Design & Constr. Complexities of Yerba Buena Island Transition Structures for SFOBB - East Spans

Authored by: Robert Dameron; Gernot Komar; Al Ely; Tony Sánchez; Jal Birdy; Brian Maroney

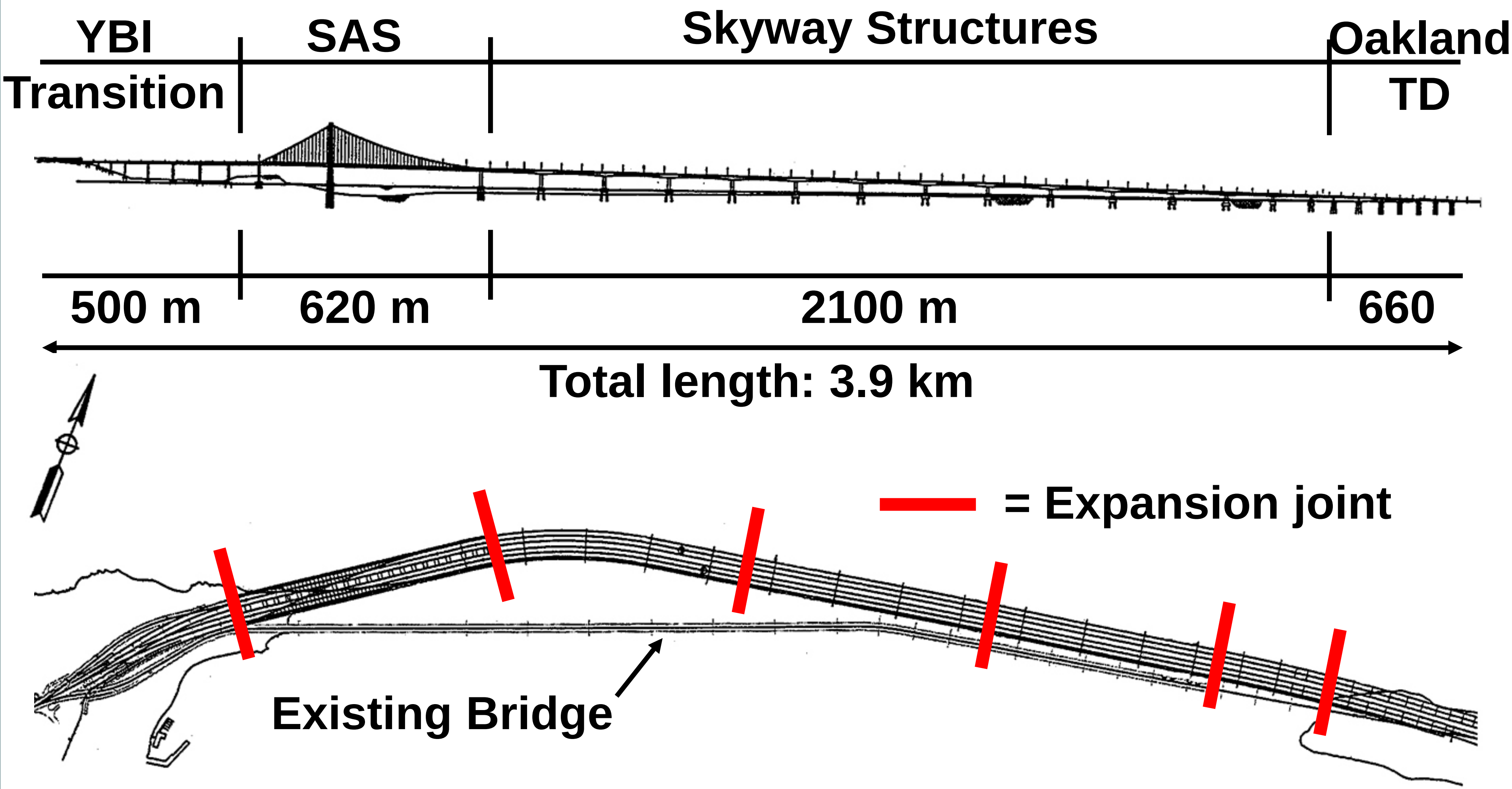
Presented by: Robert Dameron

Western Bridge Engineers Seminar

Sept. 10, 2015

T.Y. LIN INTERNATIONAL
MOFFATT & NICHOL ENGINEERS
a joint venture

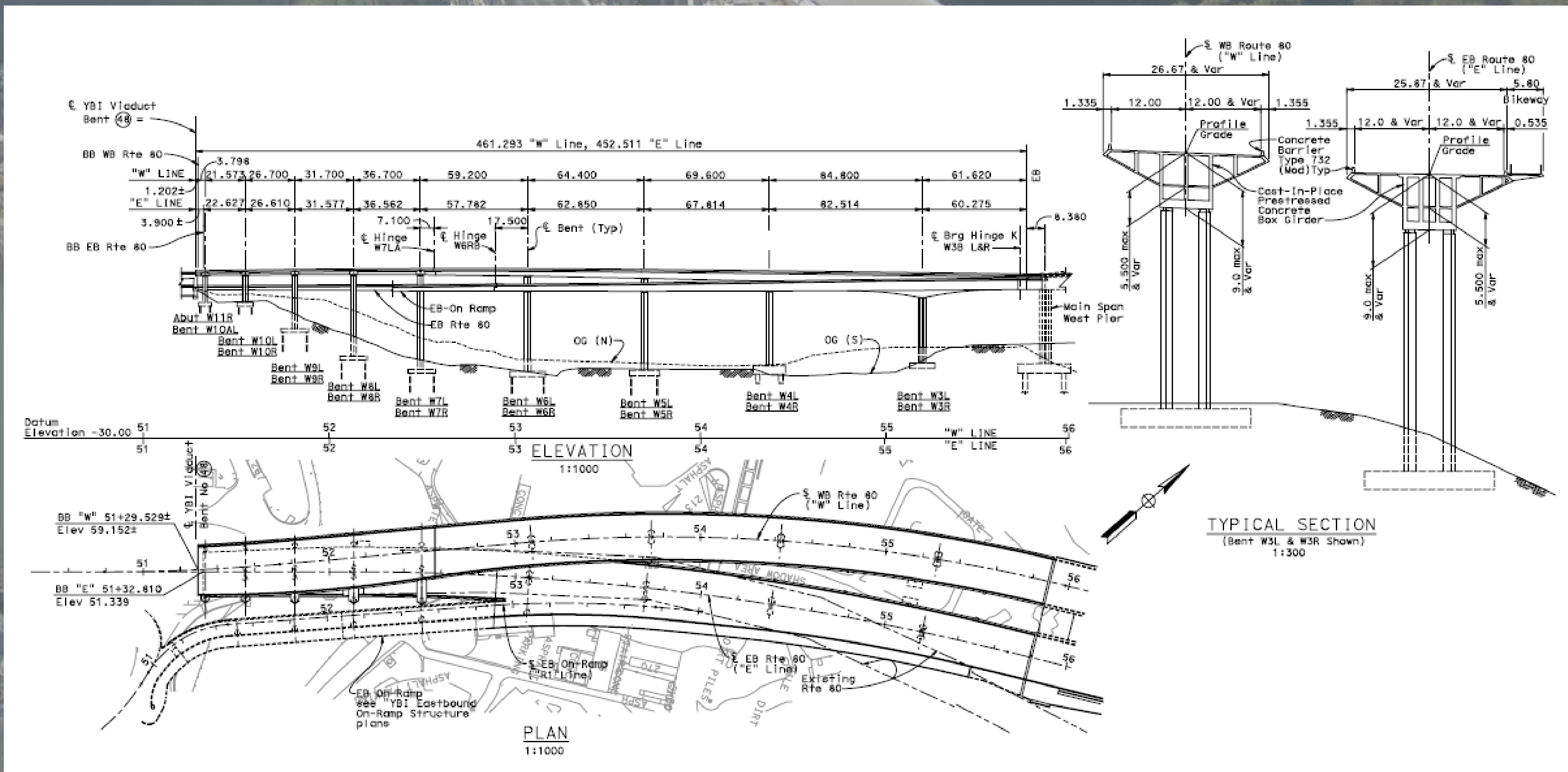
SFOBB East Span Segments



Yerba Buena Island Transition Structure: Geometry Challenges

- Deck Heights: 3m to 51m
- Westbound Transition
  - 460 meters; 2 Frames
  - Frame 1:
    - Conventional Reinforced Concrete
    - Spans are 21.6m to 36.7m
  - Frame 2:
    - Post-tensioned Concrete
    - Spans are 59.2m to 84.8m
- EB and WB transition from Parallel to Double-Deck Structures
- Outrigger Bents

YBITS – Plan & Elev.

