# Lateral Spreading Design Solutions

## Seismic Design & Retrofit

Western Bridge Engineer's Seminar

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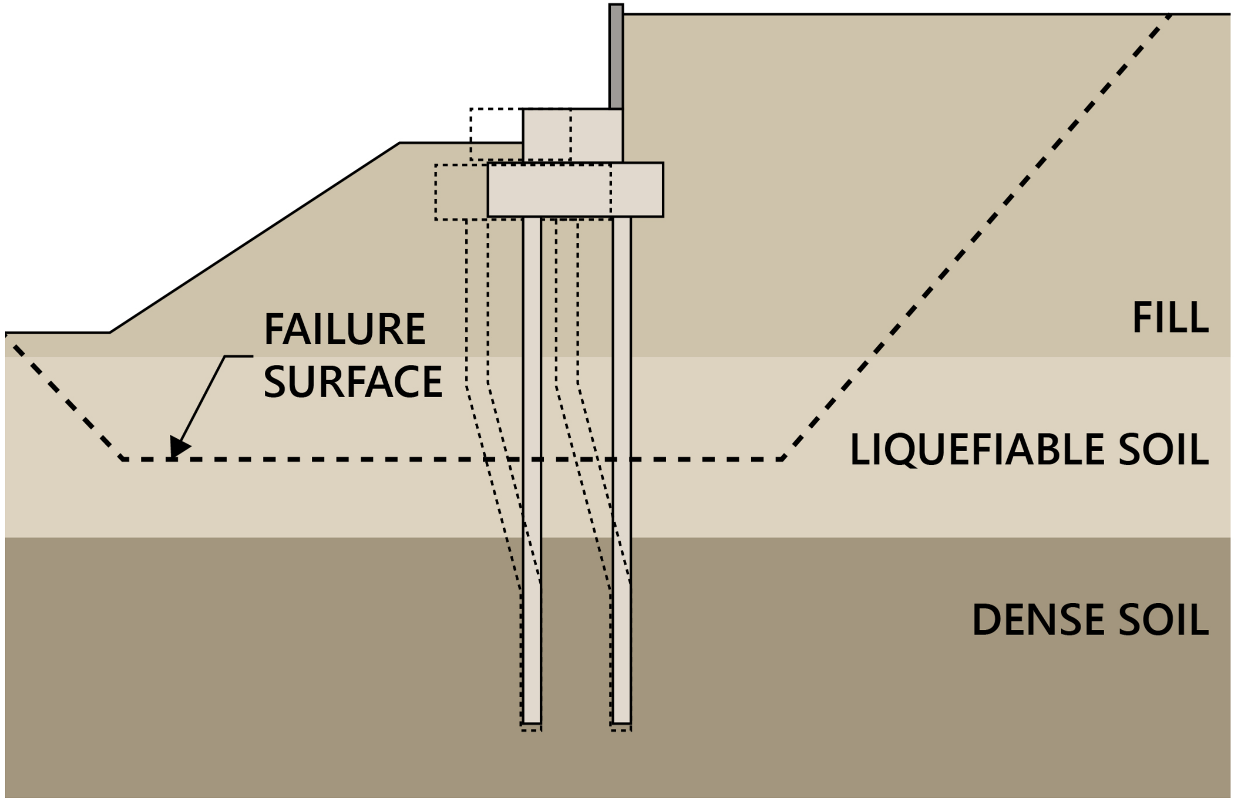
Session 3C

MARK THOMAS

# Lateral Spreading (Quick Recap)

Seismically induced Soil Liquefaction causing excessive horizontal ground displacement

*Far From Home, UCSD/UCI, August 2011*




*MTD 20-15, Caltrans, May 2017*

# Lateral Spreading Loads (Quick Review)

California Department of Transportation (Caltrans) provides Loading Guidance:

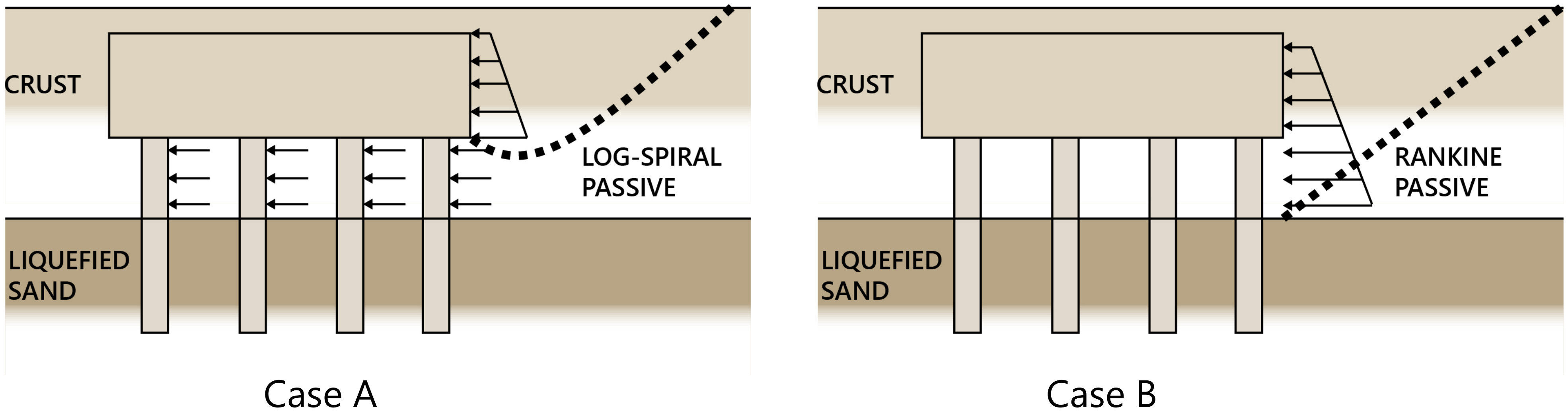



**Figure A3 Two possible design cases for the calculation of the ultimate passive load due to the soil crust**

*MTD 20-15 Attachment 1, Caltrans, May 2017*

# Lateral Spreading Loads (Quick Review)

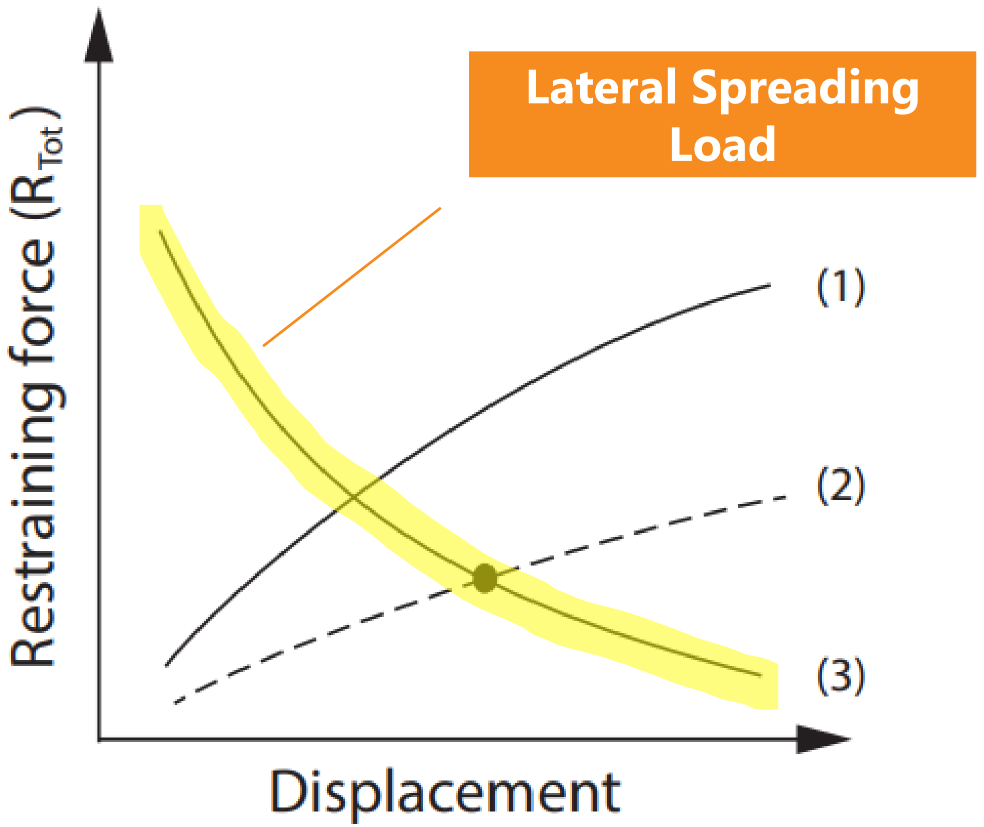
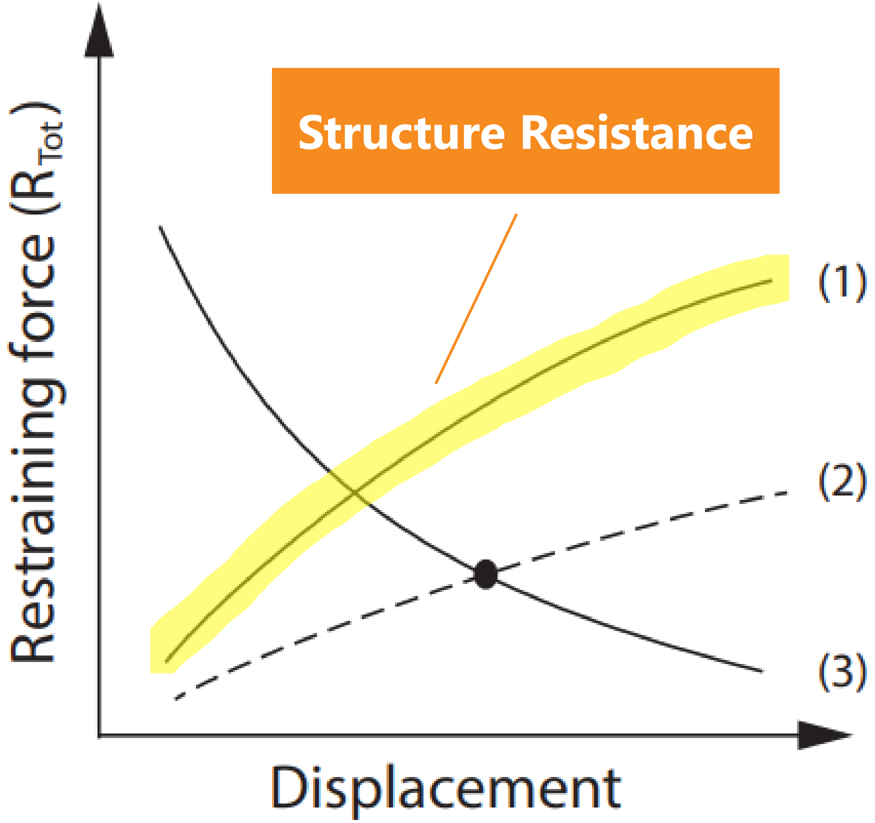



**Figure 5** Interaction Curve (1) shows the total resisting force ($R_{Tot}$) vs. the foundation displacement. Curve (2) uses a running average of the resisting force to correct Curve (1). Curve (3) represents the displacement response of the sliding mass as calculated in Step 6. The design displacement demand is determined by the intersection of curves (2) and (3).

