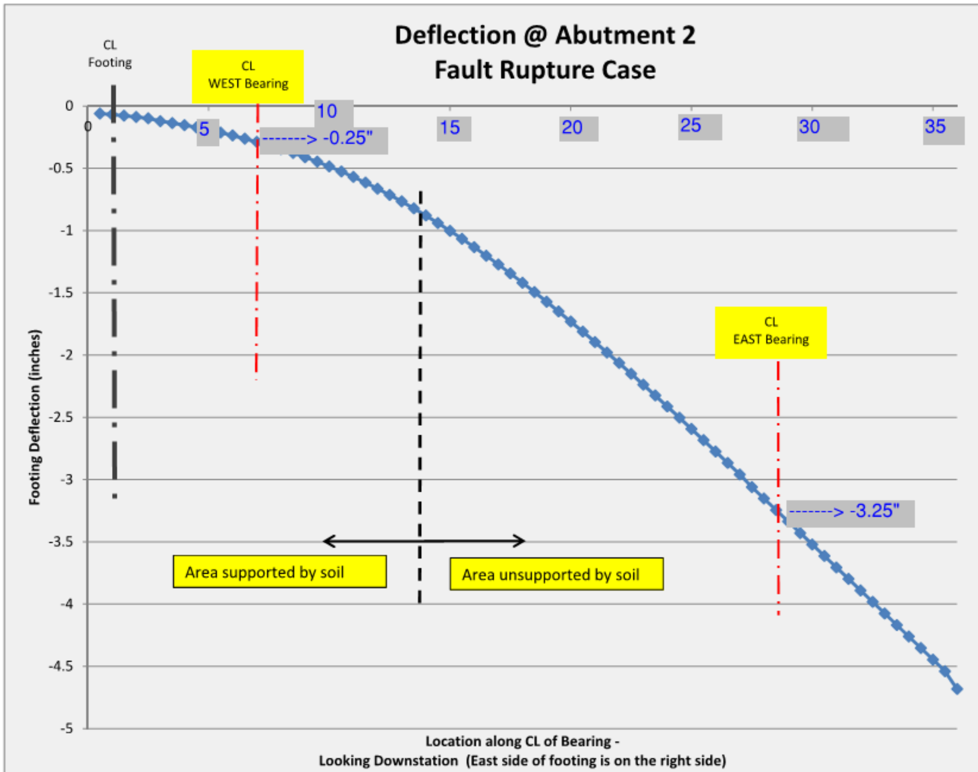
Bearing failure – end reactions

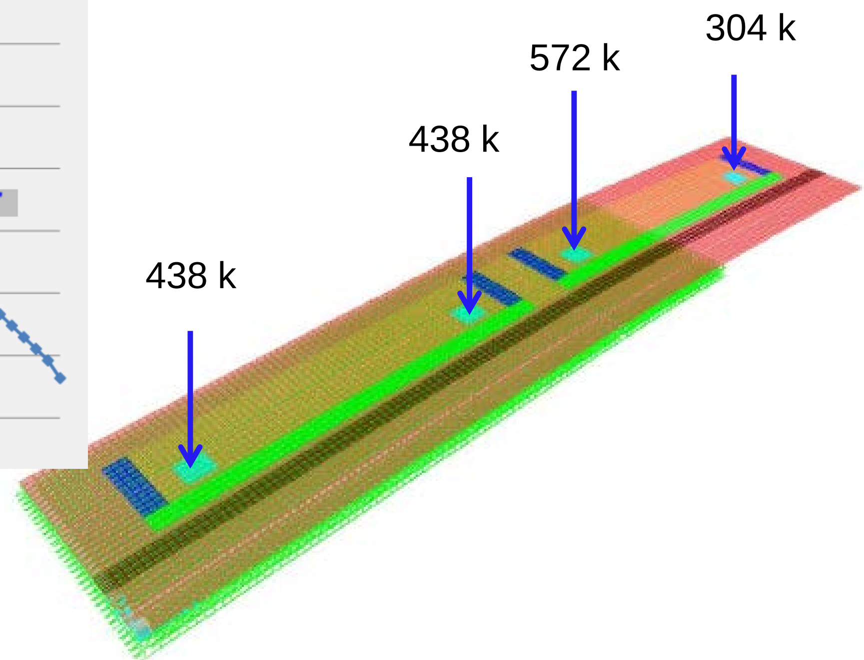




Superstructure – Vertical Fault Rupture

Bearing failure – abutment footing deflection

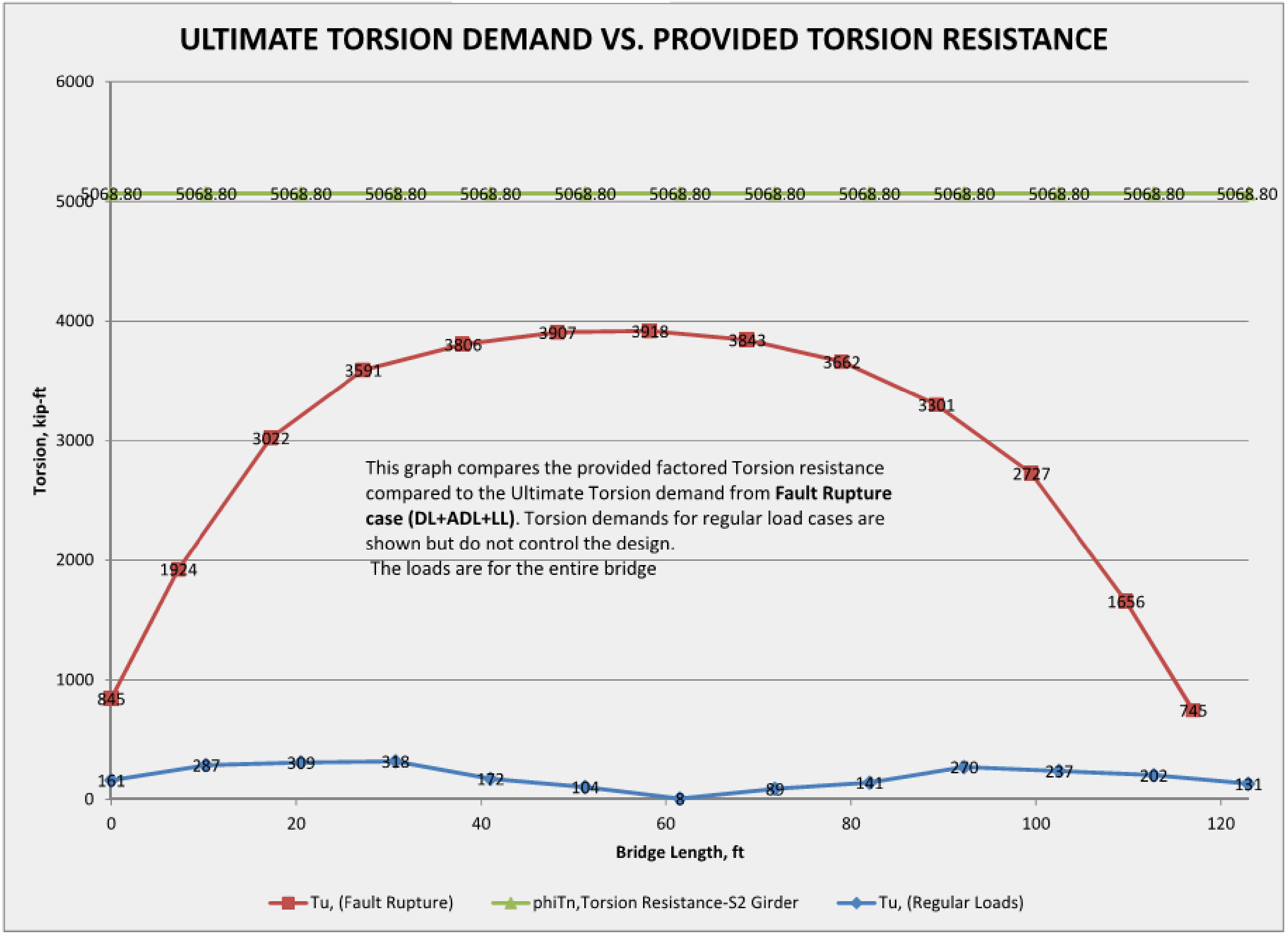




Superstructure – Vertical Fault Rupture

Girder Torsion Design

- Threshold = Tcr / 4 = 2000 kip-ft



Superstructure – Vertical Fault Rupture

TRANSVERSE DESIGN