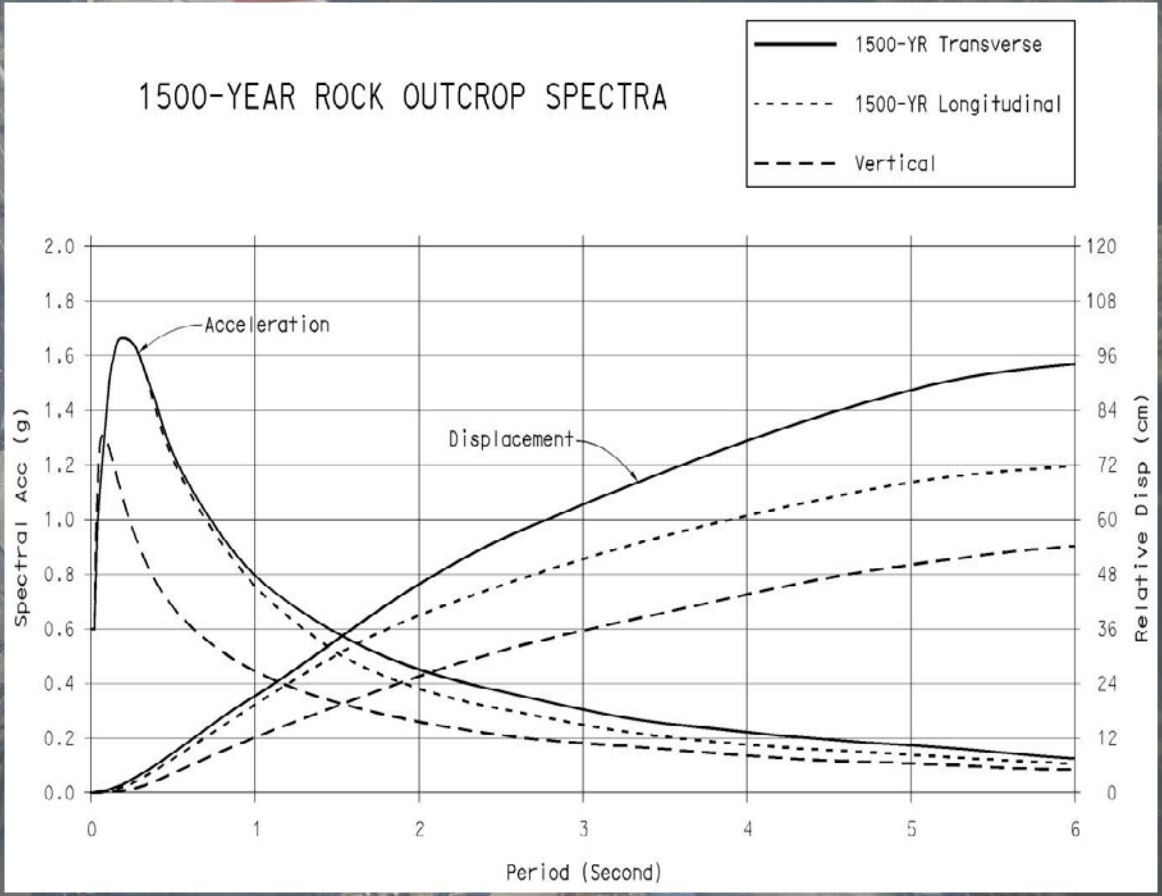


T.Y.LIN INTERNATIONAL
MOFFATT & NICHOL ENGINEERS
a joint venture

Seismic Design Criteria and Expected Performance

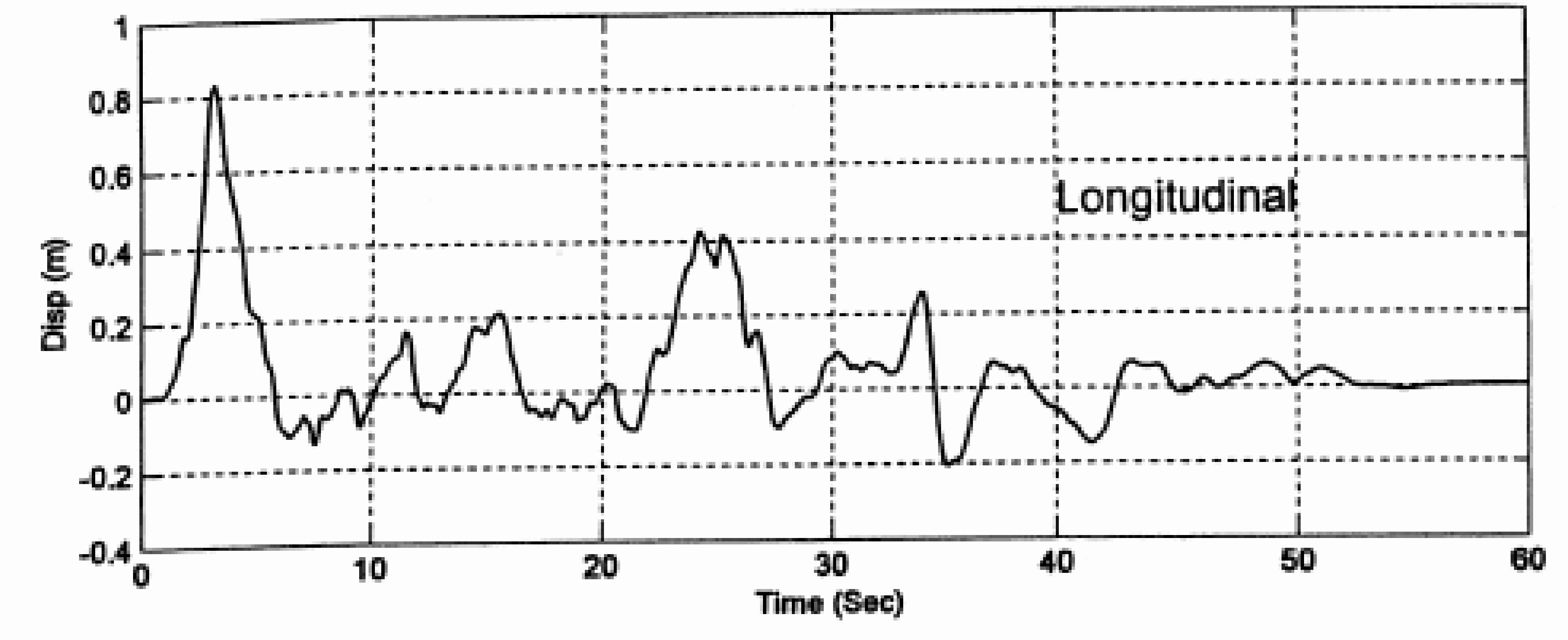
Two Levels of Ground Motions

1. Functional Evaluation Earthquake (FEE):
   - 92 yr return period or
   - 80% probability of exceedance in 150-year design life
2. Safety Evaluation Earthquake (SEE):
   - 1500 yr return period or
   - 10% probability of exceedance in 150-year design life