*MTD 20-15, Caltrans, May 2017*

# Lateral Spreading Loads (Quick Review)

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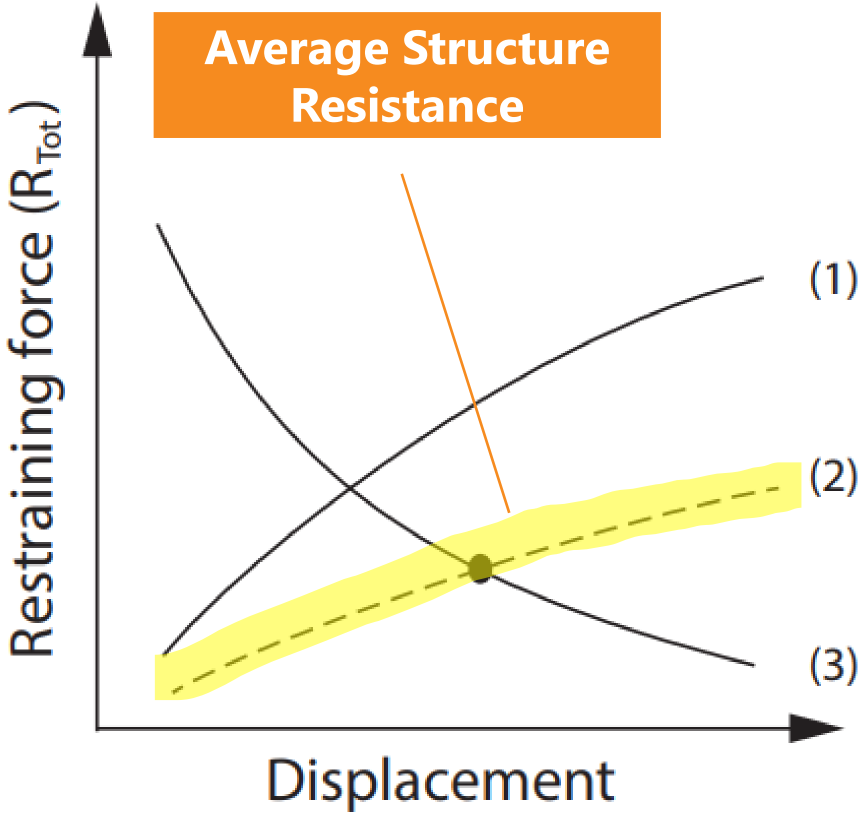


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*MTD 20-15, Caltrans, May 2017*

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# Application of Lateral Spreading

## Existing Bridge Assessment and Seismic Retrofits

- Caltrans MTD 20-4: Seismic Retrofit Guidelines for Bridges in California
- Assess & Design for No-Collapse
- Allows application of Ground Shaking, Liquefaction and Lateral Spreading separately based upon reduced remaining service life of existing bridge

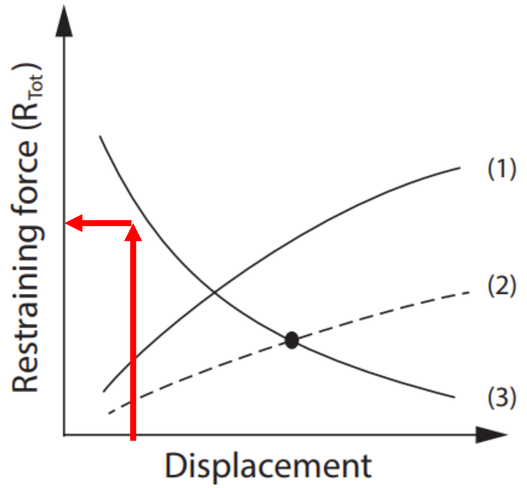
## New Bridge Design

- Must meet ductility requirements of Caltrans Seismic Design Criteria (SDC)
- Must combine Lateral Spreading with other applicable seismic hazards such as Ground Shaking and Liquefaction

# Design Options for Lateral Spreading

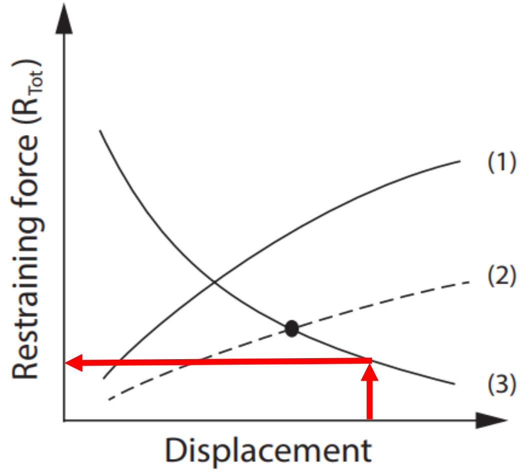
Preventing lateral spreading movement requires extensive resistance

- Ground Improvements
- Extensive Foundation Systems




Allowing deformation of bridge system reduces restraining force

- Utilize passive pressure against opposite abutment
- Utilize column resistance
- Reduce restraining force

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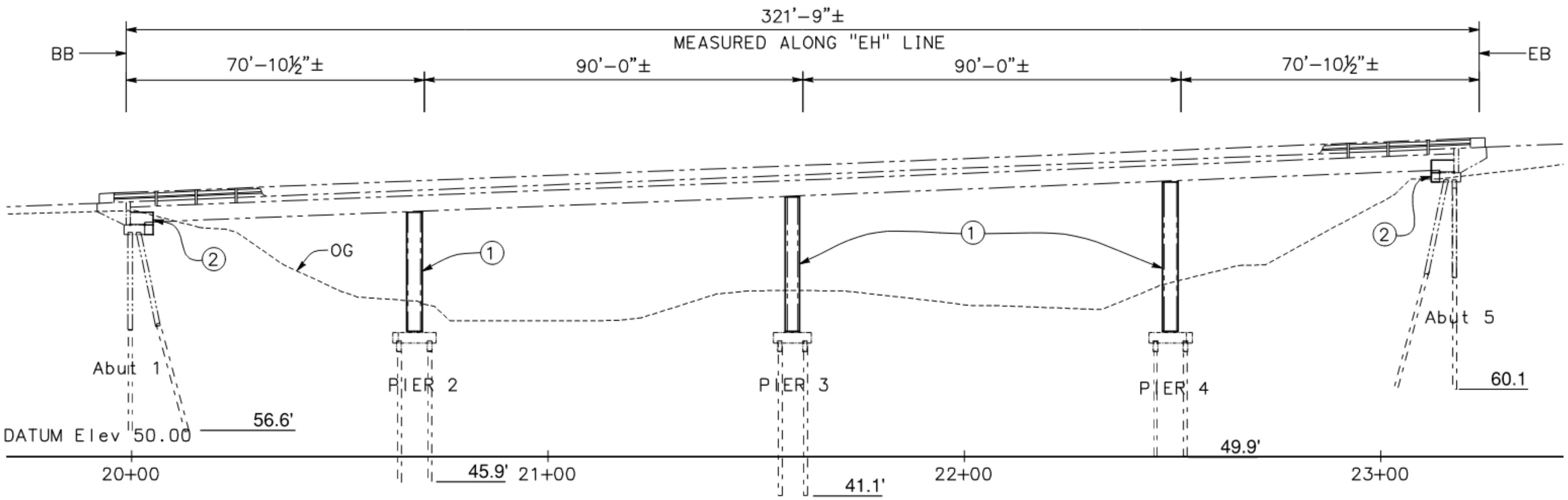
# *Case Study:* Eureka Hill Road Bridge over Garcia River Seismic Retrofit, Mendocino County, CA




- Lateral Spreading was predicted at Piers and Abutments:
- 10 inches at Abutment 1 and Pier 2
- 24 inches at Pier 3
- Unlimited movement at Pier 4 and Abutment 5