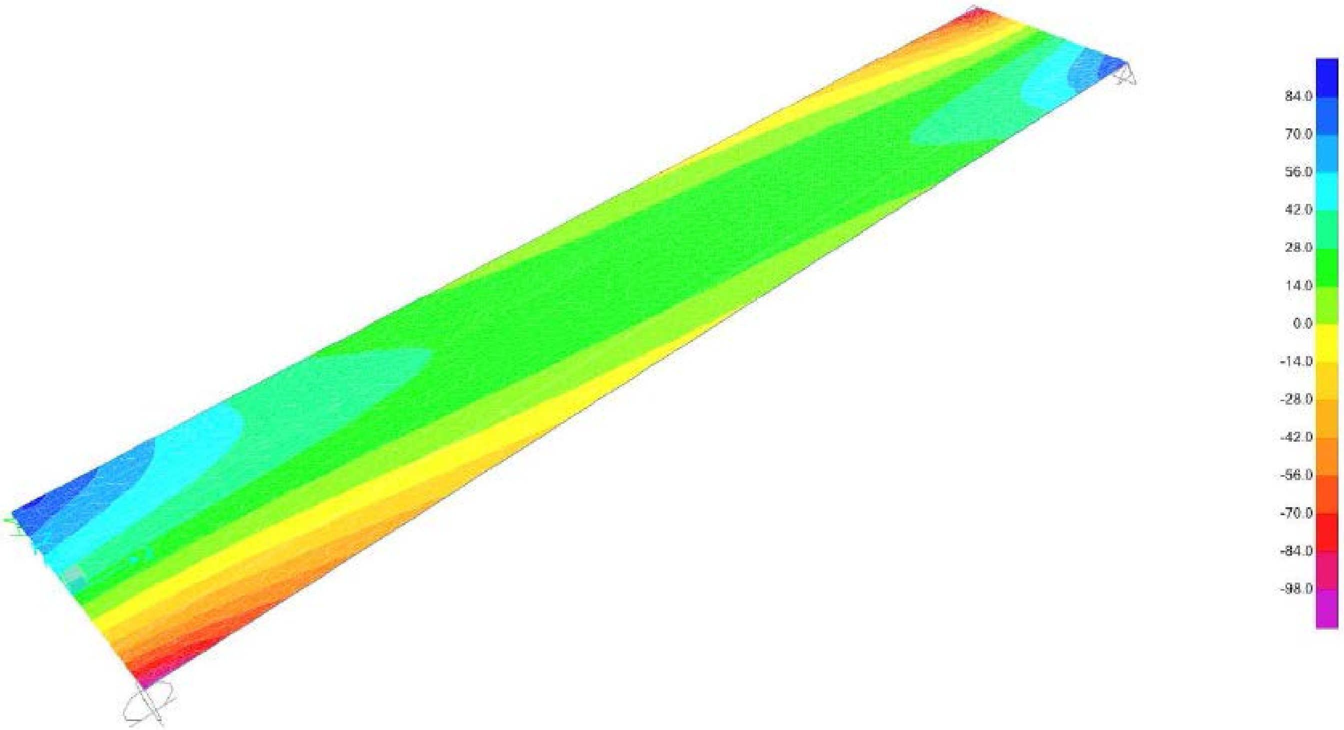
- Deck design

COMBINED Longitudinal and Transverse

- Girder Webs

Superstructure – Vertical Fault Rupture

- Loss of one bearing (fault rupture)
  - (Mu)negative = (Mu)positive = 83 kip-ft/ft



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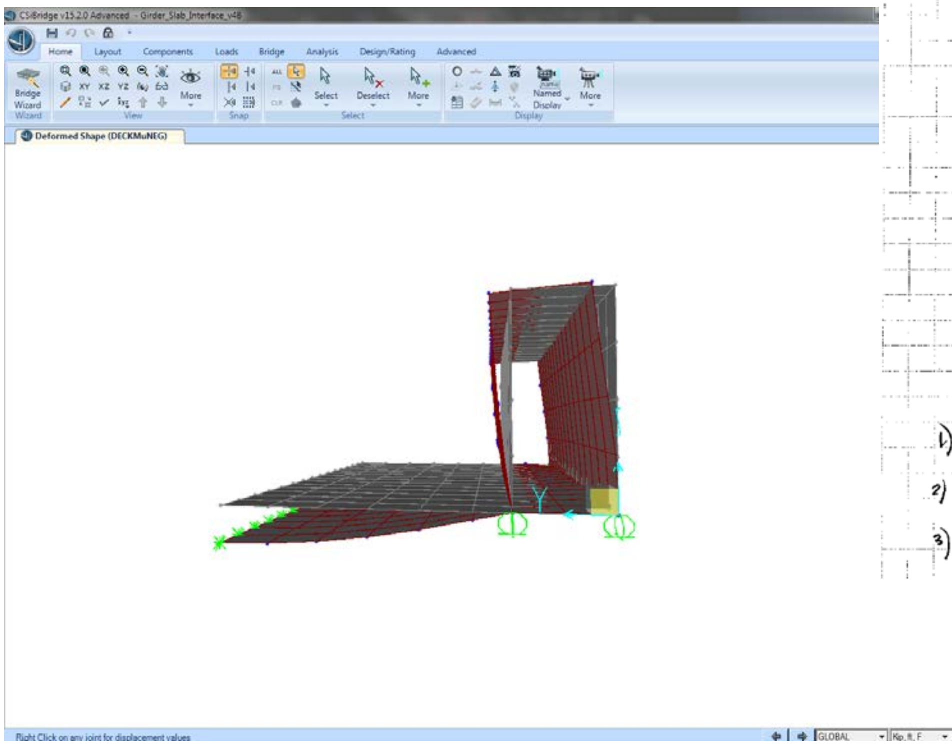
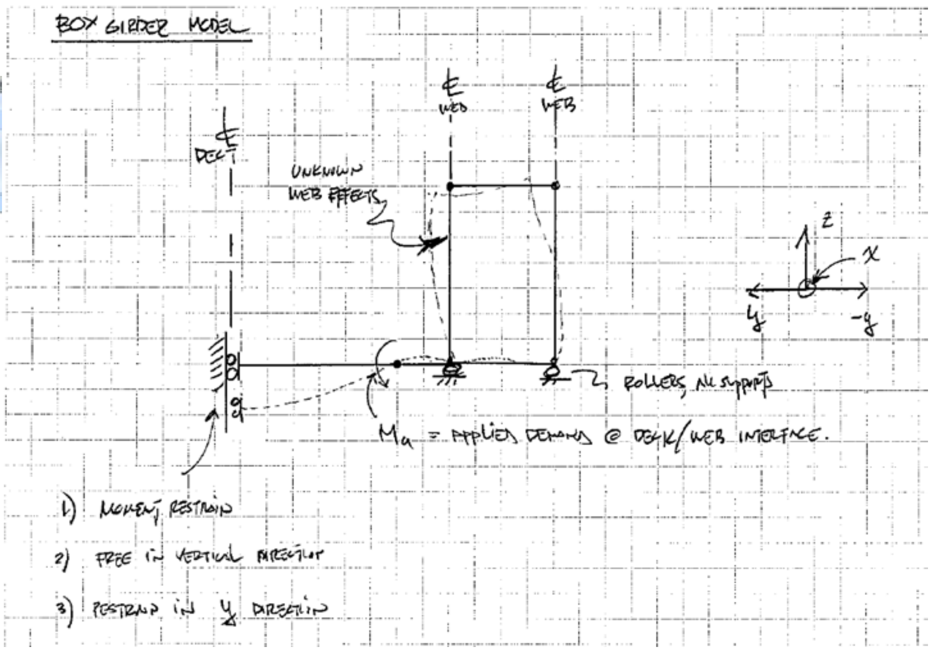
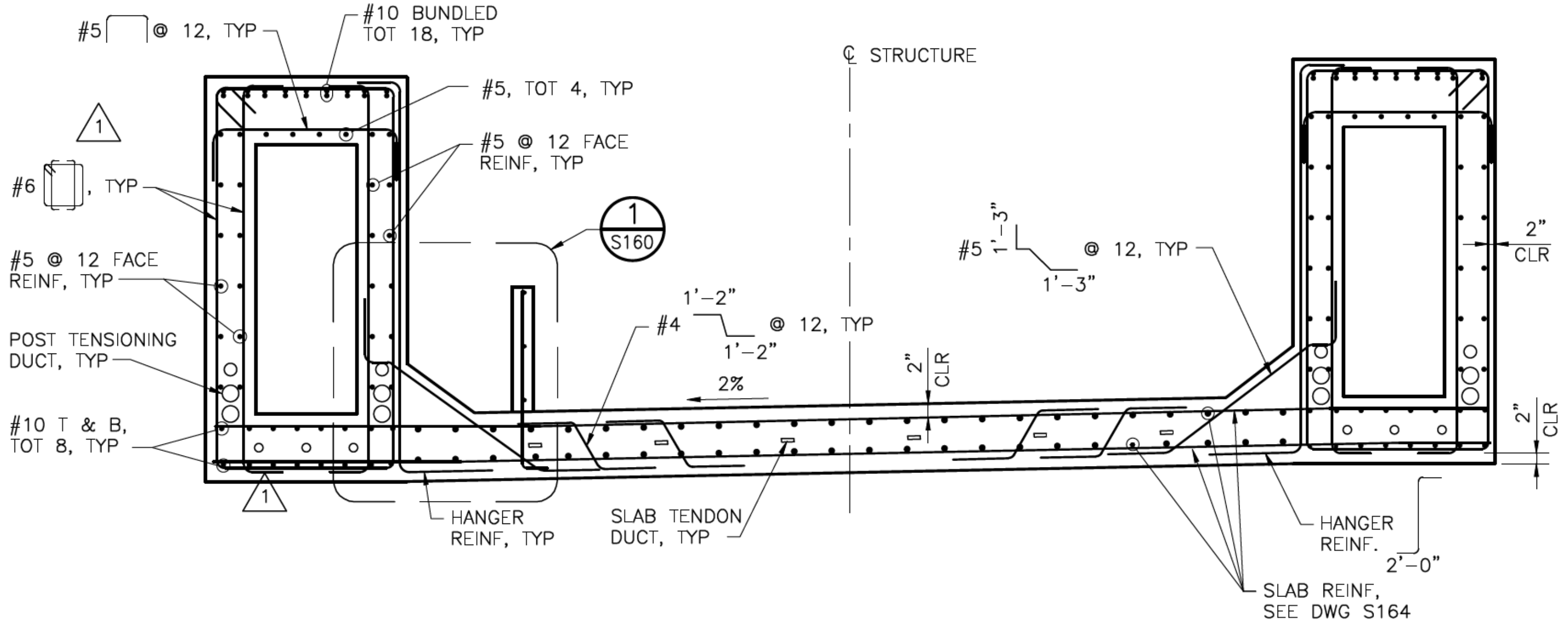
Girder Mild Reinforcement