T.Y. LIN INTERNATIONAL
MOFFATT & NICHOL ENGINEERS
a joint venture

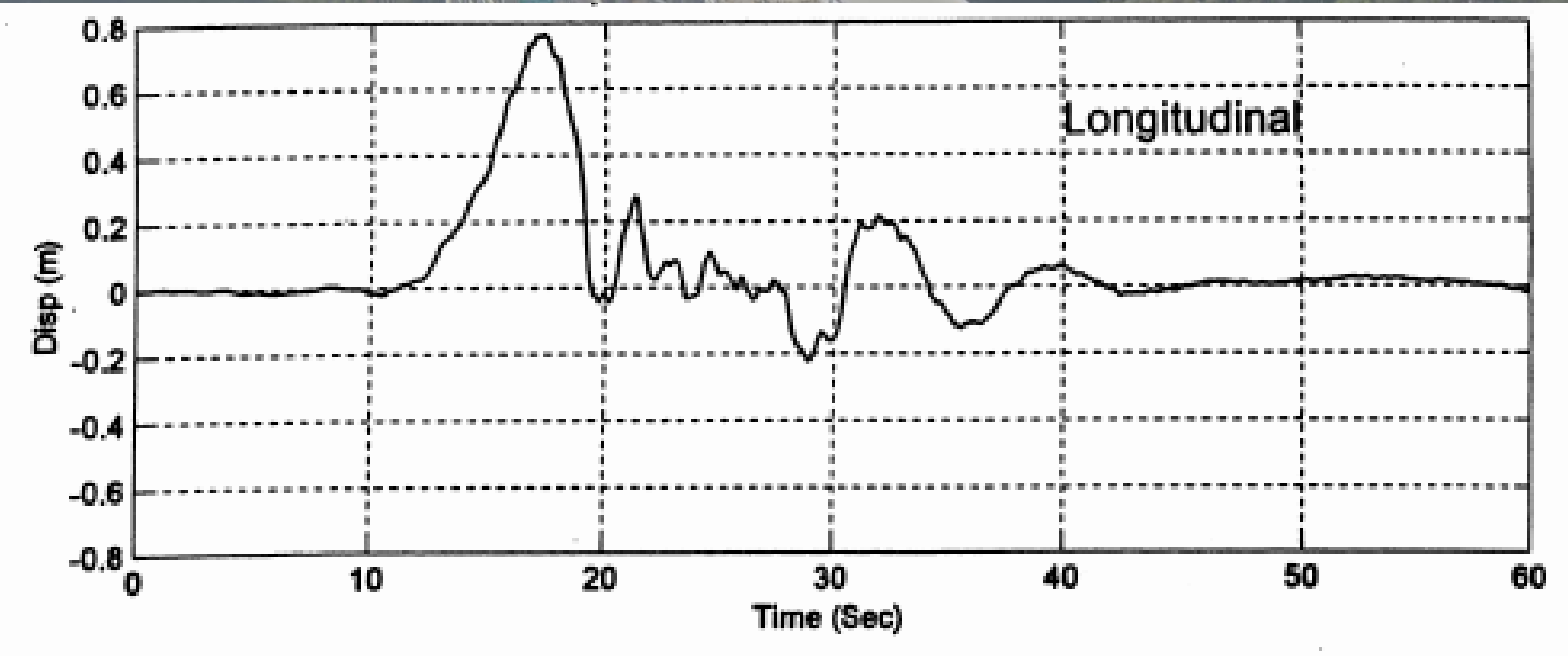
YBITS Time History Sample: Longitudinal Ground Displacements at West Pier- Set No. A1



Six sets of ground motion time histories, three postulated from Hayward Fault and three from San Andreas (prepared by the Fugro-EMI Joint Venture) were applied in the structure design

T·Y·LIN INTERNATIONAL
MOFFATT & NICHOL ENGINEERS
a joint venture

YBITS Time History Analysis: Longitudinal Ground Displacements at West Pier- Set No. 2



T-Y-LIN INTERNATIONAL
MOFFATT & NICHOL ENGINEERS
a joint venture

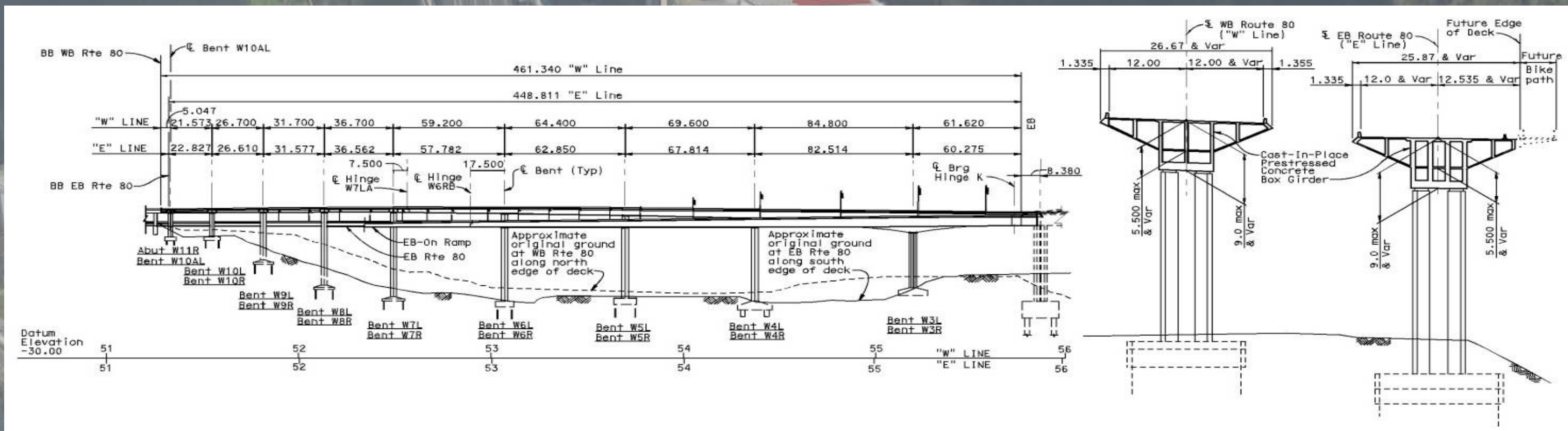
FEE Event – Perf. Criteria

- All Structure Elements to perform essentially elastically and have minimal impact between structure frames
- FEE design limits:
  - Column Concrete Strain: 0.004
  - Primary Reinforcement Strain: 0.015
- Strength Reduction Factor: 1.0