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# Eureka Hill – Abutment 1

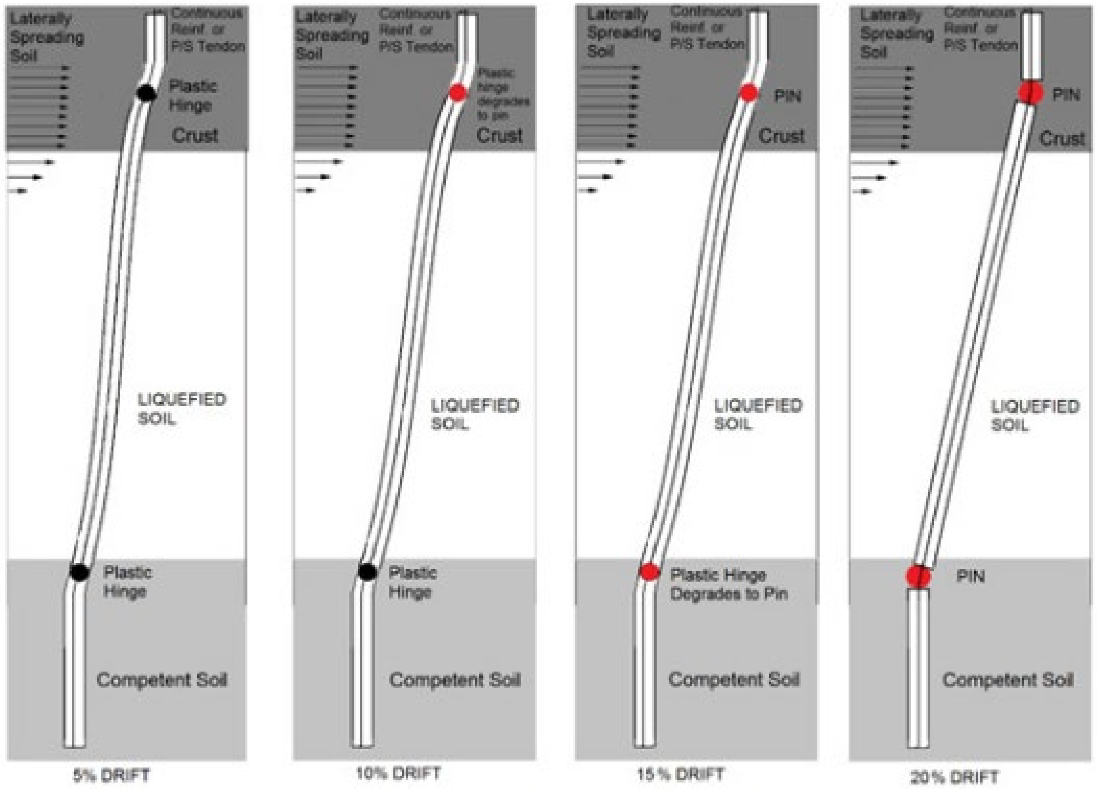


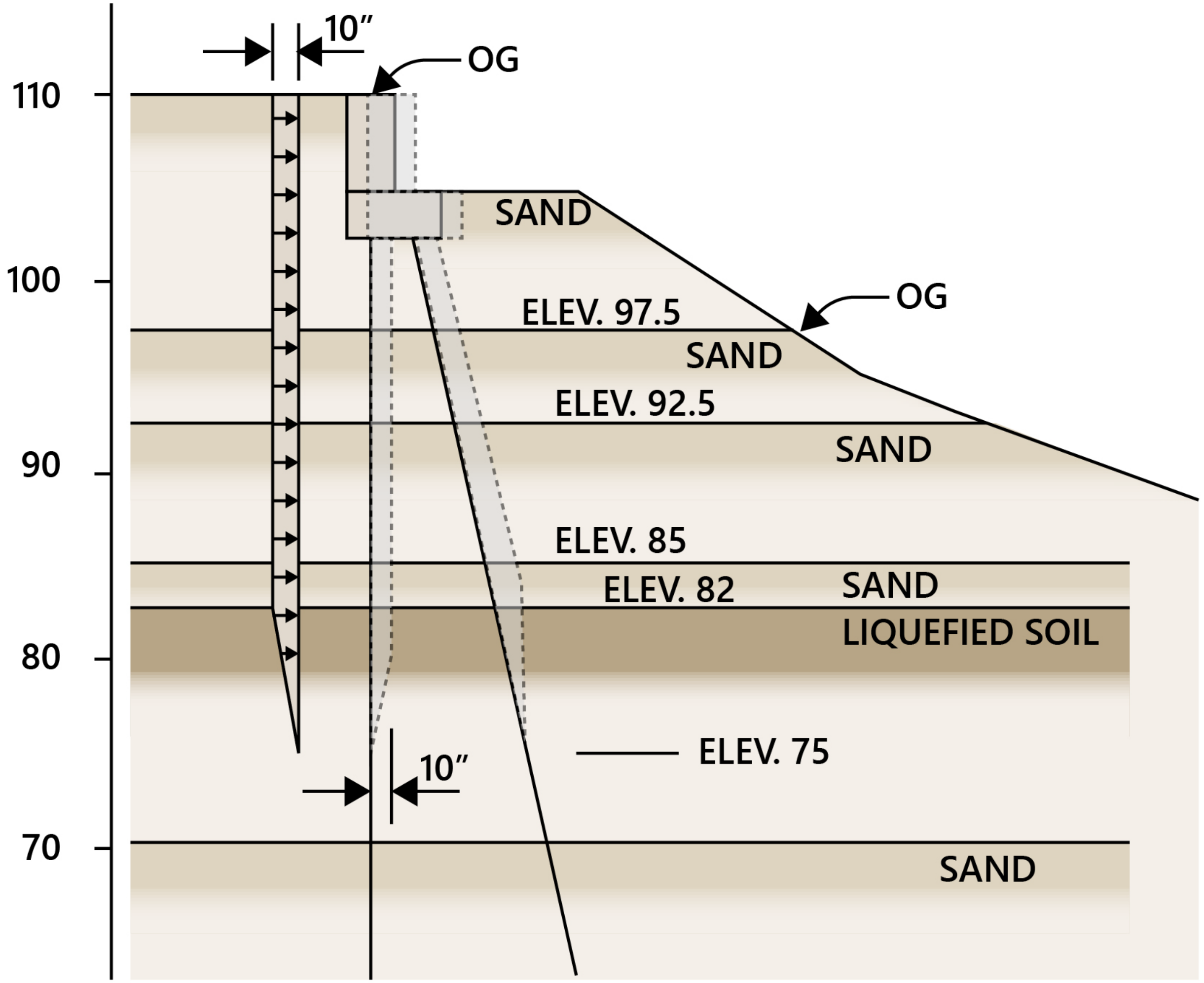

**Figure 8 Lateral spreading of existing piles showing evolution from plastic hinges to pins**

**Table 1 Allowable Drift Capacity of Existing Piles and Shafts for Lateral Spreading**

| Element | Drift Ratio | Comments |
|---|---|---|
| Step Tapered in Steel Shell Piles | 0.05 | Larger capacity allowed through analysis |
| CIDH Piles with reinforcement only in top 10 ft of pile | 0.05 | Larger capacity allowed through analysis |
| Timber Piles | 0.20 | - |
| Driven Precast Piles | 0.20 | - |
| Steel Pipe Piles | 0.20 | Larger capacity allowed through analysis |
| Steel H Piles | 0.20 | Larger capacity allowed through analysis |

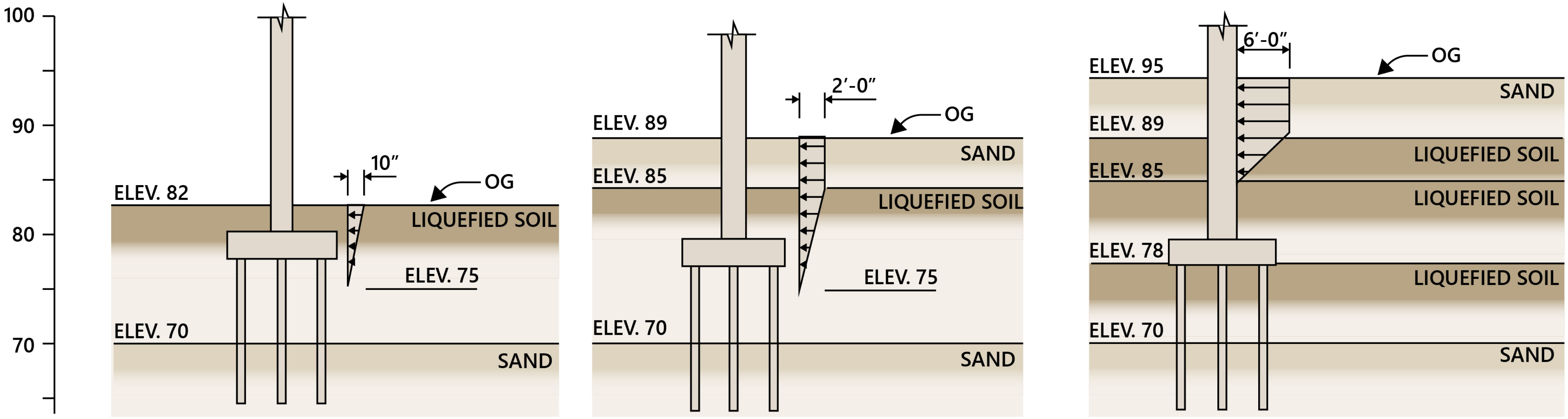
*MTD 20-15, Caltrans, May 2017*

# Eureka Hill – Abutment 1




- Drift is 10″ over 7 ft
- Drift Ratio = 12%
- Allowable Drift = 20%
- Existing piles able to accommodate expected displacement based upon Drift Capacity in MTD 20-15.
- No Retrofit Necessary