- Web design – combine longitudinal and transverse effects for the maximum of:
  - 100% transverse + 50% longitudinal
  - 50% transverse + 100% longitudinal





Girder Mild Reinforcement



TYPICAL REINFORCEMENT

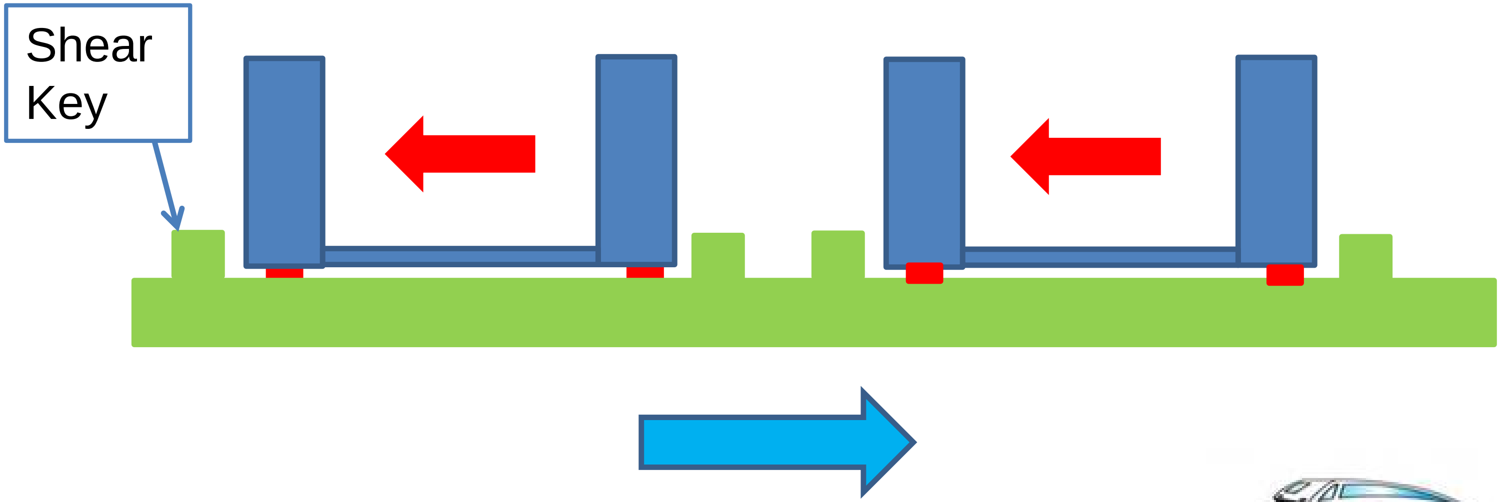
SCALE: 1/2"=1'–0"

- Web Stirrups = #6@9
- Deck Reinforcement = #8@6 (trans) top & bott
- Vertical EQ Reinforcement = 18-#10 (long) per box

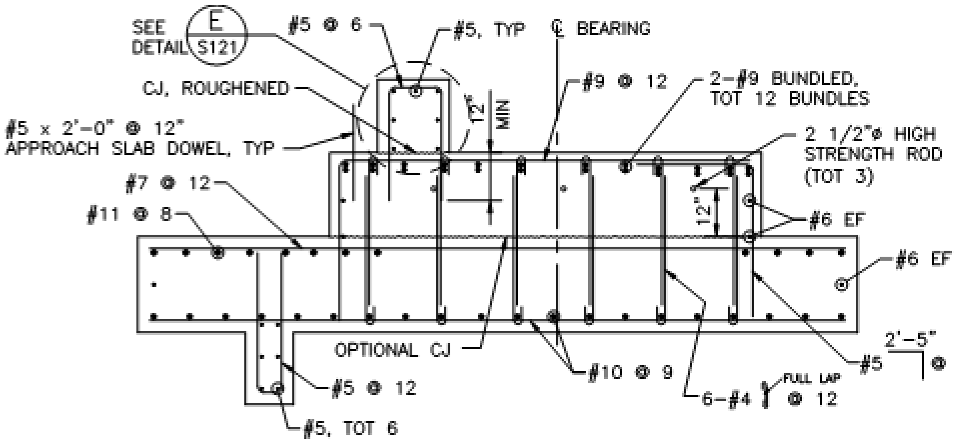
Seismic Design – shear keys

- Longitudinal – designed to remain intact

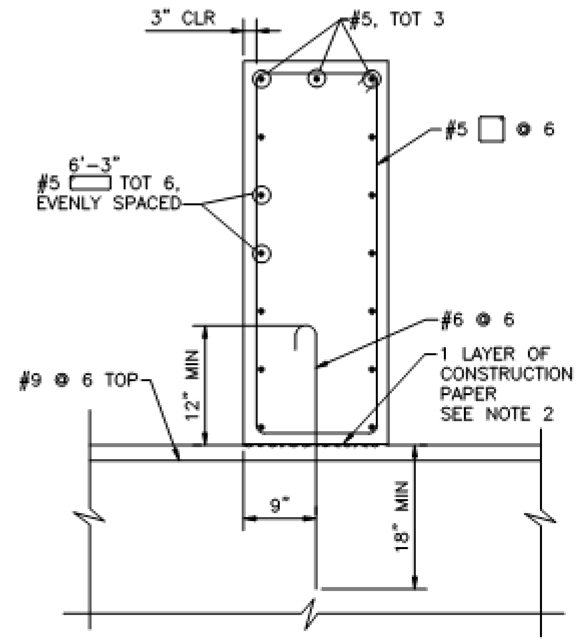
- Transverse – designed to fuse



Footing Reinforcement



ABUTMENT 2 FOUNDATION REINFORCEMENT
SCALE: 1/2"=1'-0"

