San Francisco-Oakland Bay Bridge

Connection of the Oakland Touchdown Structures and Skyway at Hinge E

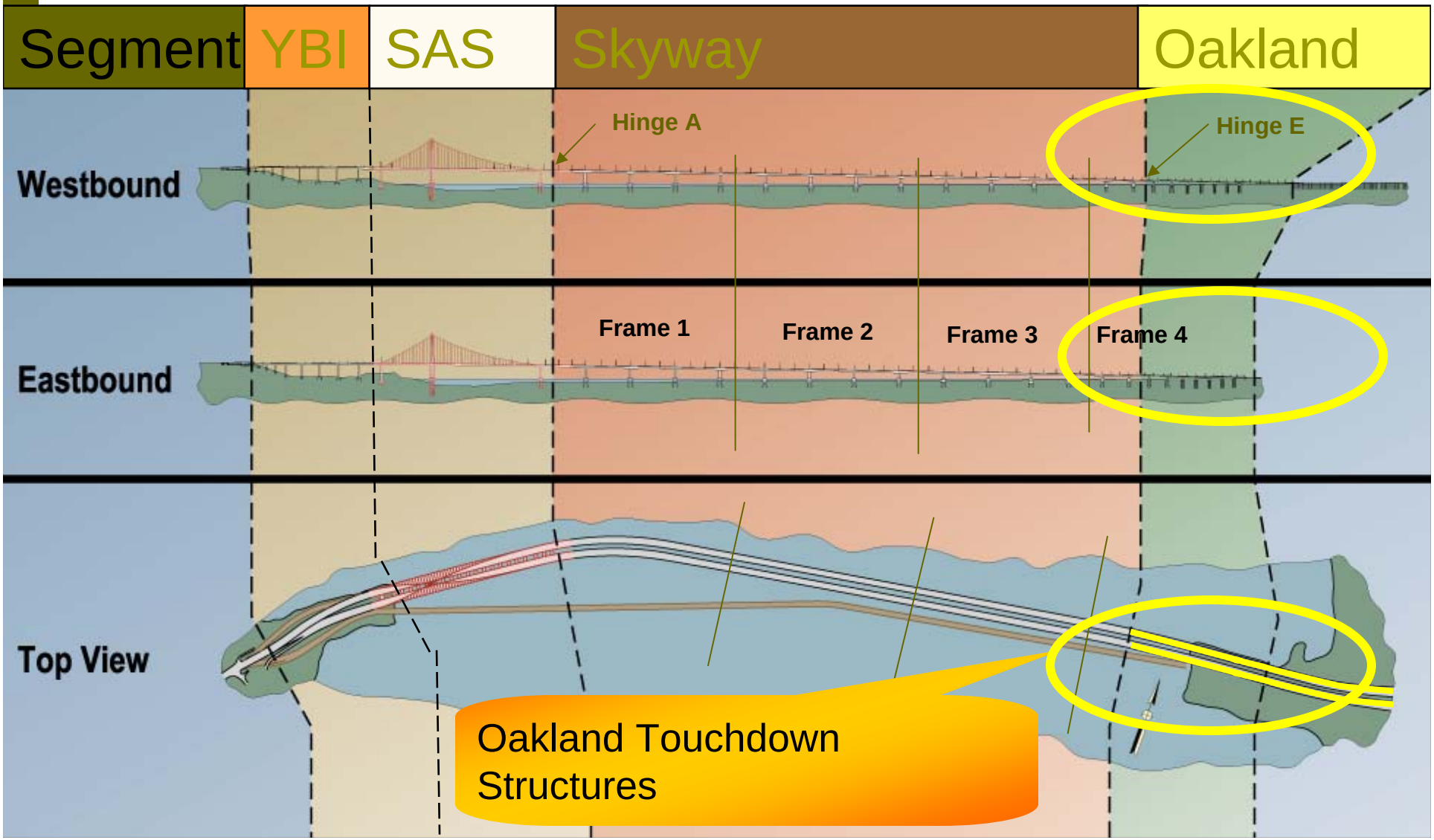
Presenters: Vinh Trinh, SE – WKE, Inc.
Xiaoyun Wu, PhD, PE – IDC Consulting Engineers, Inc.