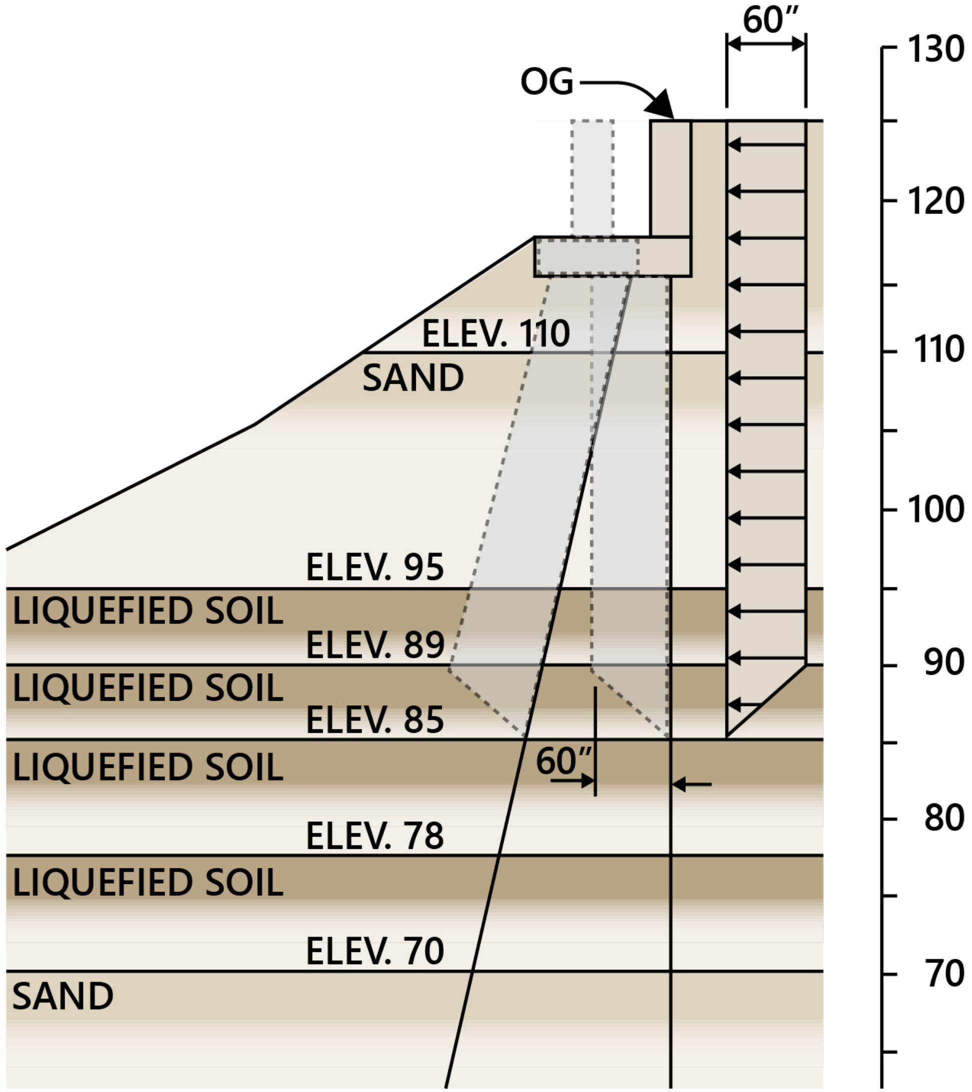
# Eureka Hill – Piers 2, 3 & 4




Checked for Moment and Shear Demand:

- Retrofitted Column
- Pile Cap
- Piles

# Eureka Hill – Abutment 5




- Drift is 60″ over 4 ft
- Drift Ratio = 125%
- Allowable Drift = 20%

- Existing piles will exceed allowable drive ratio based upon Drift Capacity in MTD 20-15.

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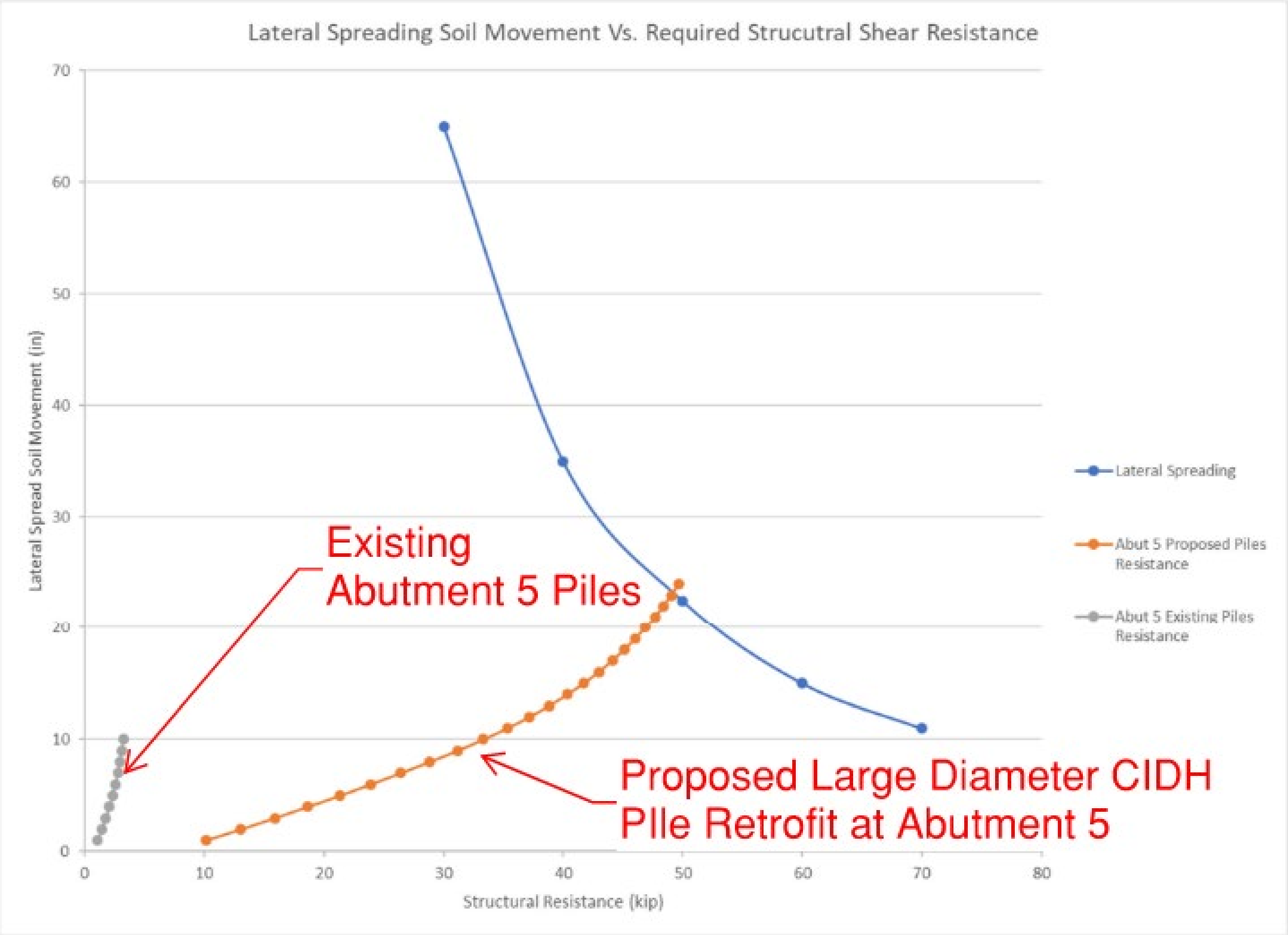
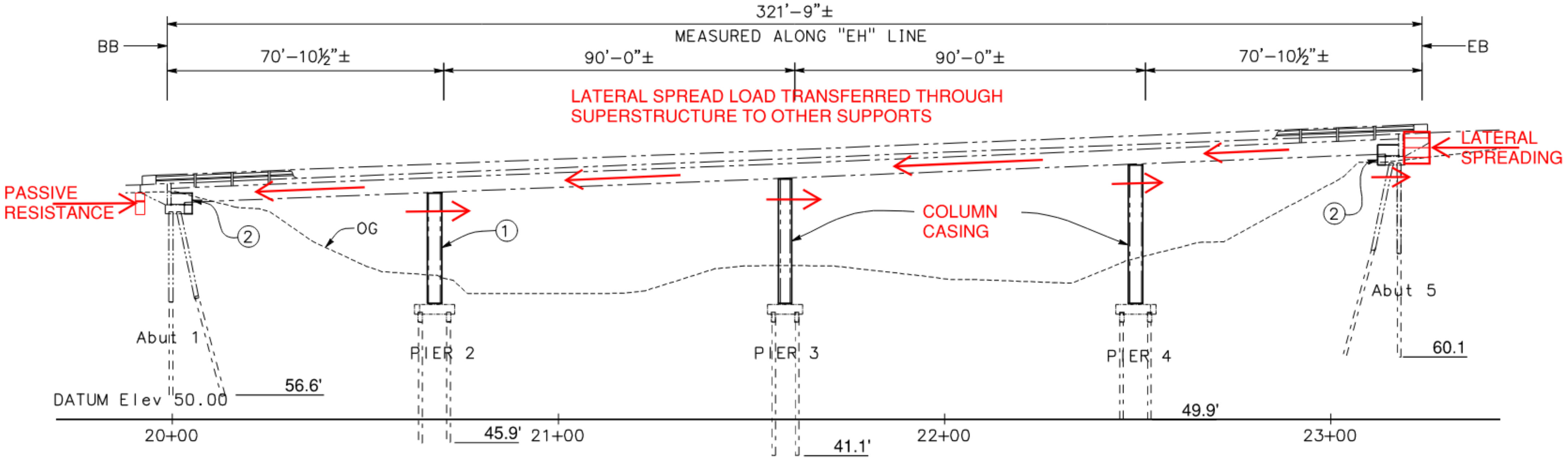
# Eureka Hill – Abutment 5




Initial retrofit strategy:

Add Large Diameter CIDH Piles at Abutment 5 to resist lateral spreading load

# Eureka Hill – Abutment 5




Use resistance from entire structure to resist lateral sliding forces

- Contributions from:
  - Abutment 1 passive resistance
  - Piers 2, 3 & 4 flexural resistance
  - Abutment 5 piles