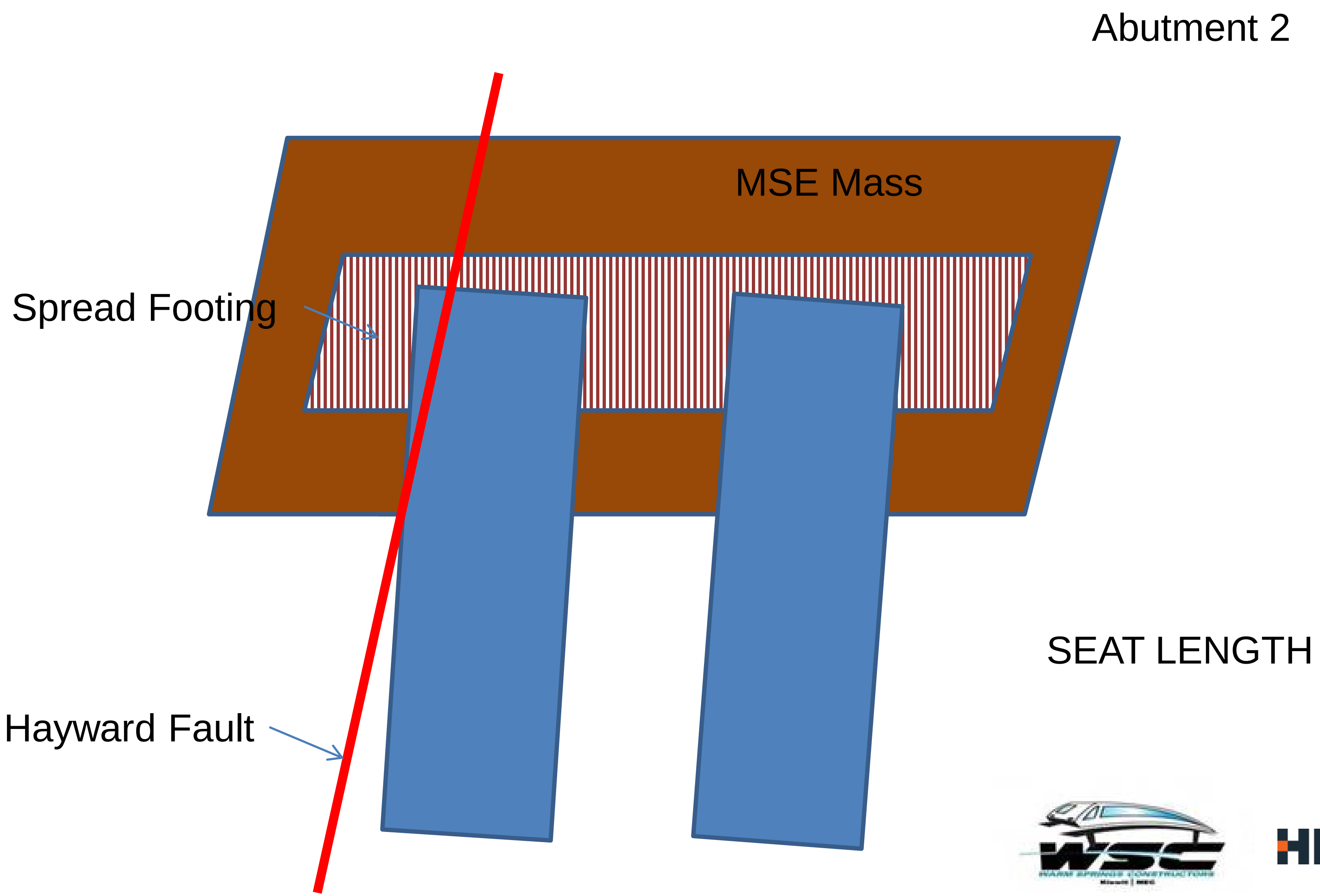


TRANSVERSE SHEAR KEY REINFORCEMENT
SCALE: 1"= 1'-0"

- 3-2.5” dia High Strength PT rods
- Transverse Shear Key – detailed to fuse

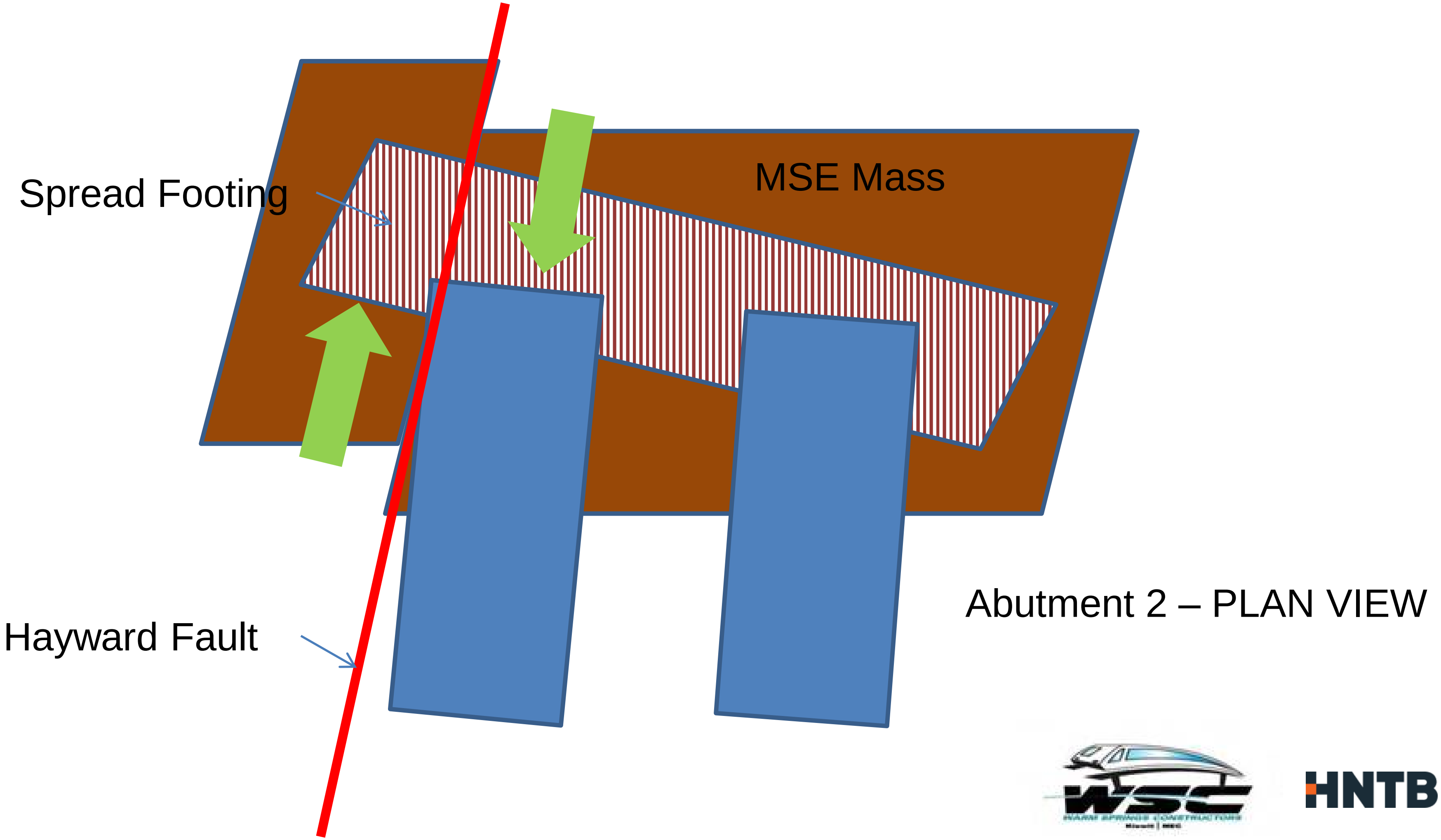
Superstructure – Horizontal Fault Rupture