SEE Event – Perf. Criteria

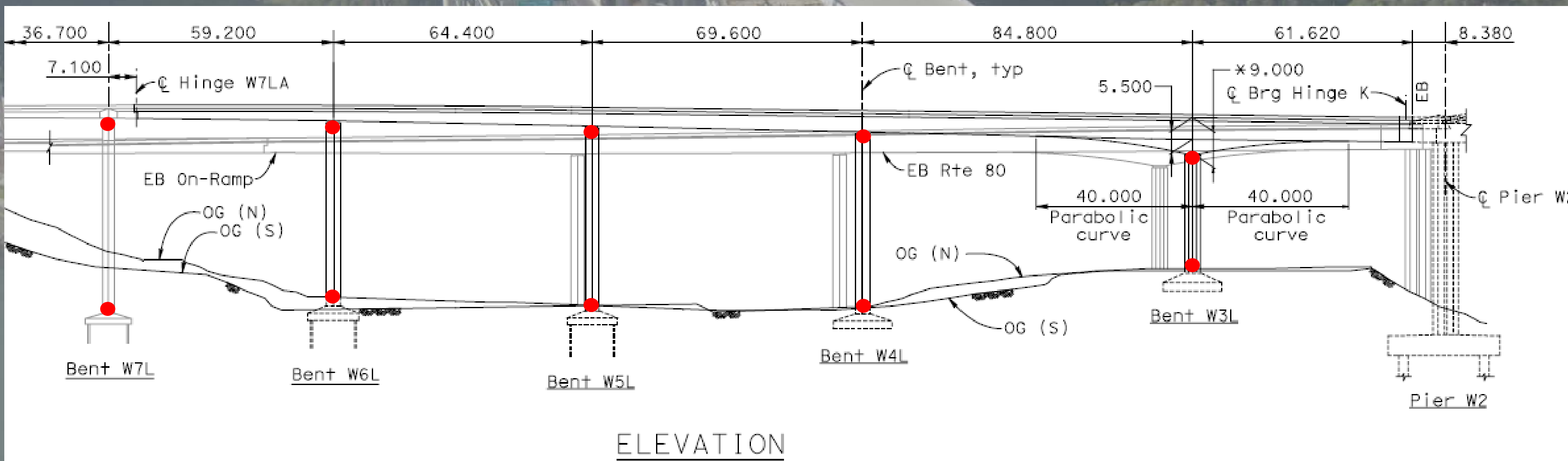
- All Structure Elements except Columns remain essentially elastic; impact between frames is expected but unseating of hinges and abutments not allowed
- Columns
  - Ultimate Strain in Columns Primary Reinforcement
    - 0.12 (confinement bars #13 - #25)
    - 0.09 (main bars #29 - #57)
  - Relative Displacement Demands: 80% of calculated capacity
  - Column Shear Capacity: SDC - 1999
- Superstructure, Bent Caps & Column Footings
  - Maximum Moment induced by columns

Site Challenges



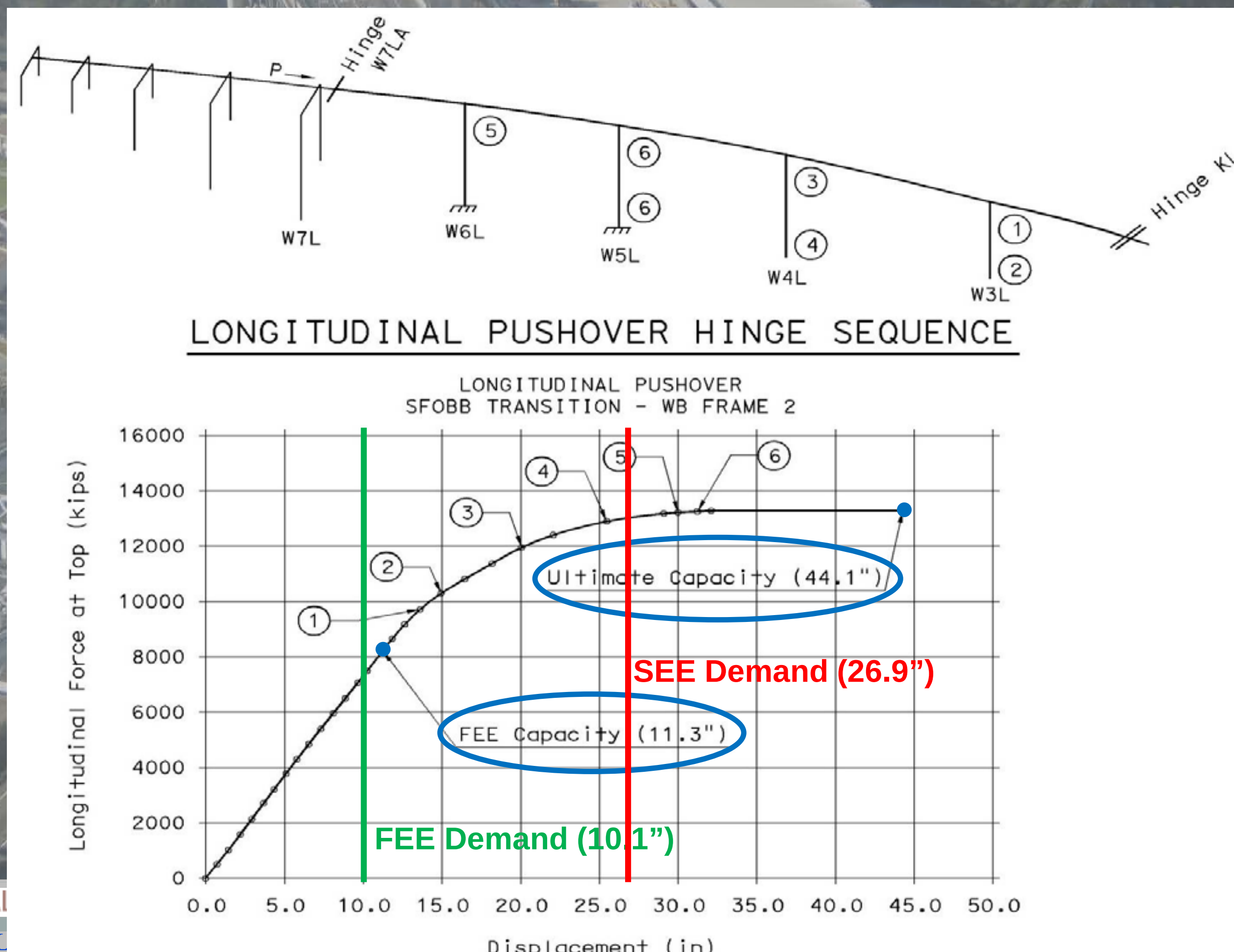
- Steep Inclines
- Steep Cross-slopes
- Varying Soil Conditions Along Length
- Connect Hinge K to SAS Main Span-West Pier

YBITS – Westbound Frame 2 Ductile System with Plastic Hinging



Analysis and Design Overview: Substructure

- Pushover Analyses: Column Transverse & Longit. Displacement Capacities
- NASTRAN: Longitudinal behavior of the frame