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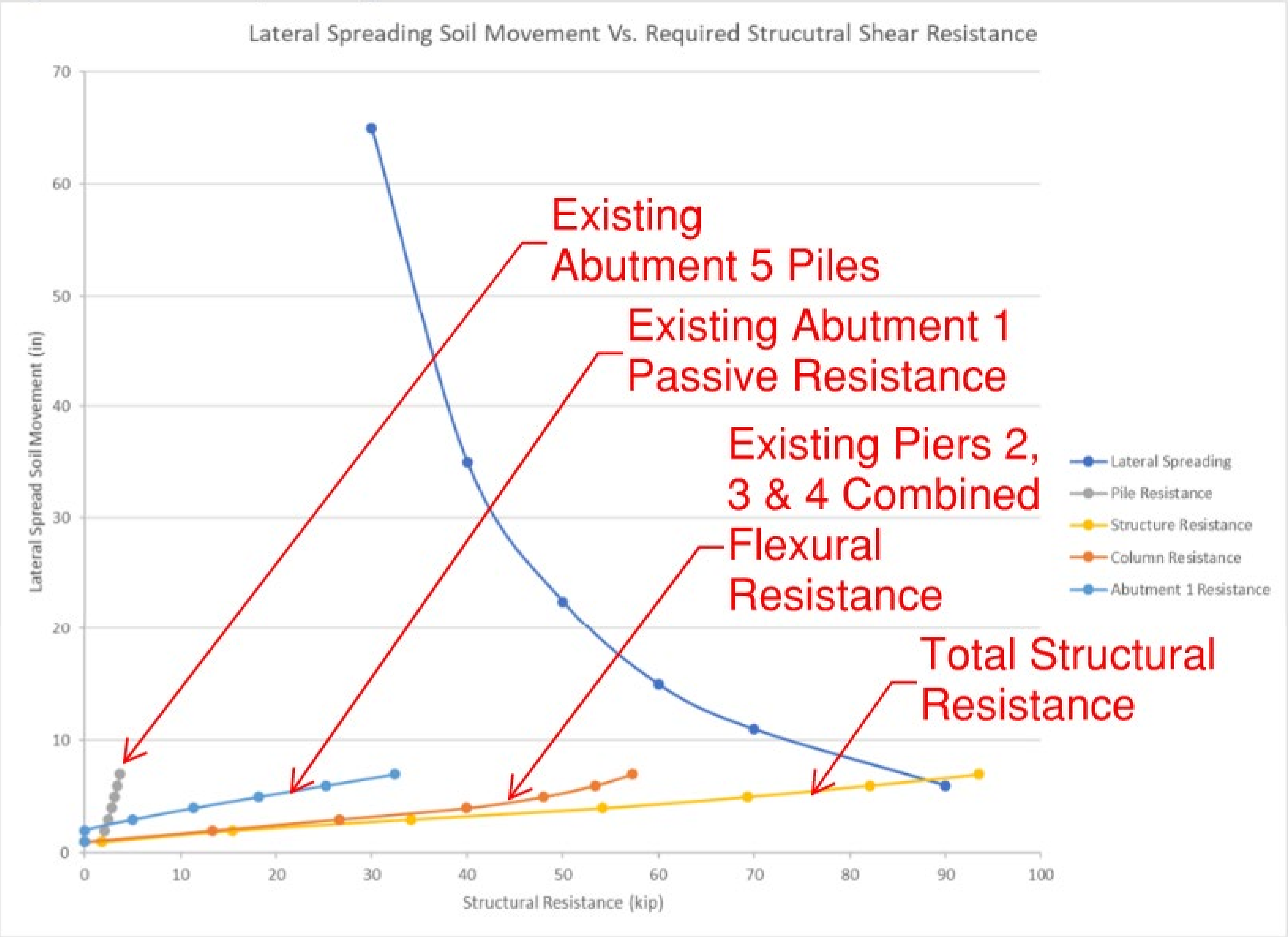
# Eureka Hill – Abutment 5




- Revised retrofit strategy:
  - Use resistance from entire structure to resist lateral sliding forces
    - Abutment 1 passive resistance
    - Piers 2, 3 & 4 flexural resistance
    - Abutment 5 piles
- Eliminates the need for large CIDH piles at Abutment 5
- $500,000 Cost Savings

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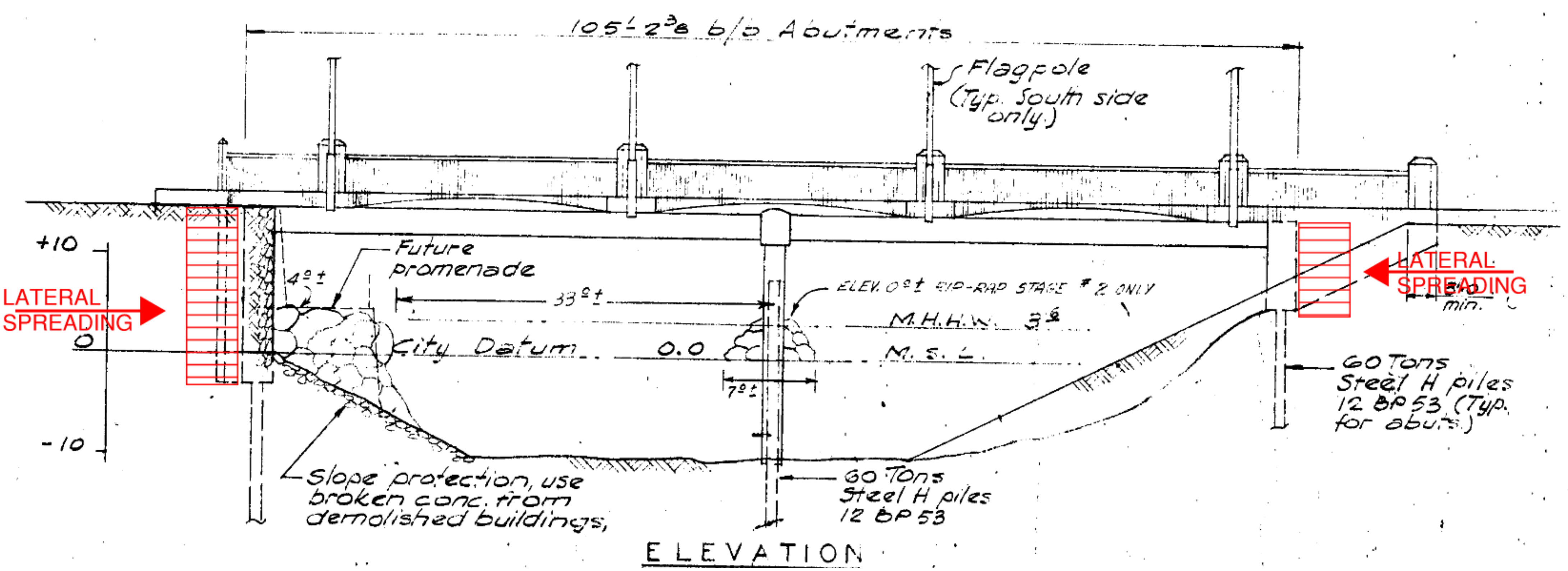
# *Case Study:* Washington Street Bridge over Petaluma River Seismic Retrofit, Petaluma, CA




- 2 inches of Lateral Spreading was predicted at both Abutments

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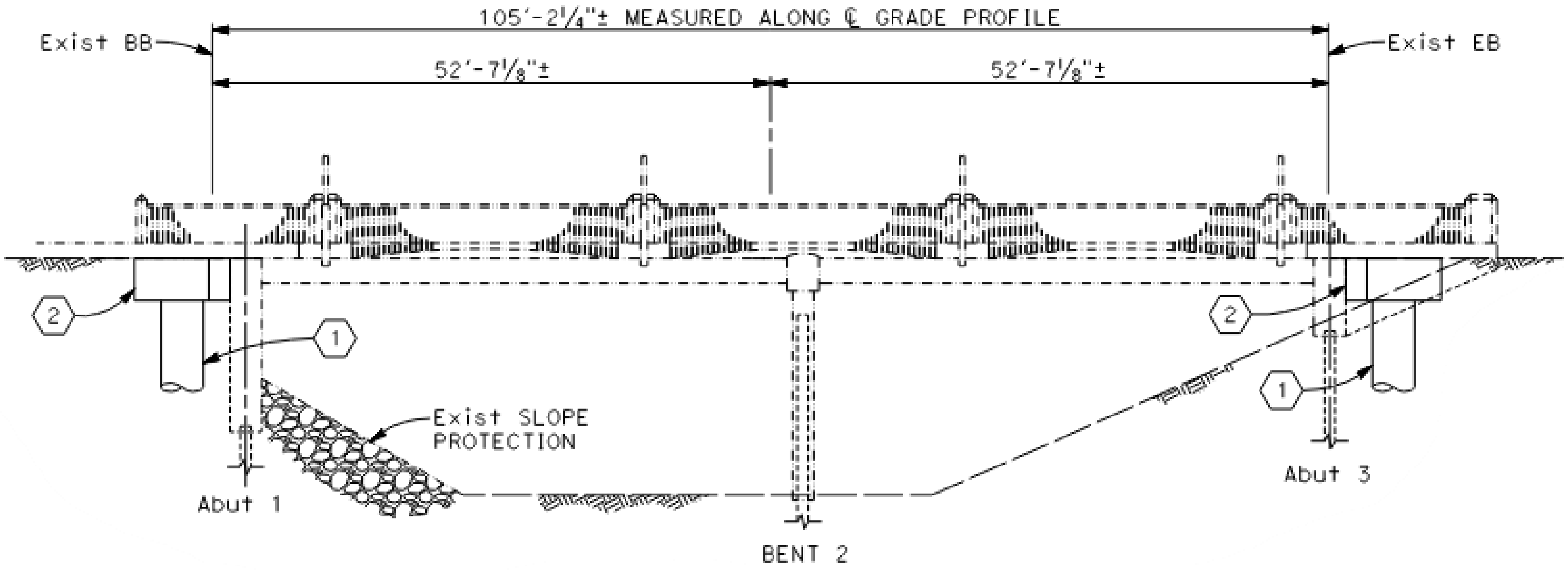
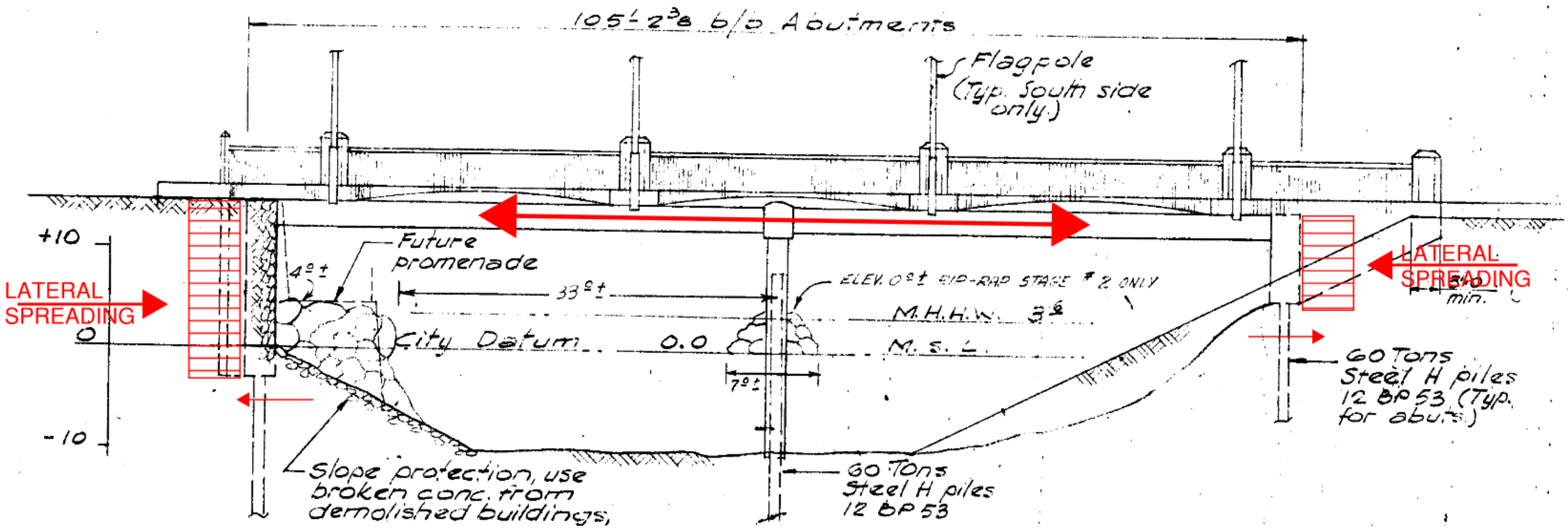
# Washington Street Bridge Original Retrofit