- ABUTMENT 2 – Before Fault Rupture



Fault Rupture – SEAT LENGTH

- ABUTMENT 2 - Sufficient seat length is provided



SUBSTRUCTURE

Substructure - MSE Abutments

ABUTMENT 1

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Substructure - MSE Abutments

ABUTMENT 2

Substructure - MSE Abutments

BEHAVIOR OF REINFORCED WALL SYSTEM DURING THE 1999 KOCAELI (IZMIT), TURKEY, EARTHQUAKE

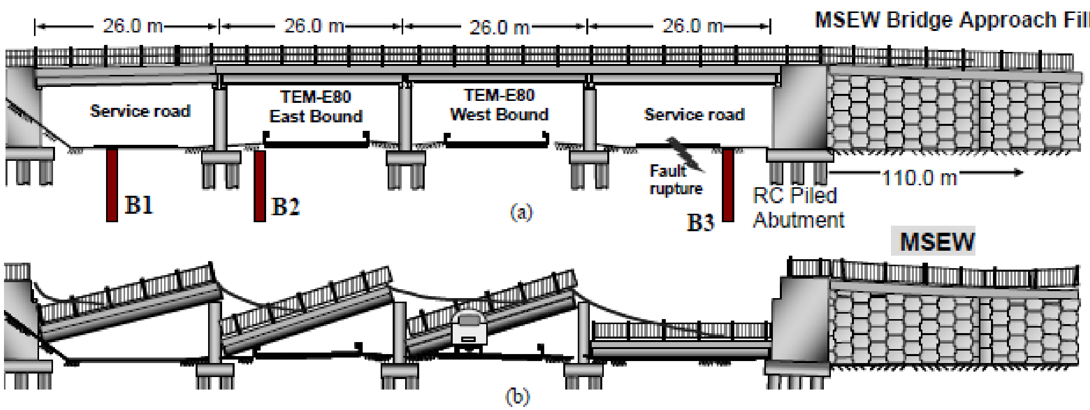


Fig. 2. The bridge overpass at Arifiye and mechanical stabilized bridge approach fill walls (a) before, and (b) after the earthquake.

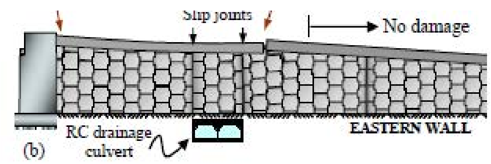
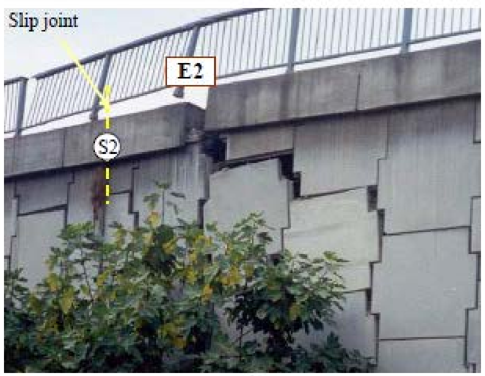


Fig 5. MSE bridge approach (a) plan view of approach fill with damage-concentration; (b) schematics of eastern wall after the earthquake.

(a)



(b)

Substructure - MSE Abutments

Postearthquake Reconnaissance Report on Transportation Infrastructure Impact of the February 27, 2010, Offshore Maule Earthquake in Chile

PUBLICATION NO. FHWA-HRT-11-030 OCTOBER 2011

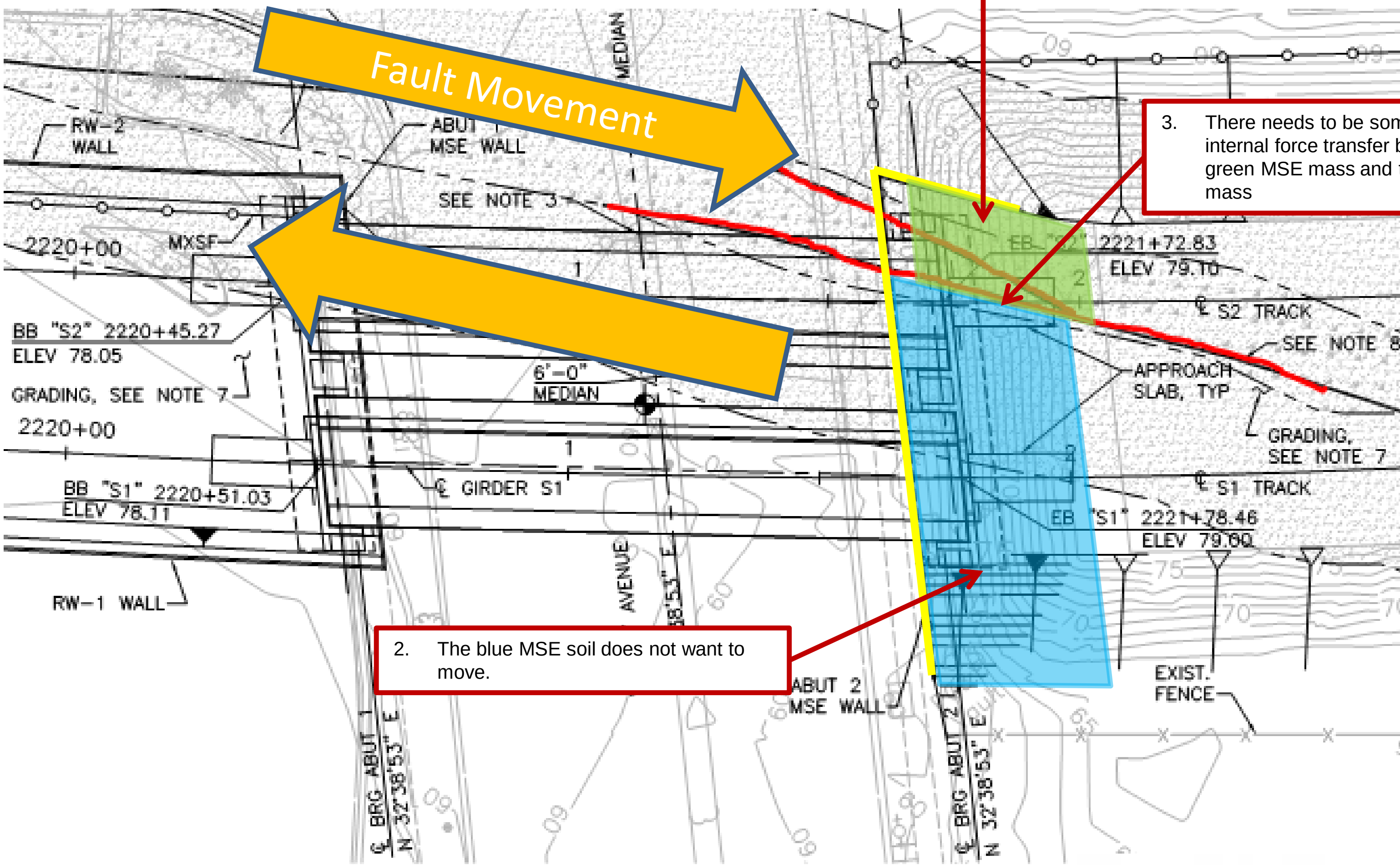
Figure 268. Photo. Wall corner tilting outward at wall site 28B.

Thanks to: Professor Nicholas Sitar, UC Berkeley

Substructure - MSE Abutments

Seismic Event

1. As the fault moves, the green MSE soil wants to move with it due to the forces being imparted on it by the slip plane friction.