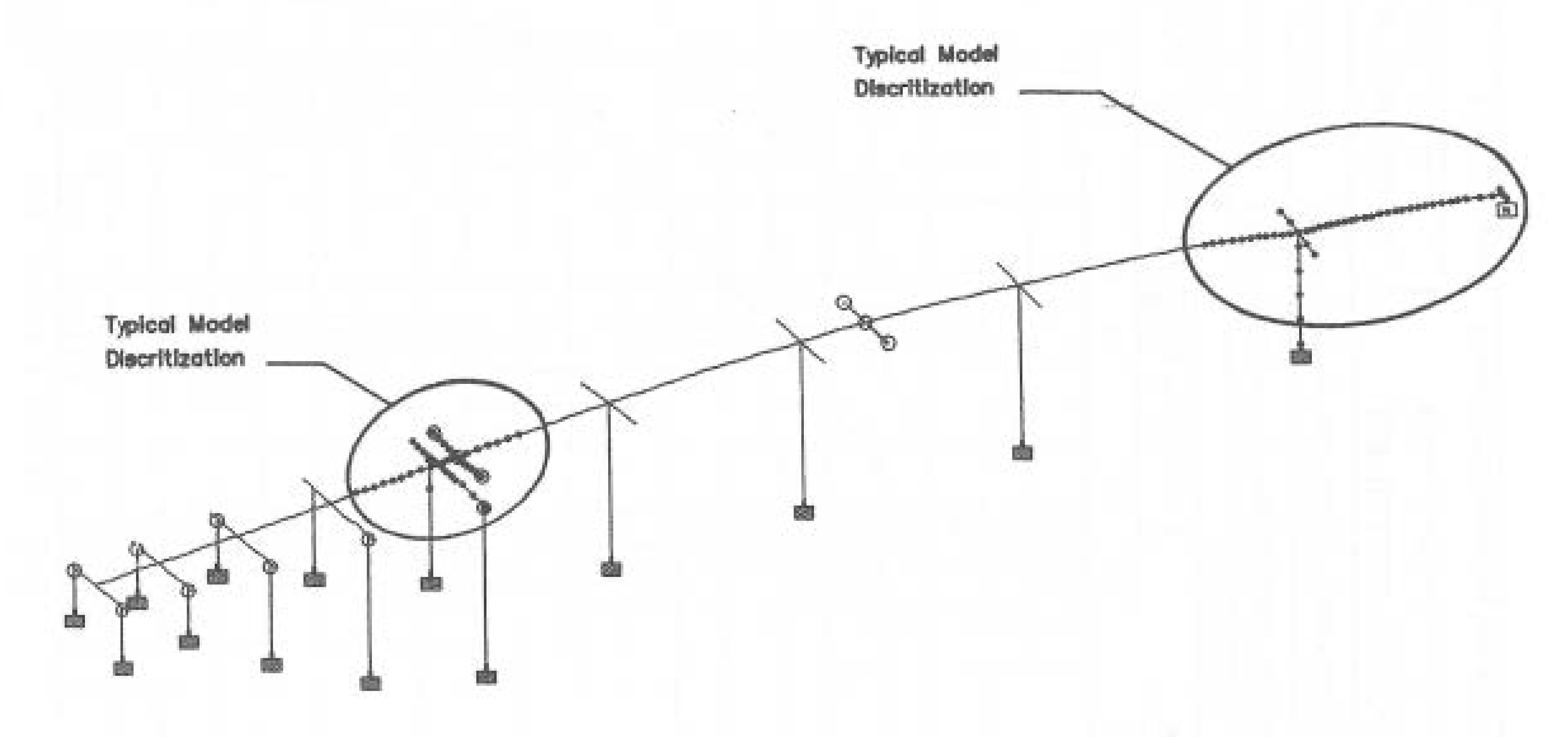


T.Y.LIN INTERNATIONAL
MOFFATT & NICHOL ENGINEERS

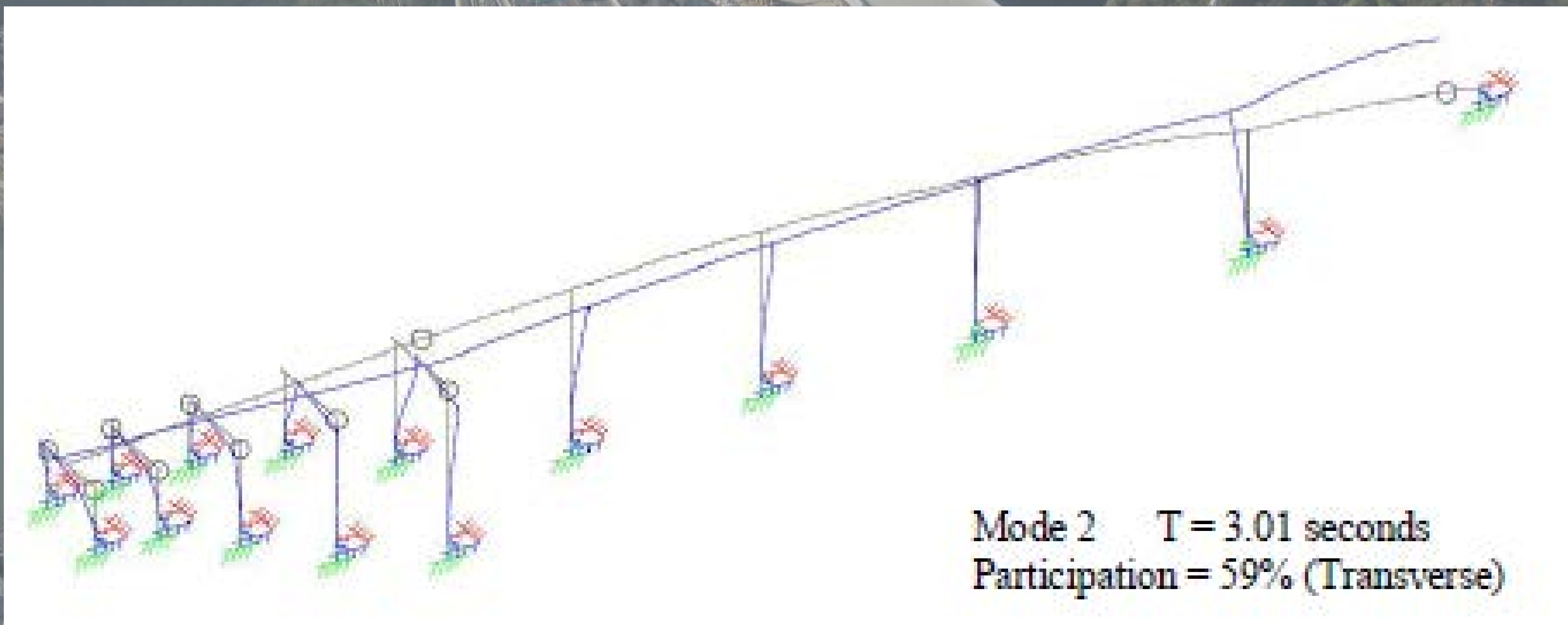
Response Spectrum Analysis

- mass distribution well discretized to nodes
- Releases between adjoining frames at hinges
- Linear Fdn. Springs to represent fdn. flexibility
- Both “tension” and “compression” models analyzed
- 1st Period WB: 3.32 sec (long); 3.01 sec (transv.)
- Peak Displacement WB: 26 in (long); 28 in (trans)