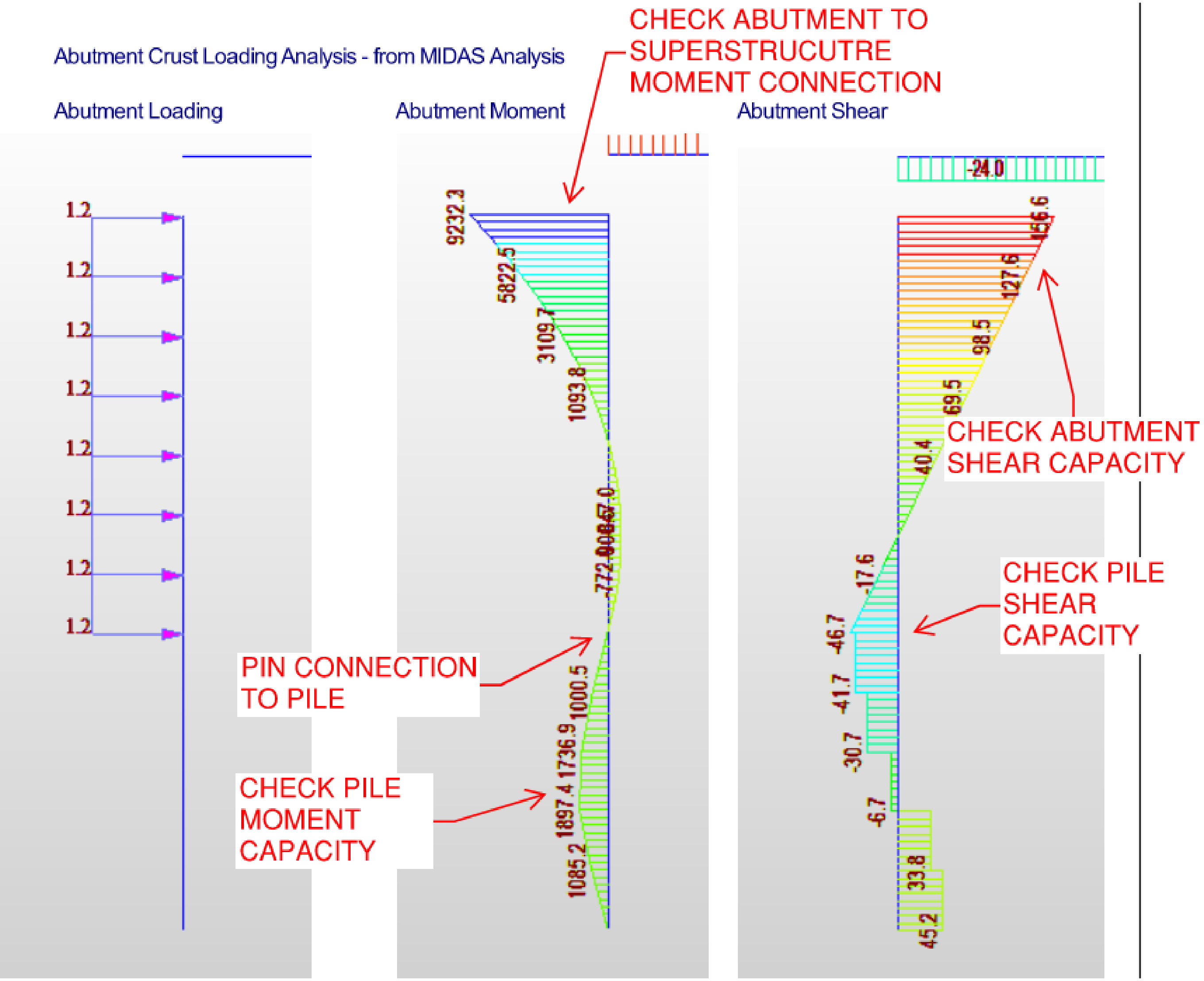

- Large Diameter CIDH Piles at Abutments
- $1 M Construction Cost

# Washington Street Bridge Structure Resistance




- Transfer load through abutments and superstructure to opposite embankment
- Primary resistance from opposite abutment
- $1 M Construction Cost Savings

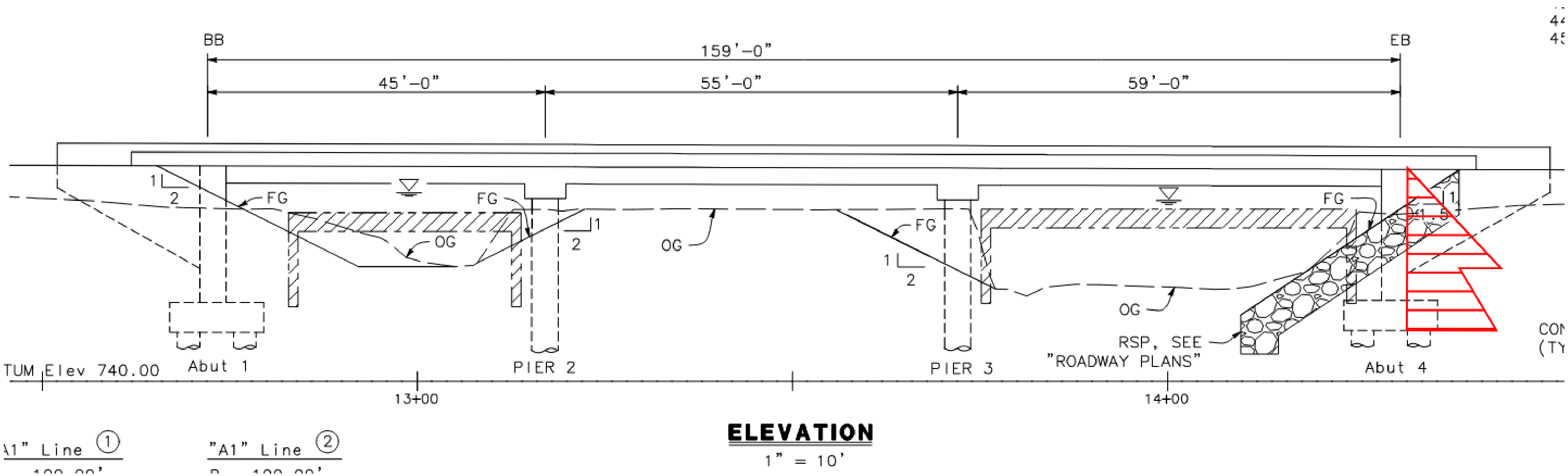
# Washington Street Abutments




Check Abutment Capacity:

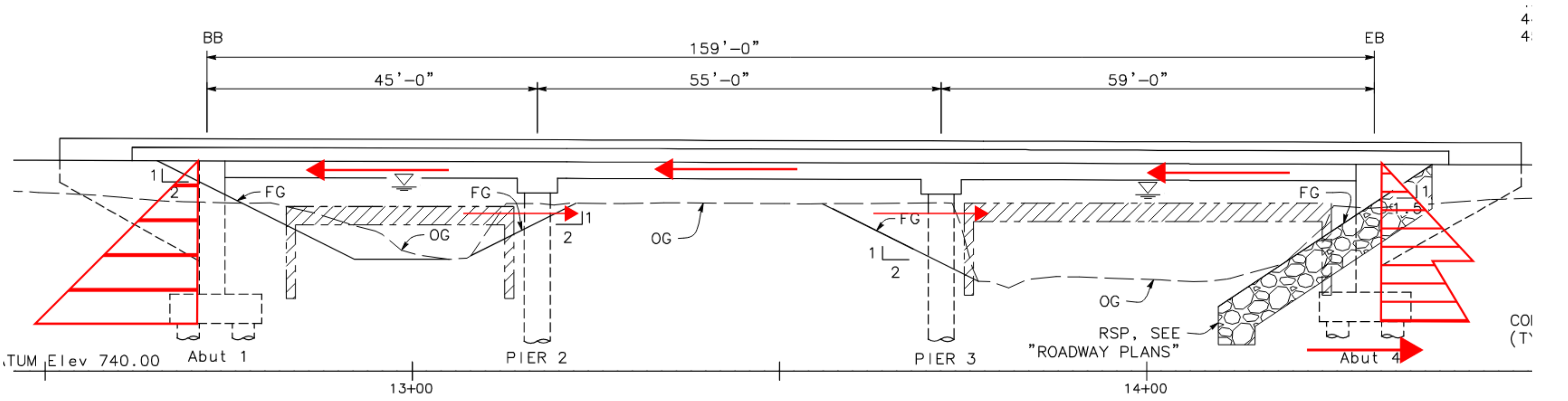
- Transfer loading to single pile foundation & to fixed connection with superstructure