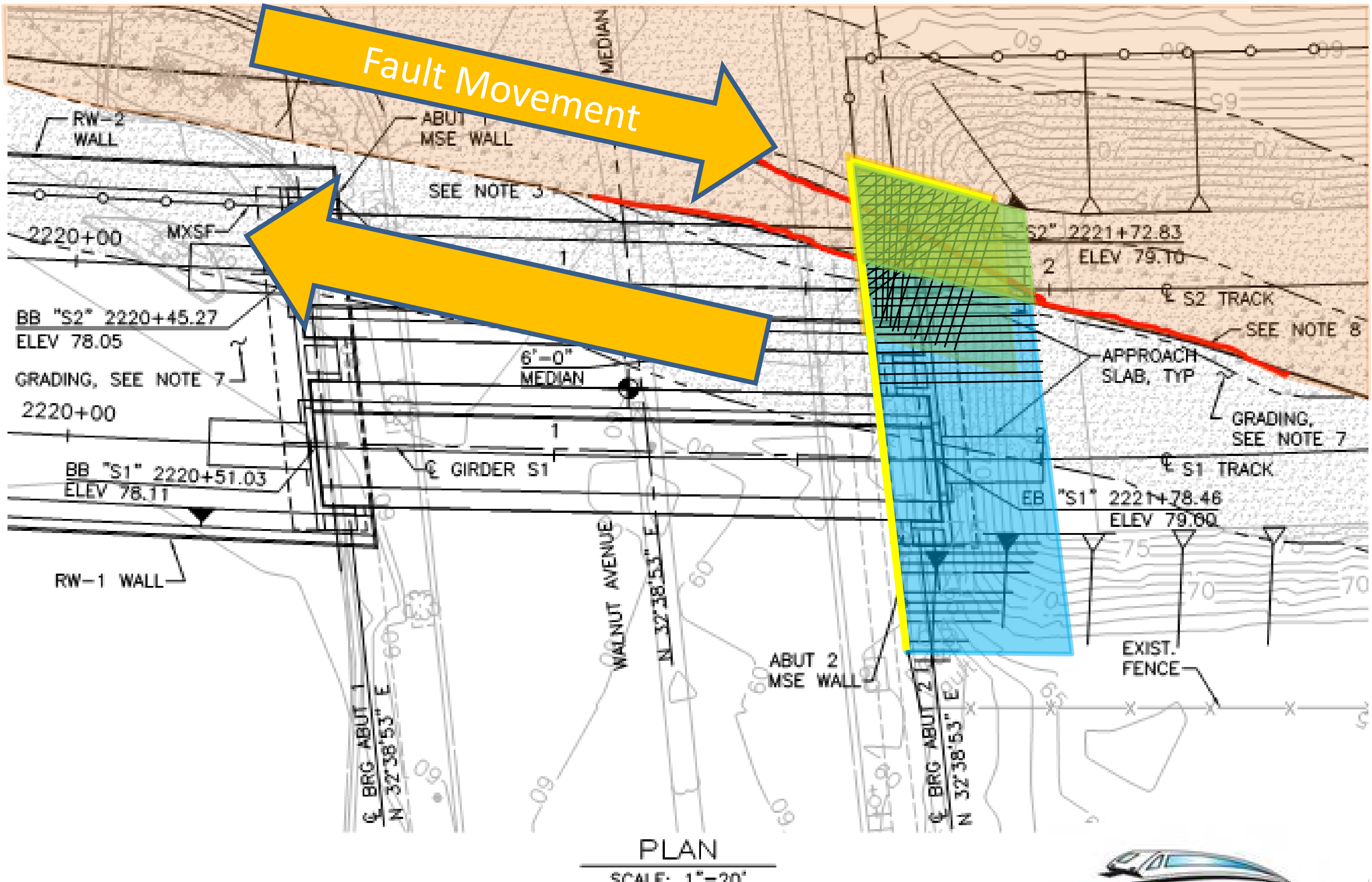
3. There needs to be some kind of internal force transfer between the green MSE mass and the blue MSE mass

2. The blue MSE soil does not want to move.

PLAN
SCALE: 1"=20'

Substructure - MSE Abutments

- Integrity of MSE mass is maintained
- Need to reduce friction between MSE mass and supporting soil