YBITS – Westbound Response Spectrum Analysis

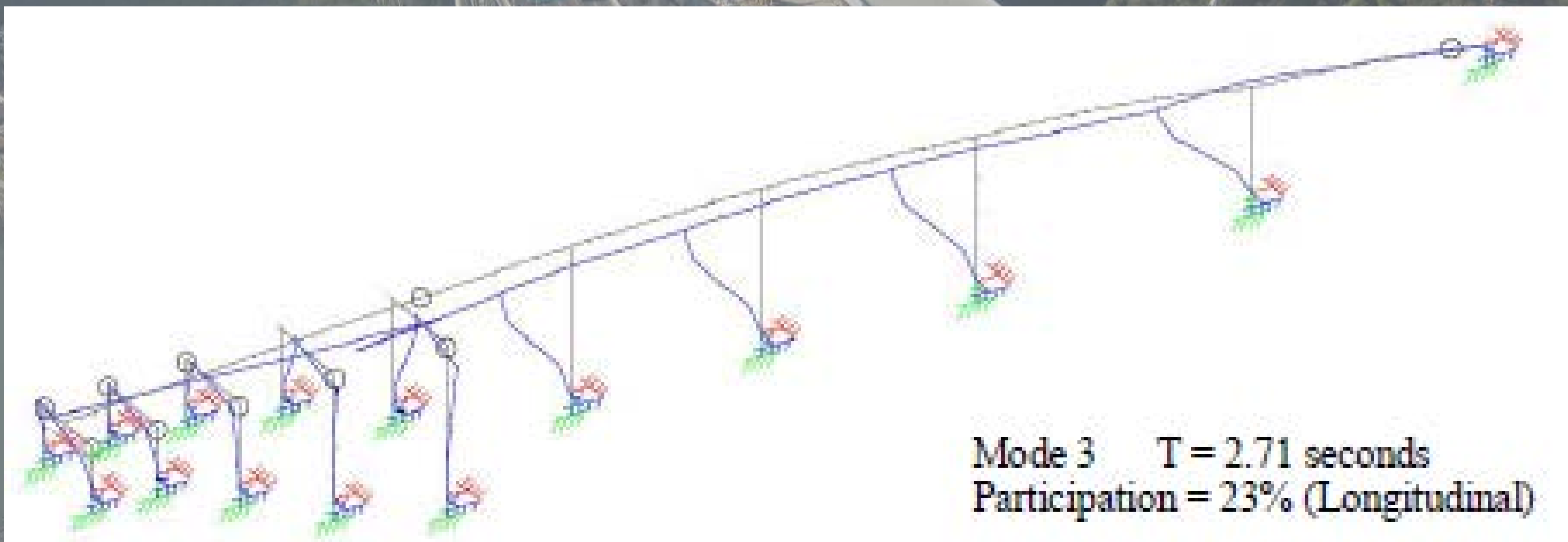


YBITS – Connected Westbound Structure Response Spectrum Analysis Mode Shapes

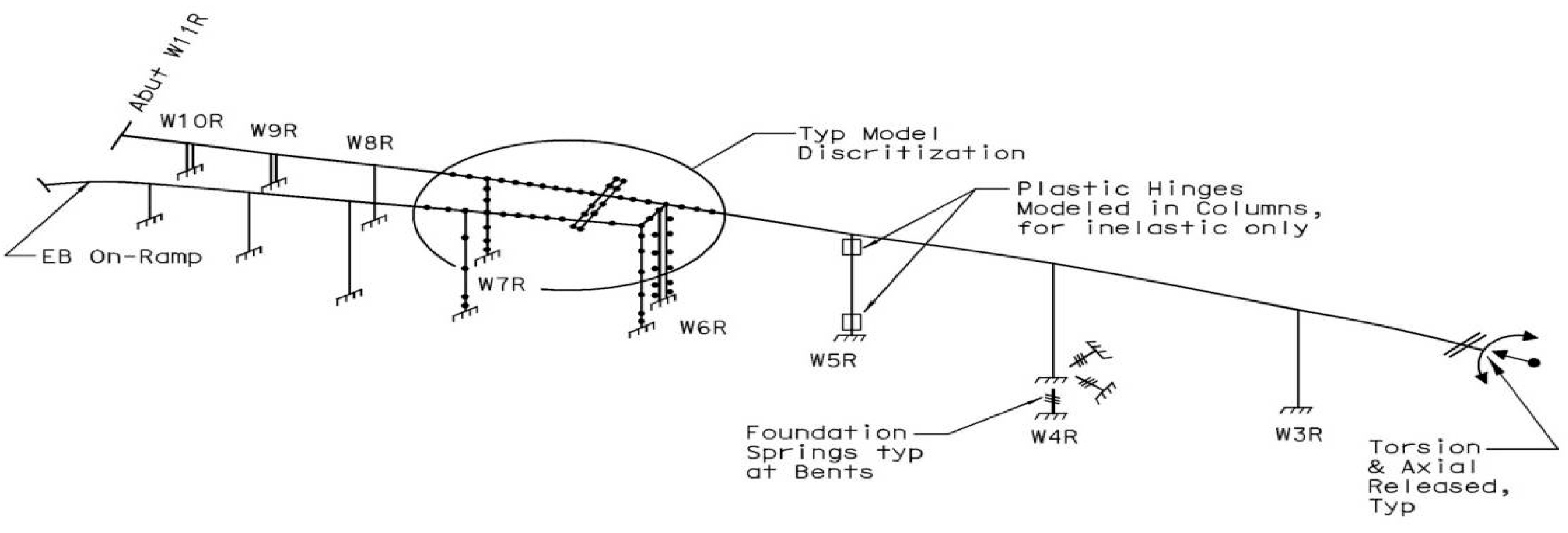


T.Y.LIN INTERNATIONAL
MOFFATT & NICHOL ENGINEERS
a joint venture

YBITS – Connected Westbound Structure
Response Spectrum Analysis
Mode Shapes



- NASTRAN Model used for Elastic and Inelastic Time History Analysis
- Average Peak Demands to Capacity Displacement Ductility Ratios of 1.8
  - Tall Piers ~1
  - Short Piers Max 4.2 (Transv. Direction) WB and 5.4 EB



EB STRUCTURE

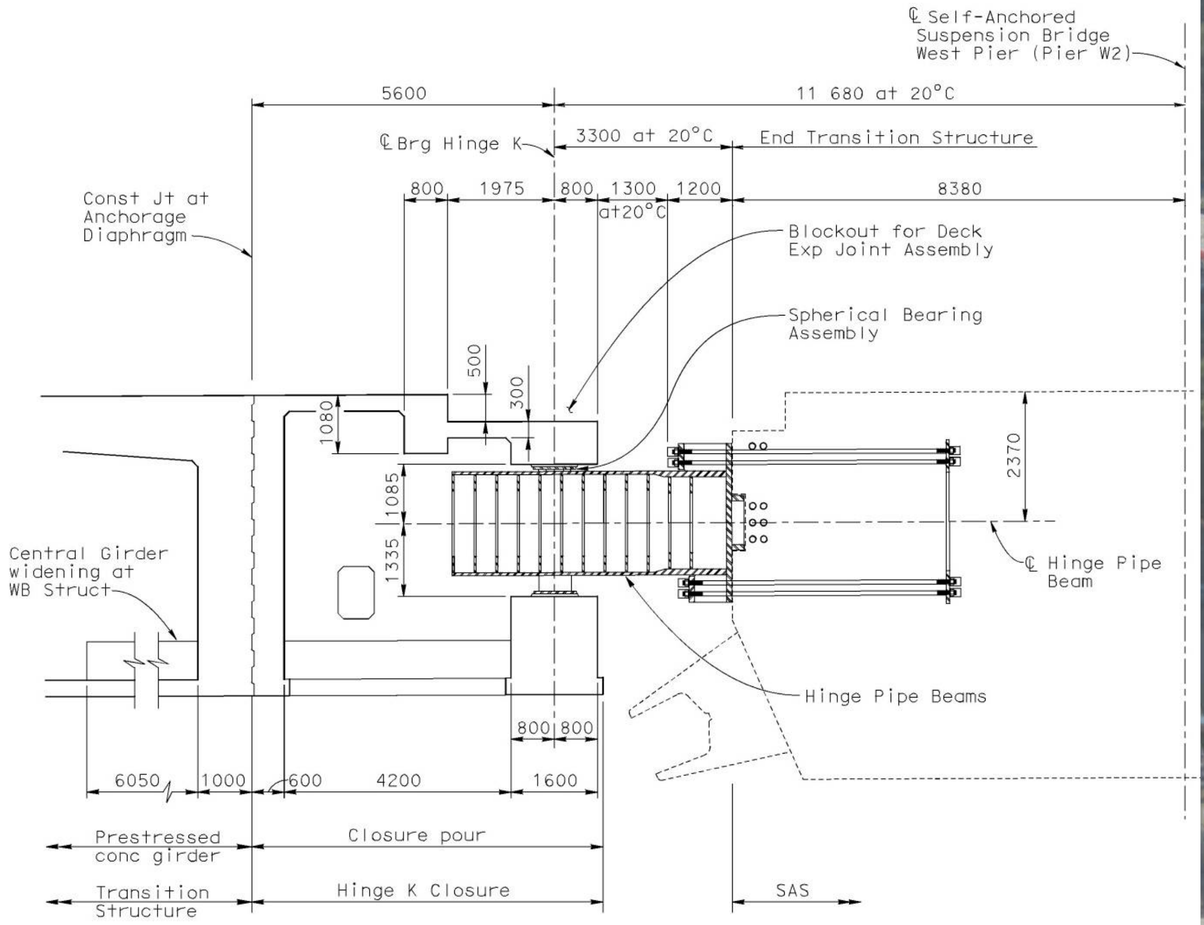
Analysis and Design Overview: Superstructure and Hinges