Co-authors: Mohan Char, PhD, PE – AECOM/LAN
George Saad, PhD, PE – Moffatt & Nichol
Hasan El-Natur, PhD, PE – Caltrans

Project Structures Design Team

- Caltrans
- T. Y. Lin/Moffatt & Nichol, Joint Venture
- PB&SJ
- AECOM/LAN
- WKE, Inc.
- IDC Consulting Engineers, Inc.
- EMI/Fugro

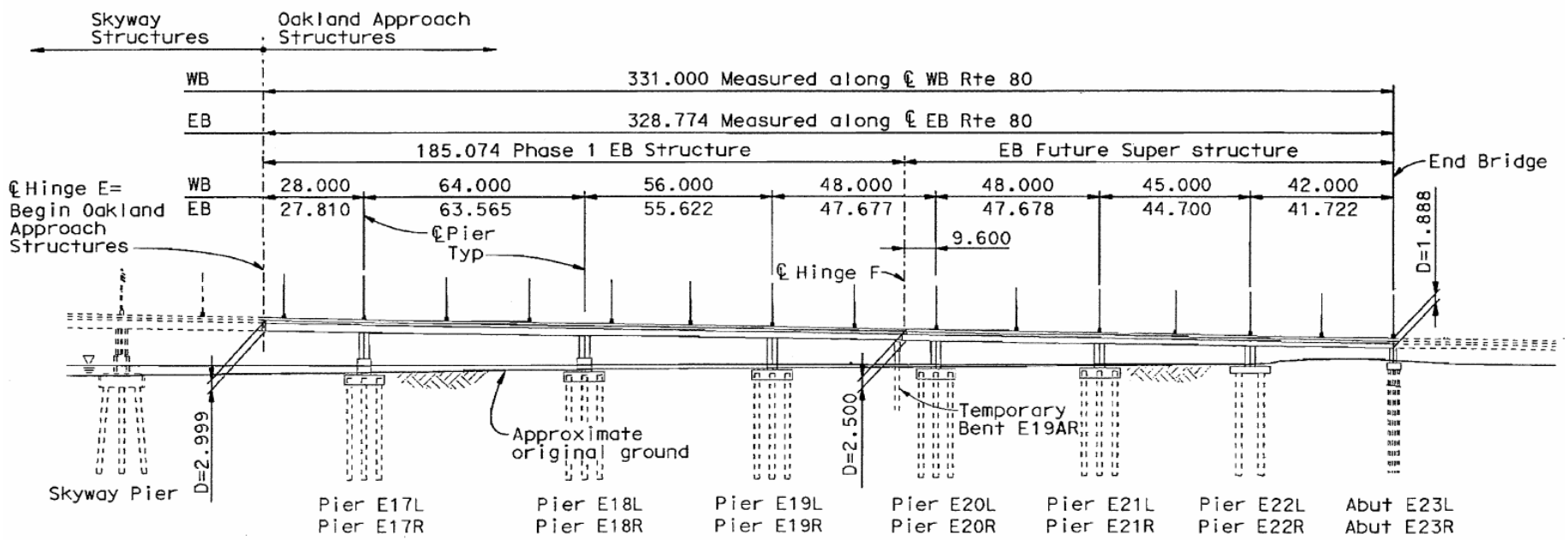
Oakland Touchdown Structures (OTD)