# *Case Study:* Aldercroft Heights Road Bridge over Hooker Creek & Los Gatos Creek, Santa Clara County, CA



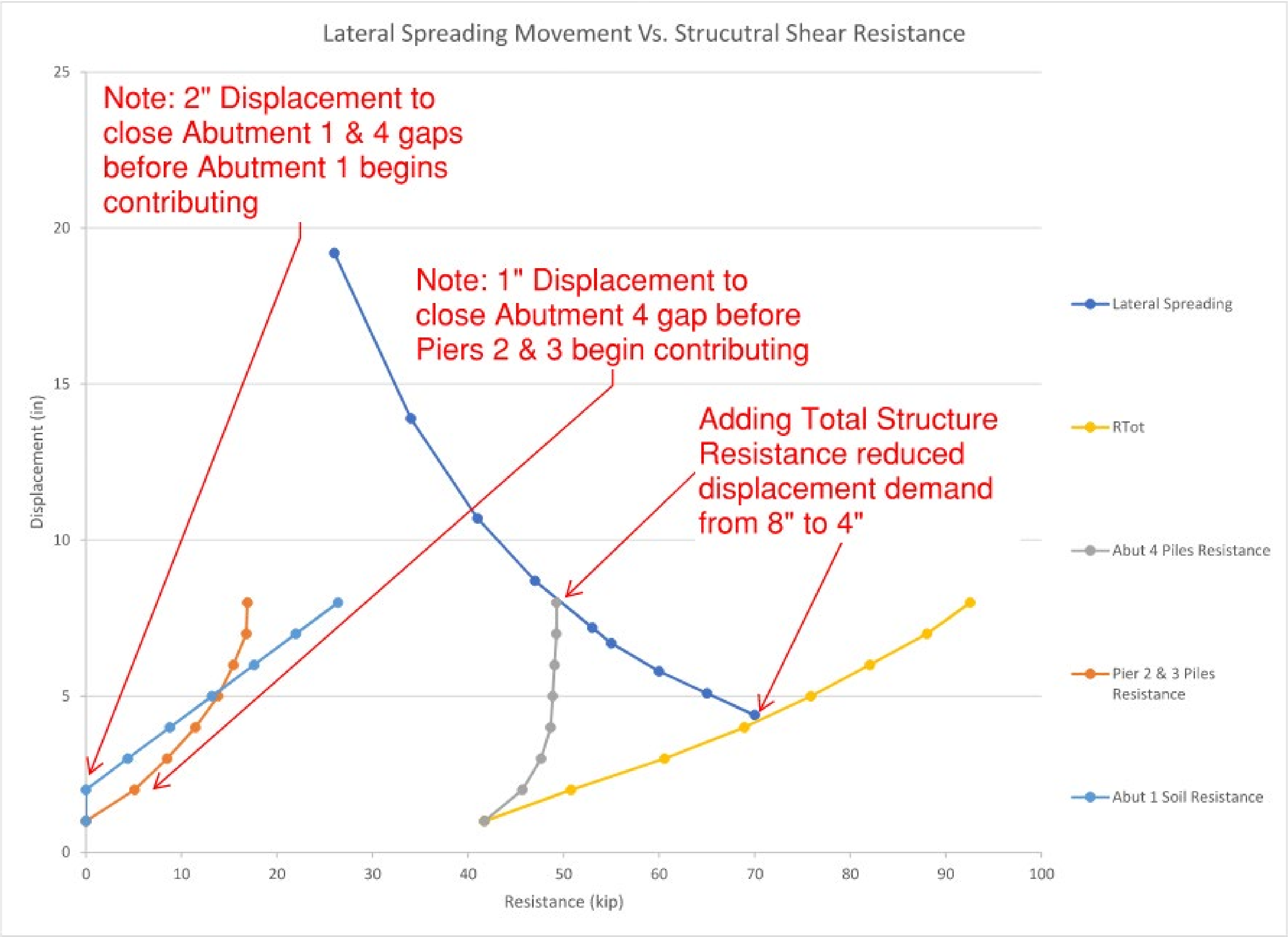

- 20" of Lateral Spreading was predicted at Abutment 4

# Aldercroft Heights Road – Total Structure Resistance




- Resist with total structure
  - Abutment 1 Passive Pressure
  - Pier 2 & 3 Flexural Resistance
  - Abutment 4 Pile Resistance

# Aldercroft Heights Road – Abutment 4




- New Structure must meet SDC ductility limits
- Total structure resistance reduces deflection of Abutment 4 piles from 8″ to 4″

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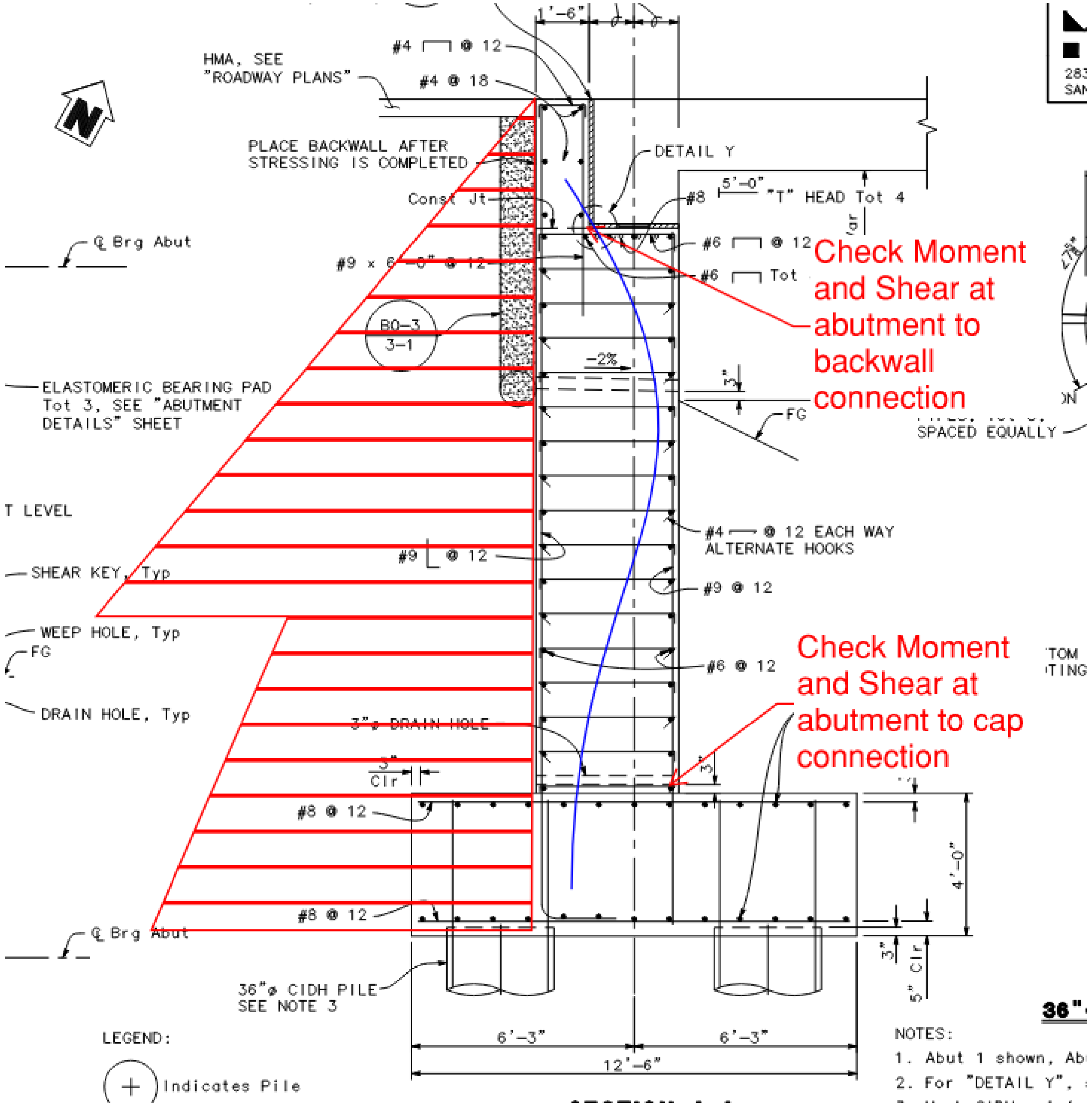
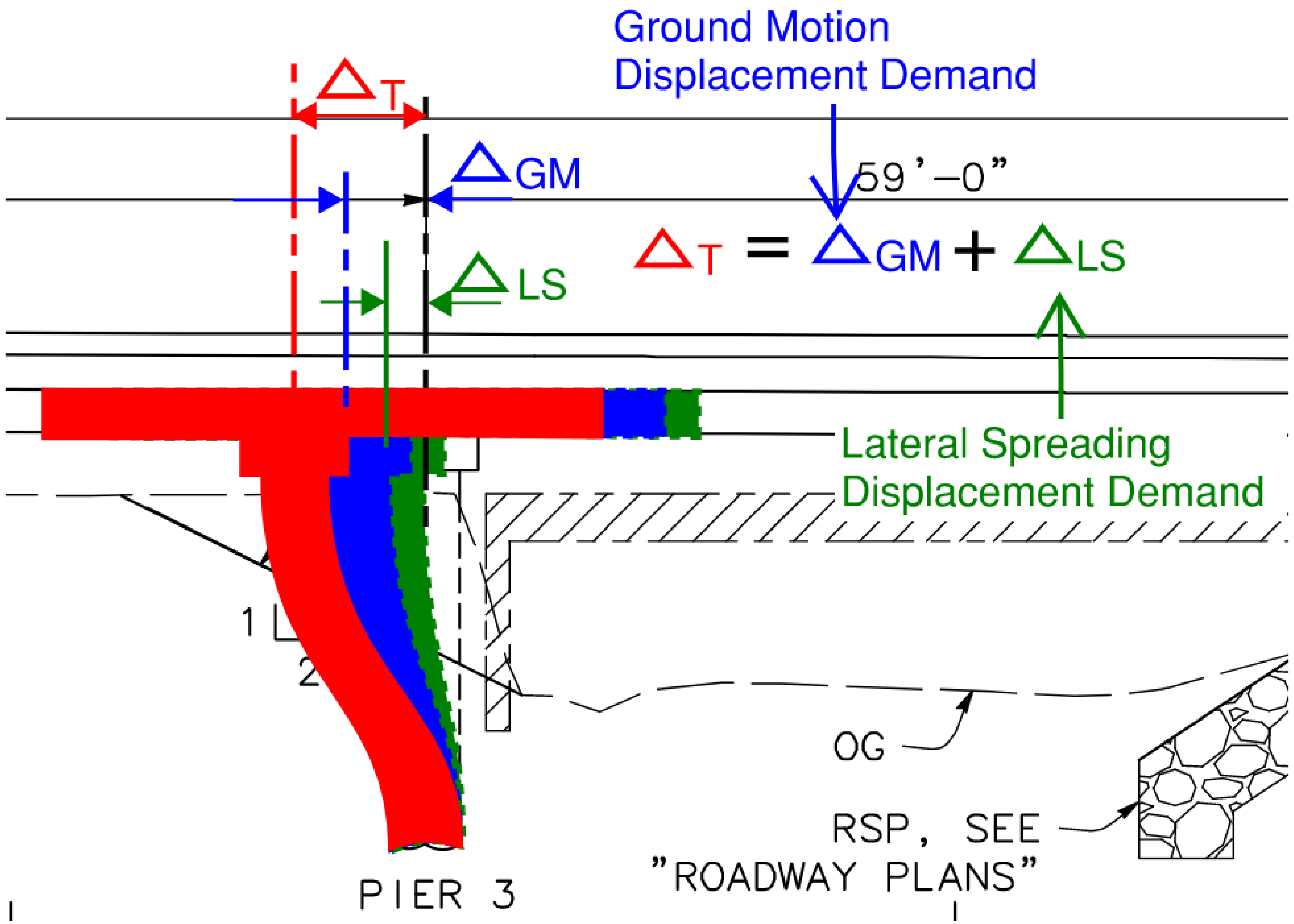
# Aldercroft Heights Road – Abutment 4