- Modular Expansion Joints:
  - FEE Event: Fully Functional
  - SEE Event: Beyond normal operating range resulting in tearing or parting of flexible seals
  - Used Between Frames 1 & 2 and ramps
- State Developed Joints w/ Steel Bridging Plates:
  - SEE Event
    - Bridging Plates Maintain Bearing
    - Seat Width allows full movement
    - Restrainer cables engage with full SEE gap
  - Used at East and West Ends of YBITS (Abut 10 & 11 and Hinge K)

Construction

Hinge K

- Cast-in-place concrete closure pour
- 6.4m long
- Extension of YBITS supported on two pipe beams extending from SAS
- Bearings: Isolate longitudinal forces
- Gap under Pipe: Unrestrained Uplift

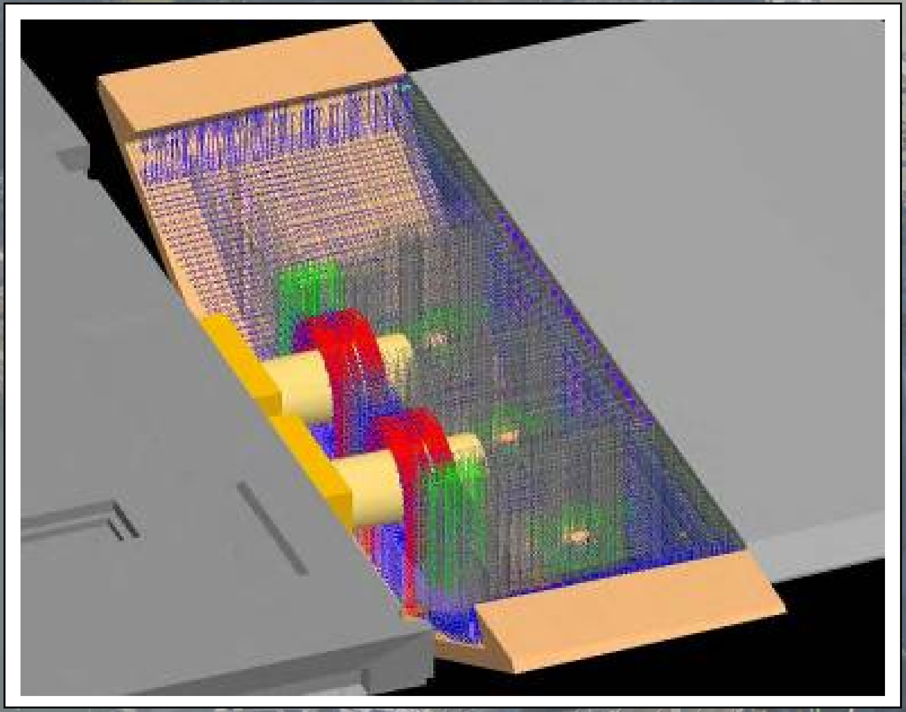


Hinge K Pipe Beams

Hinge K Pipe Beams

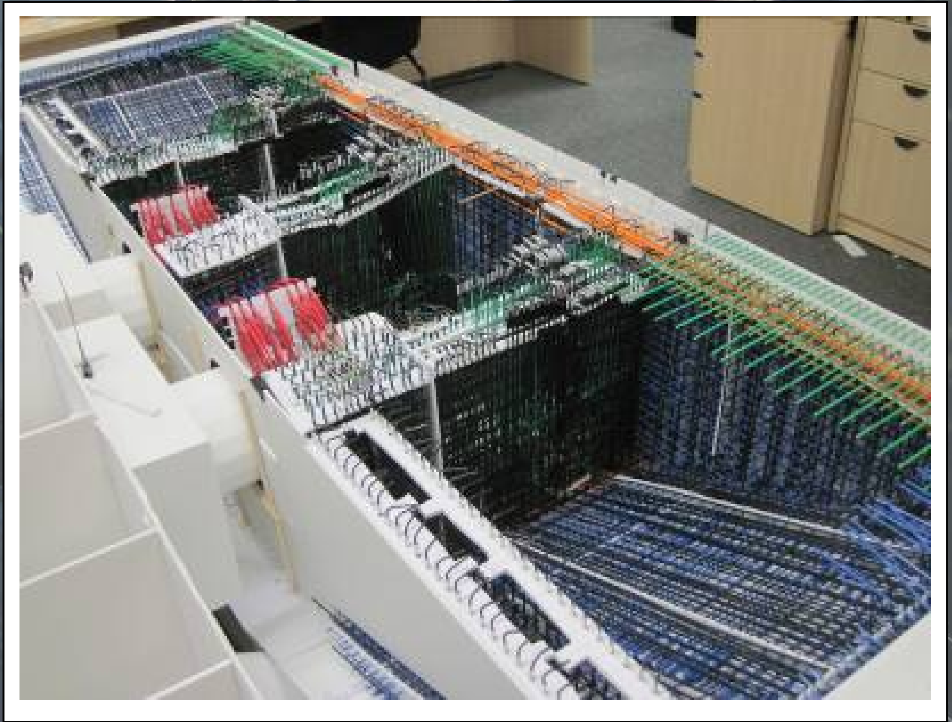
- SEE Philosophy: Pipes may sustain plastic damage but are replaceable
- Fabricated Pipes stronger than Designed → YBITS evaluated for 27,000 kip pipe beam reaction
- Hinge K checked using strut-and-tie models
- Main Alterations
  - Girder Thickness
  - Stirrup Spacing
  - Bar Length
  - Additional Bars