Substructure - MSE Abutments

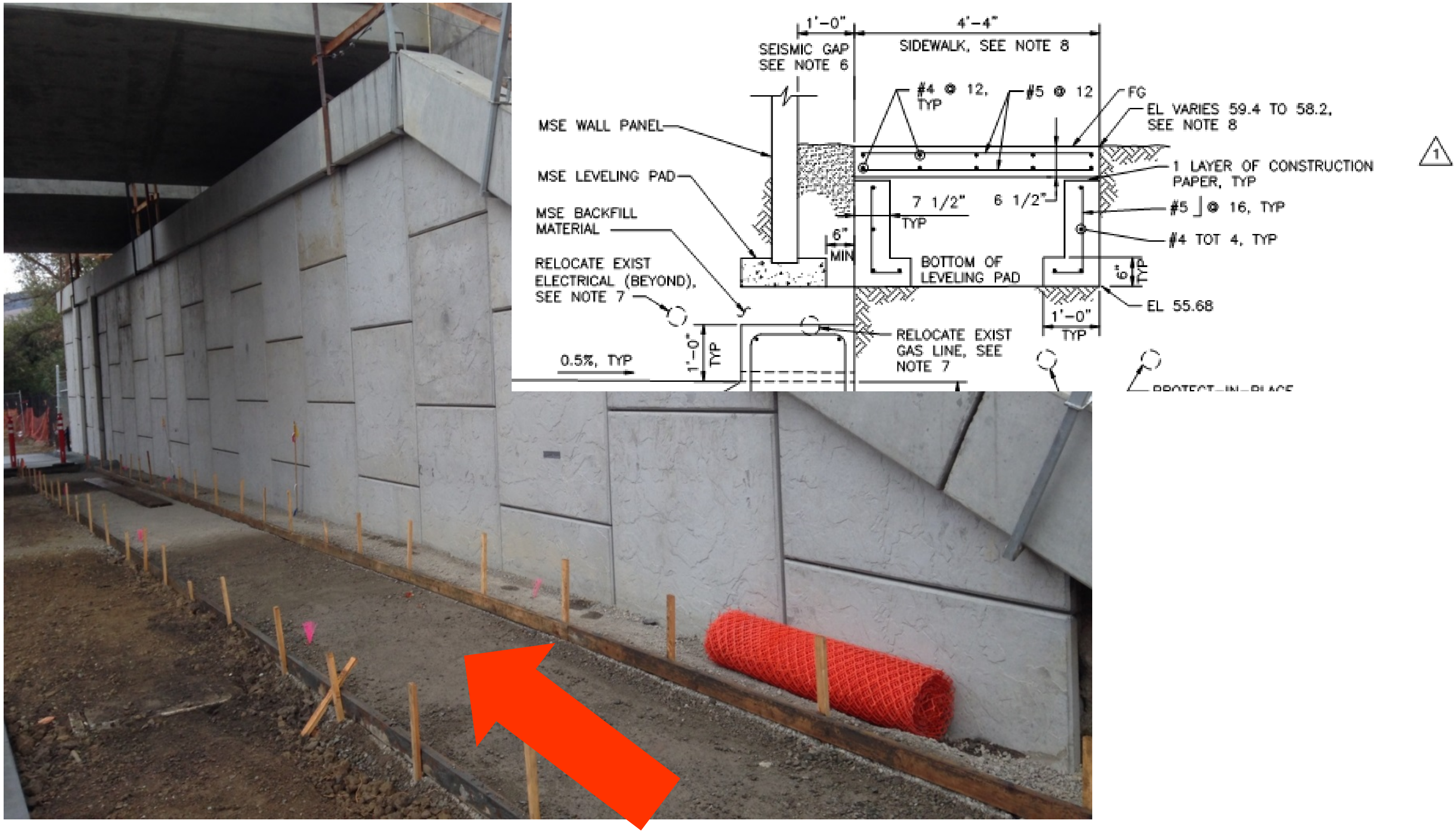
Slip Plane

Substructure - MSE Abutments

Courtesy of: Forell/Elsesser Engineers,
Jonathan D. Bray, Phd, P.E. UC Berkeley

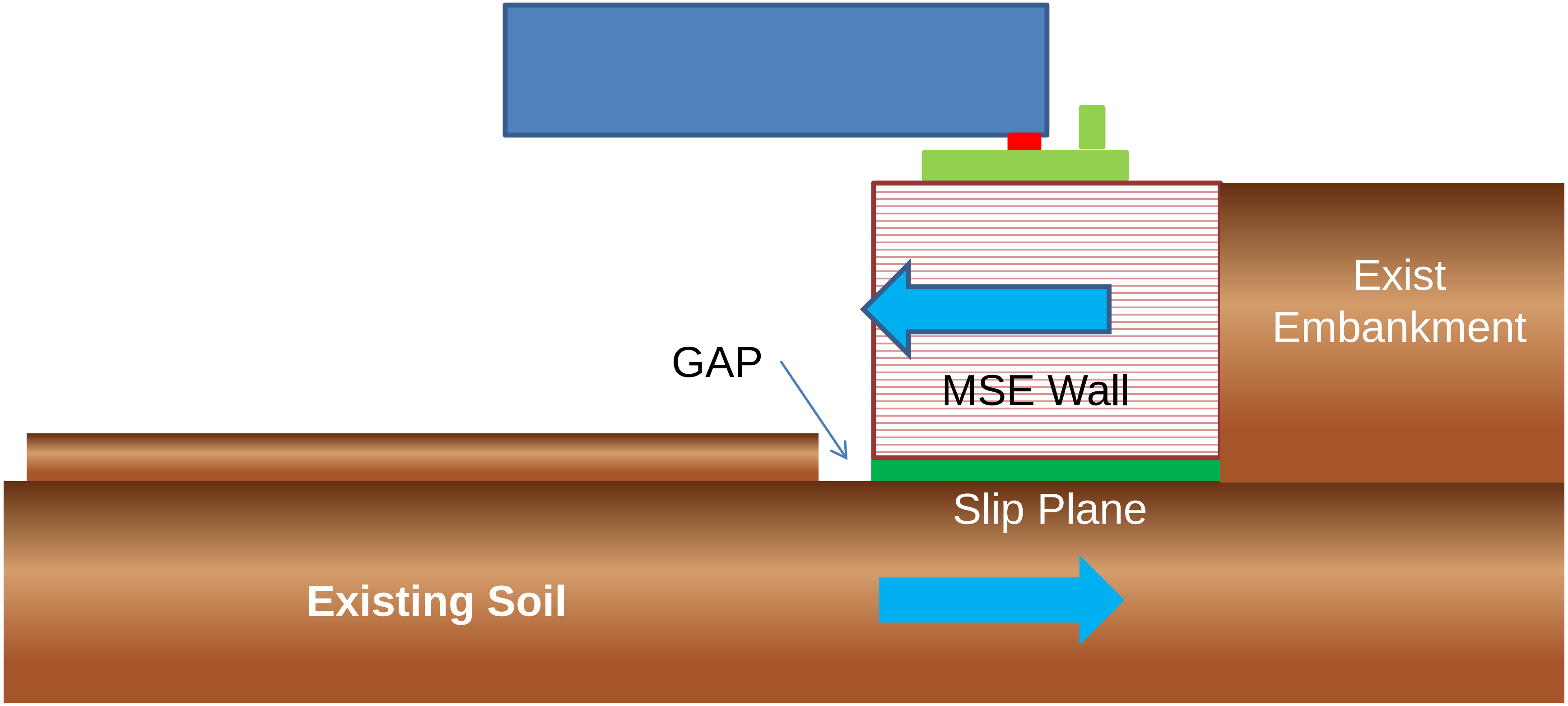
Substructure - MSE Abutments

ABUTMENT 2 – Seismic Gap



MSE Abutments

- To reduce sliding forces between the MSE block and the underlying soil, we added a slip plane. PVC or HDPE plastic membrane.



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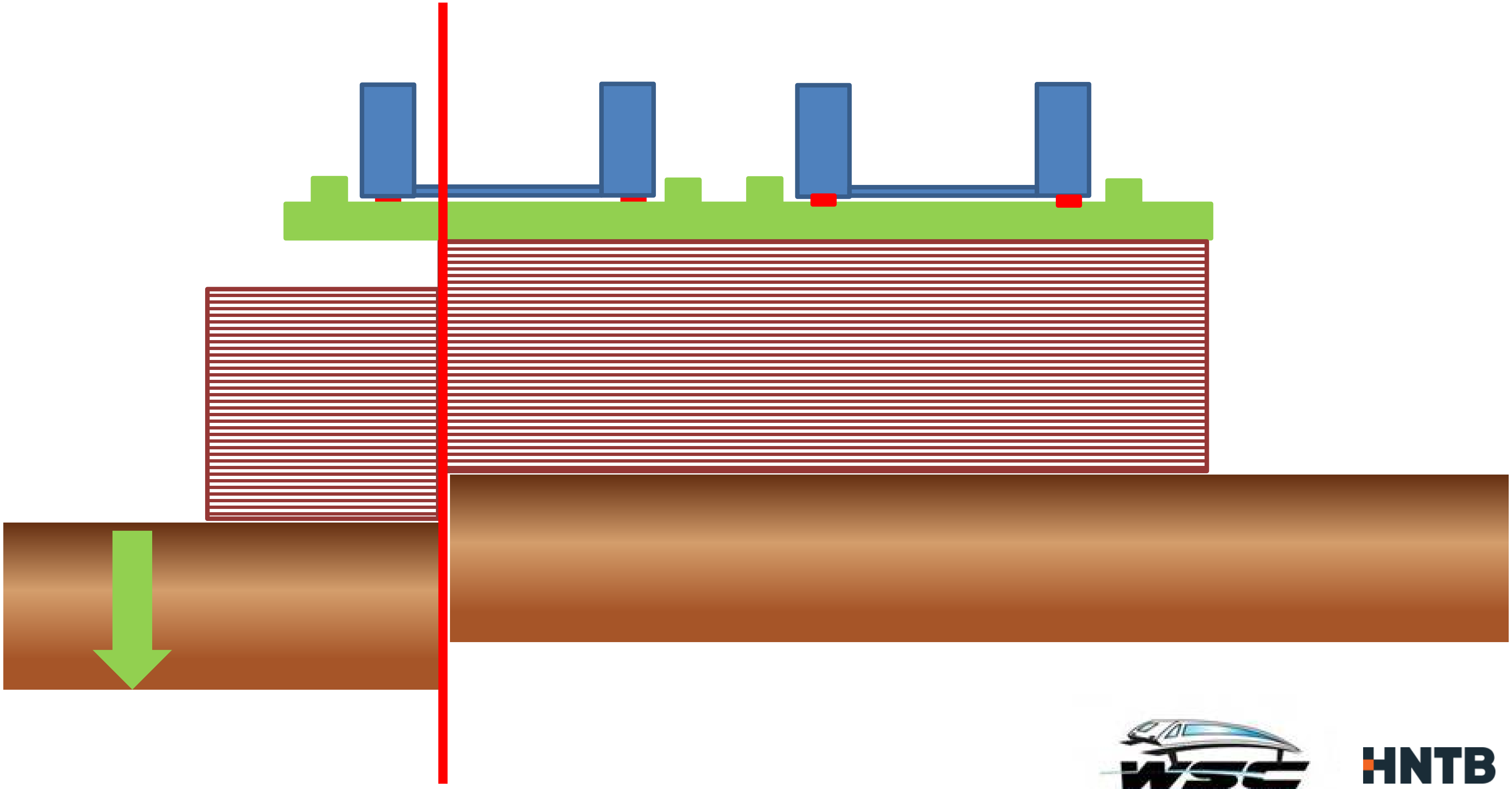
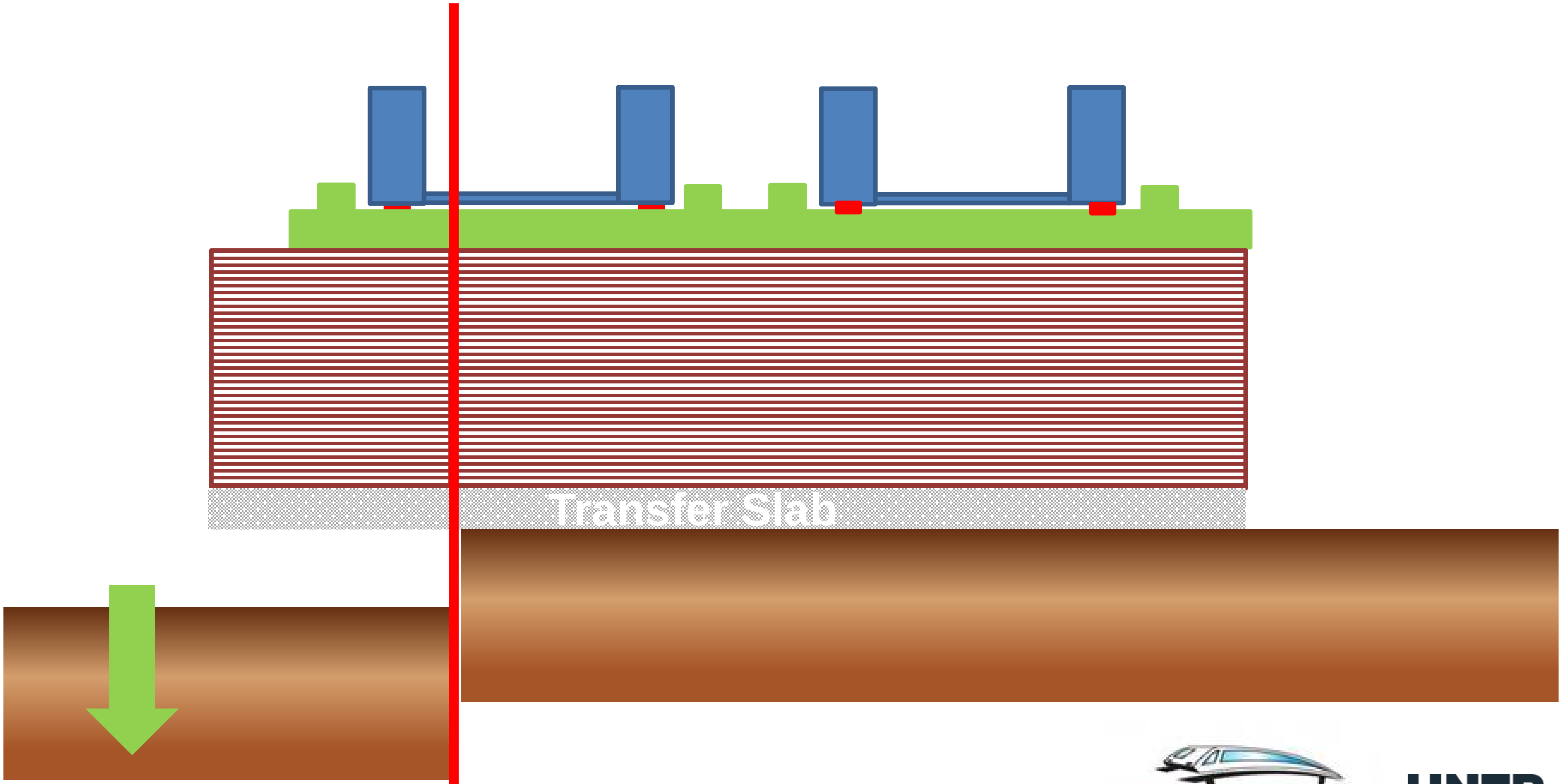
MSE Abutments