Check Abutment Capacity:

- Transfer Loading to Pile Cap
- Transfer Loading to Backwall

# Aldercroft Heights Road – Piers 2 & 3




- New Structure must meet SDC displacement ductility limits
- Add Ground Motion longitudinal displacement to Lateral Spreading displacement

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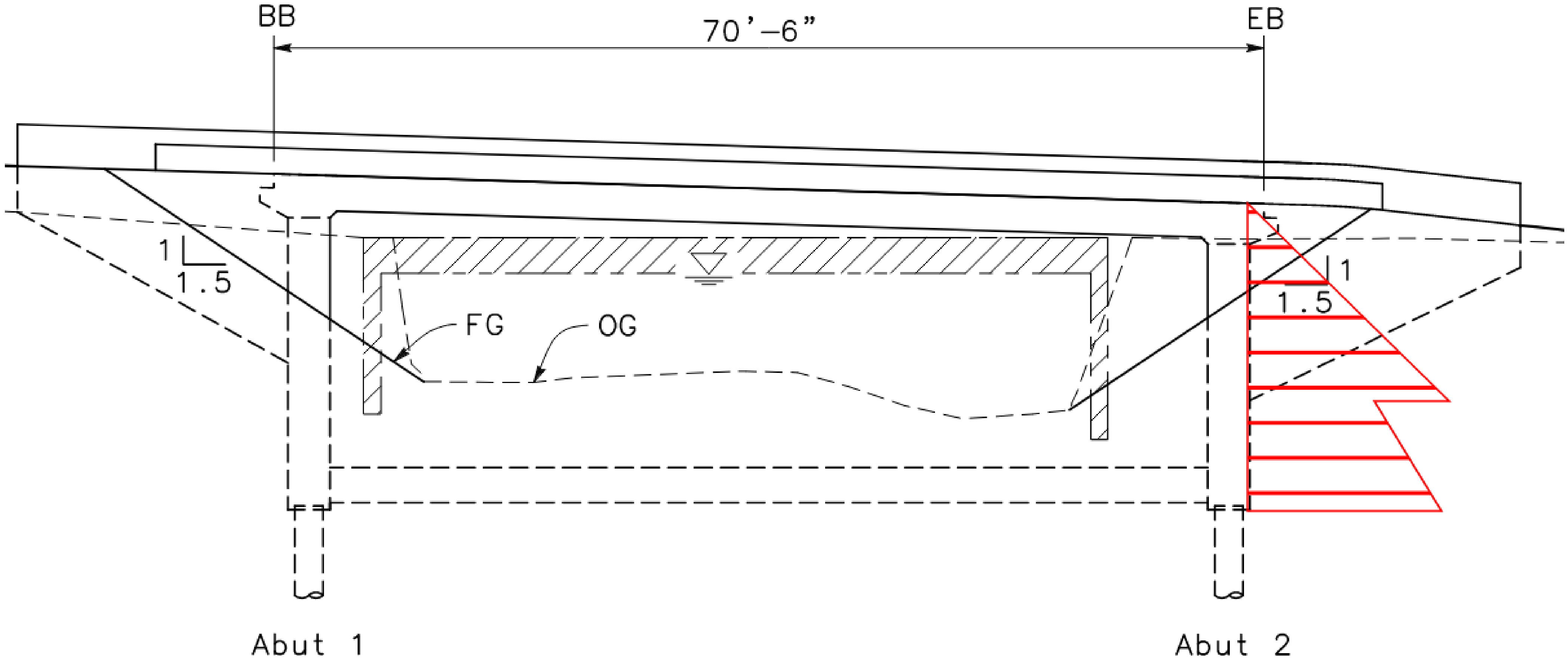
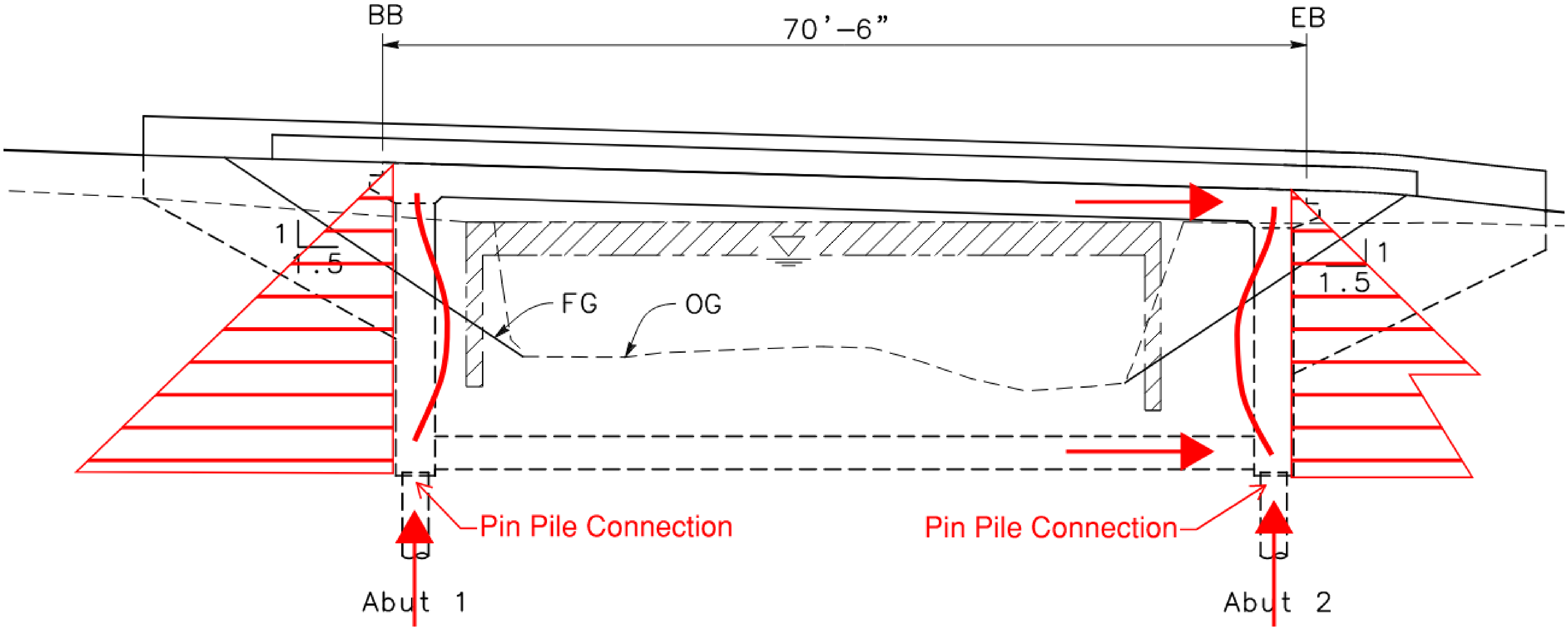
# Aldercroft Heights Road – Abutment 2




- Lateral Spreading was predicted at Abutment 2

# Aldercroft Heights Road – Abutment 2




- Use Grade Control Sill Beams in Creek & Superstructure to transfer loading to Abutment 1 and resist with Passive Pressure
- Piles only required to resist vertical loading

# Summary

**Designer should account for total resistance of bridge structure to resist lateral spreading**

- Include column resistance
- Include passive pressure from opposite abutment

**Existing Structures**

- Allow piles to hinge
- Check displaced piles for their ability to continue to carry vertical loading

**New Structures**

- Increase foundation flexibility to allow deflection
- Reduces lateral spreading force demands
- Allows other components to help resist lateral spreading demands

# Questions?

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