Hinge K Rebar – A Partnering Approach



Challenges of Hinge K Rebar Placement

- Time
- Space
- Density of Rebar



Hinge K Rebar – A Partnering Approach

<u>Solutions</u>

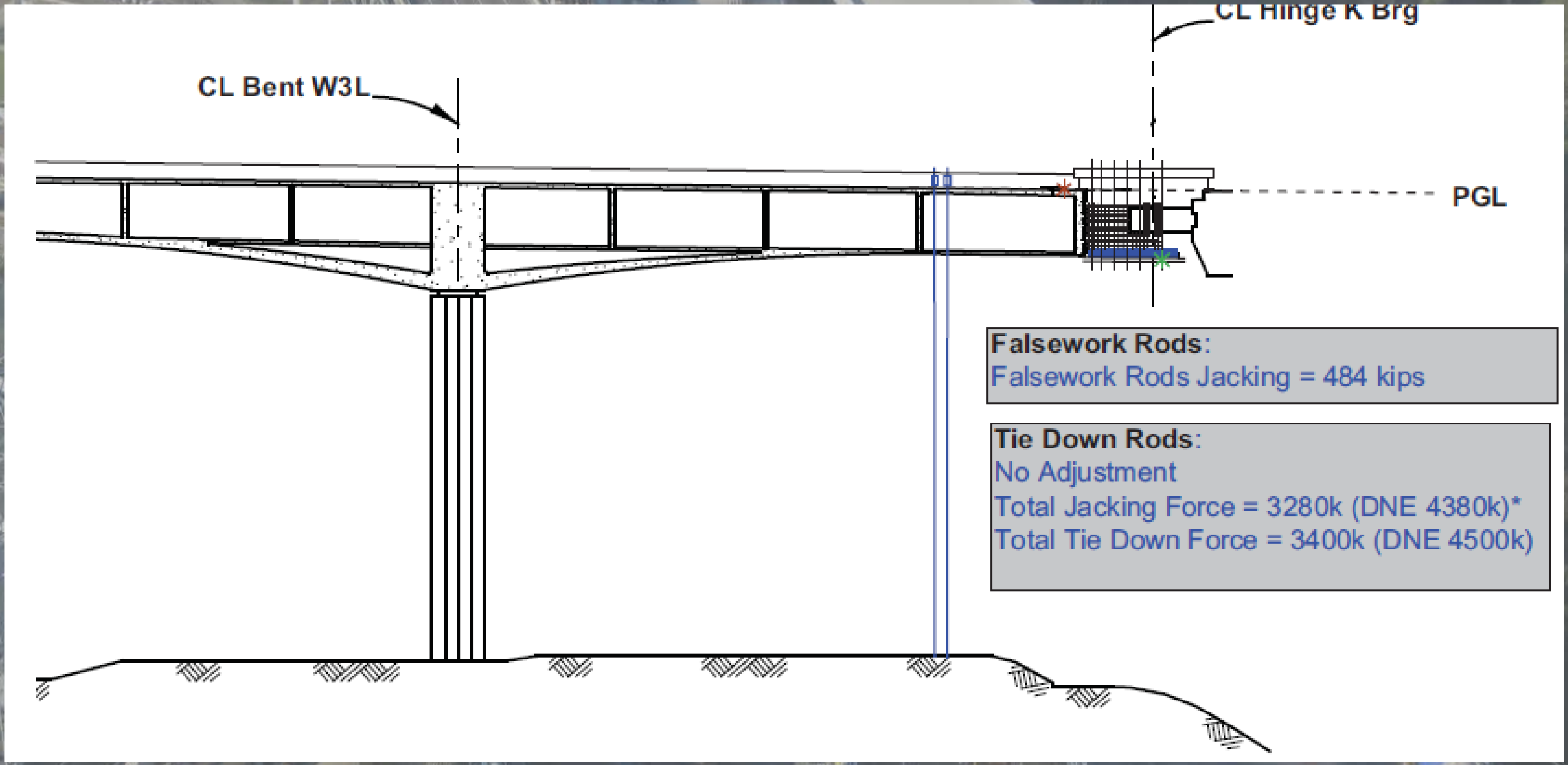
- Models
  - -3D Computer Model
  - -1:10 Scale Physical Model
- Weekly Meetings with Caltrans, Designers, and Contractor
- Review of Design Criteria
  - •Elimination of Heads on U-bars

Hinge K Rebar Placement

Hinge K Construction – Elevation Control

Challenges

- Hinge K Cantilever During Construction
- Falsework Supported on Decks of YBITS and SAS
- Tie Down System to Control Elevation
  - Temperature and Construction Load Fluctuations



Tie-down system

Tie-down Jacks

T·Y·LIN INTERNAT

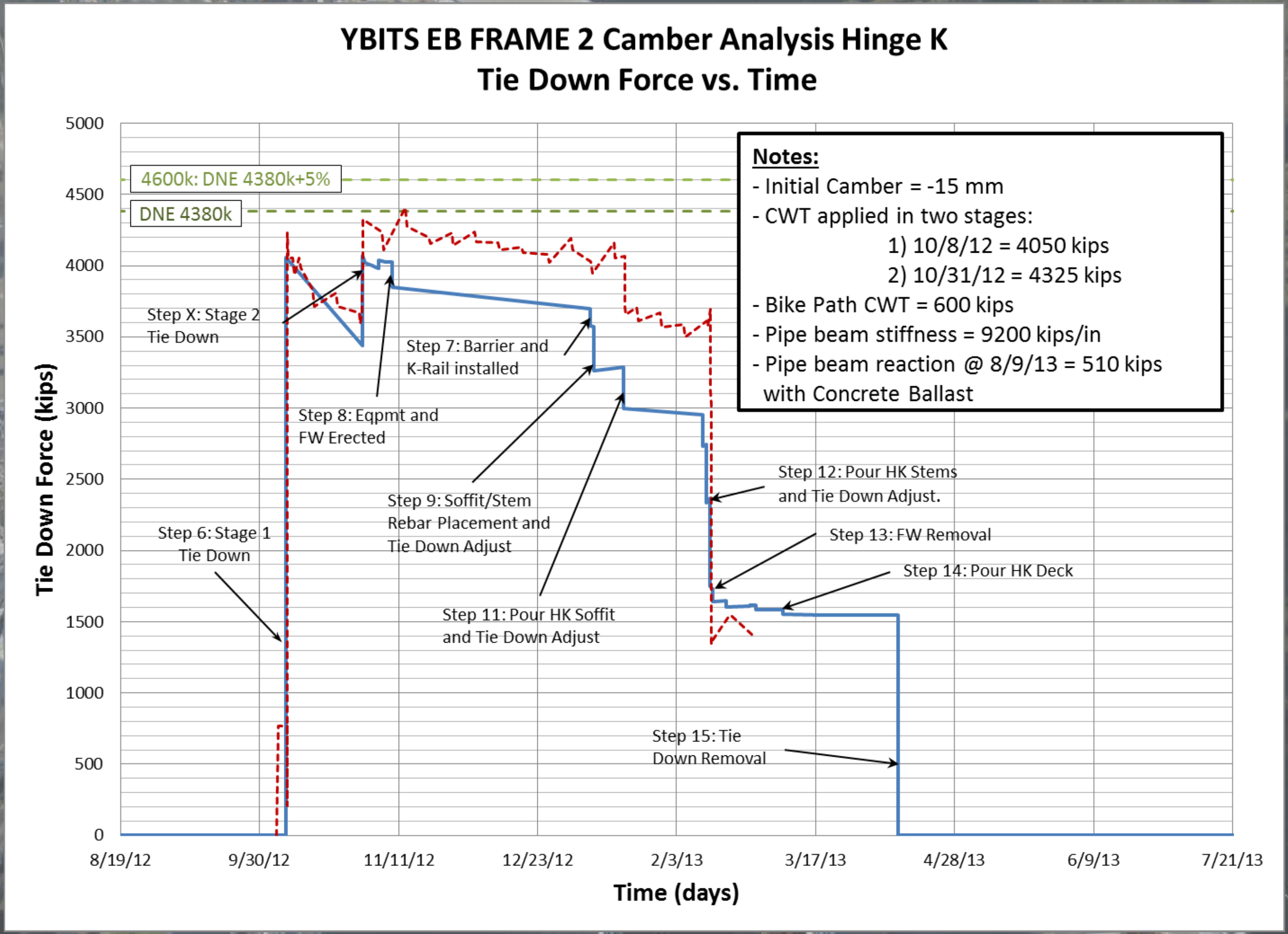
MOFFATT & N

Tie-down System

T·Y·LIN INTERNATIONAL
MOFFATT & NICHOL ENGINEERS
a joint venture

Hinge K Construction- Elevation Control

- Continuous Tie-Down Force Monitoring
- Temperature Monitoring
- Survey taken weekly and for major construction steps
- Computer Models Updated Weekly



T.Y.LIN INTERNATIONAL | a joint venture
MOFFATT & NICHOL ENGINEERS

Conclusions for Hinge K

- Dynamic dissimilarities of YBITS & SAS
- Designed-in a “capacity protected” failure mode at hinge
- Accelerated, zero-tolerance schedule for Hinge K rebar placement
- Hinge K Cantilever Elevation Control