- Vertical Displacement = 1.3 ft (16 inches)

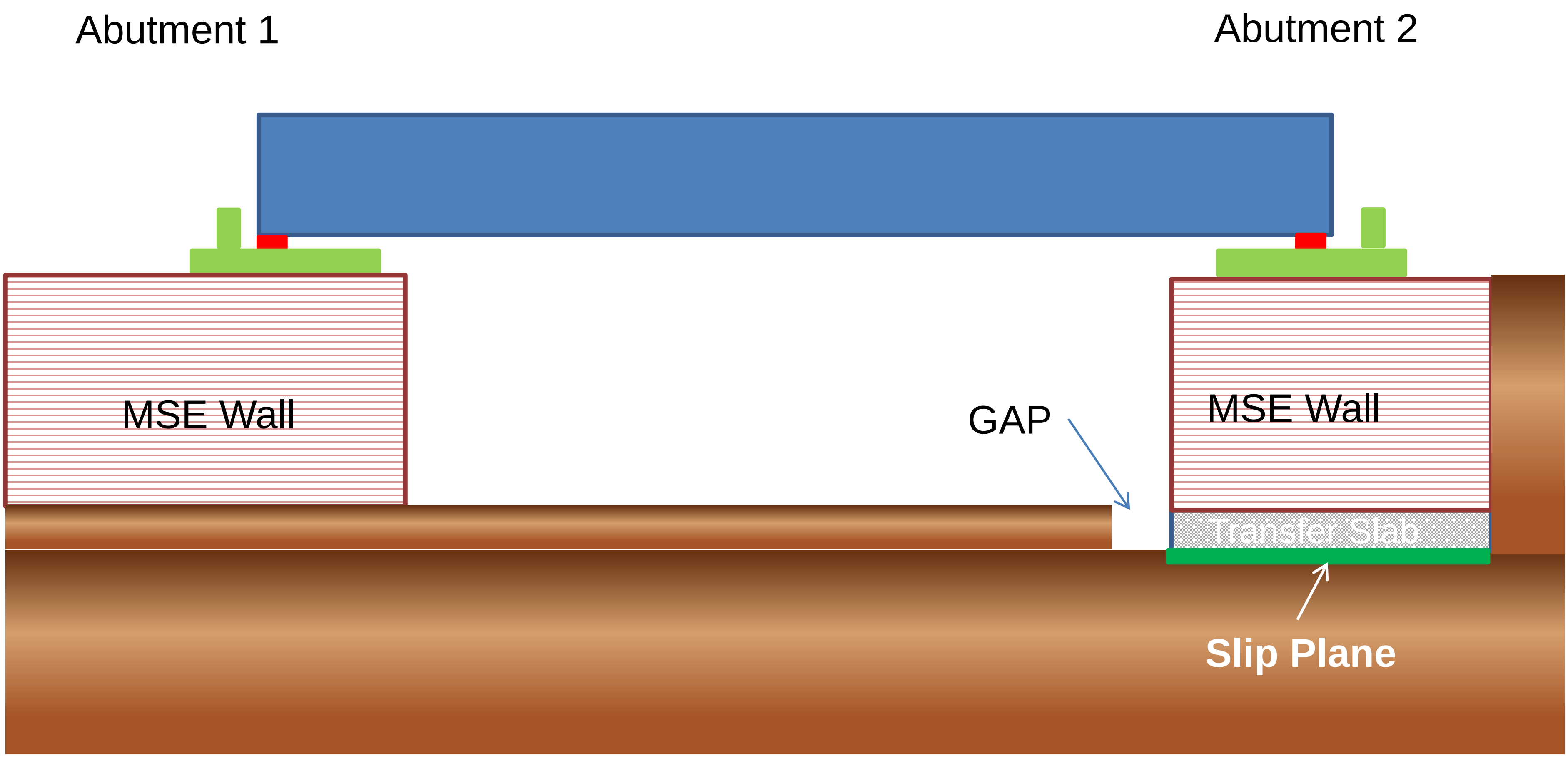


Substructure - MSE Abutments

- Transfer slab supports MSE and Bridge when Vertical Rupture Occurs



WALNUT AVENUE BRIDGE SEISMIC SYSTEM



Construction – ELEVATED FALSEWORK

- Limited Vertical Clearance
- Constructed on Elevated Falsework
- Lowered in Place using Strand Jacks

Construction – ELEVATED FALSEWORK

Straddle Lowering Bent

Construction - LOWERED BRIDGE

- Limited Vertical Clearance
- Constructed on Elevated Falsework
- Lowered in Place using Strand Jacks

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Construction - REINFORCEMENT

Reinforcement

Construction - REINFORCEMENT

Reinforcement – Web Reinforcement

Construction - POST TENSIONING

End diaphragms

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Construction - POST TENSIONING

Anchor Blocks & Abutment Backwall

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Construction - POST TENSIONING

Anchor Blocks & Lowering Frame

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Construction - AESTHETICS

- Architectural Treatment

Acknowledgements

CLIENTS

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- Kiewit
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WSC WARM SPRINGS CONSTRUCTORS

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Questions