Oakland Touchdown Structures

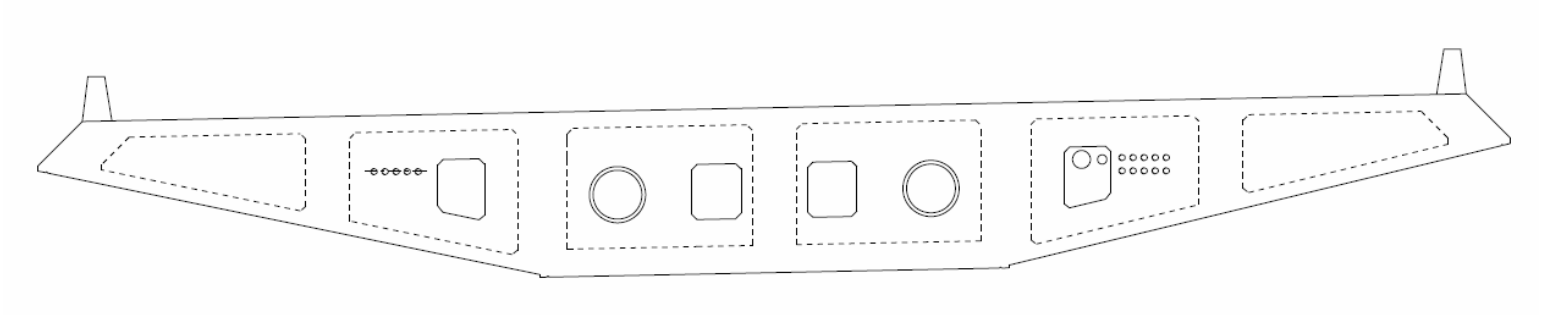
Oakland Touchdown Structures

- 2 Parallel Structures:
  - WB Structure (PBS&J, WKE, & IDC)
  - EB Structure (AECOM/LAN)
- Cast-in-place Prestressed Concrete Box Girder
- 7-Span, 2-Frame



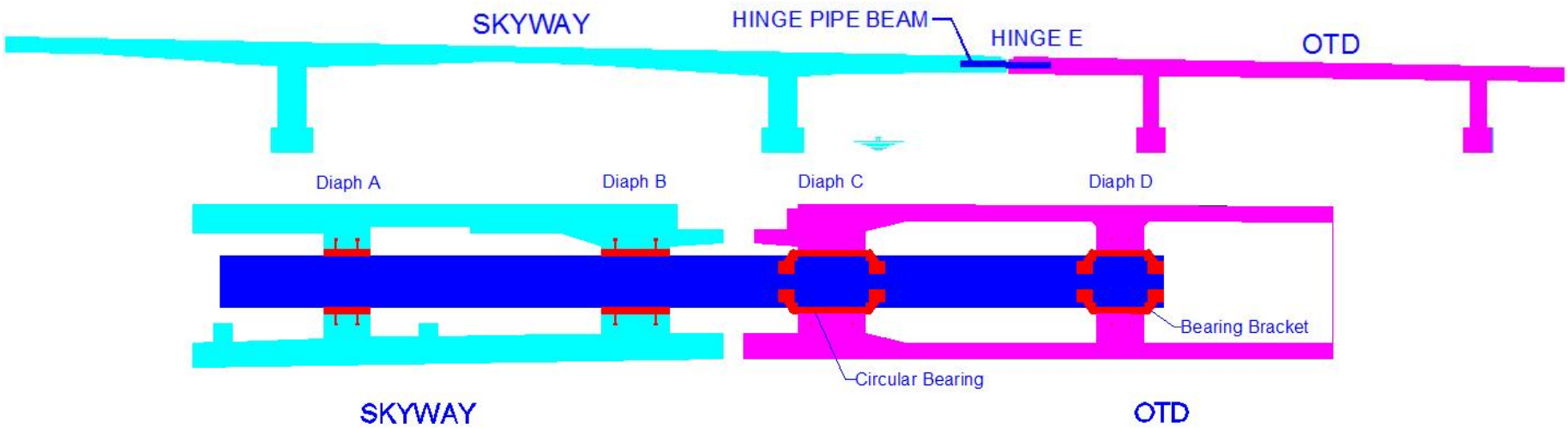
Hinge E – Design Challenges

- Connecting 2 Different Structure Systems
- Constructed at Different Time
- Time Dependent Loss Analysis
- Limited Cross Section Area



Hinge E

- Connects 2 Structures with Pipe Beam
  - Hinge at Mid-span
  - Different structure types = different behaviors
  - Connected with steel pipe beam
    - Cantilever for DL
    - Continuous for LL



Hinge E

- Connect Aged Precast Segmental Box to New CIP Box
  - East end of Skyway was completed 3 years ago
  - Skyway supported on temporary towers with 4 jacks

Hinge E

- Time Dependent Loss Analysis to Determine Camber
  - Accurate analytical modeling
    - Short Term Deflection at Connection Time for Hinge Pipe Beam Installation
    - Long Term Deflection to determine the loading on the Hinge Pipe Beam
  - Post Design Camber Verification

Camber Estimation Parameters

1. Variation in Material Properties
   - Test concrete mix design to determine
     - Compressive Strength
     - Density
     - Creep and Shrinkage
     - Modulus of Elasticity
2. Construction Loadings/Falsework
   - Including actual form works and construction equipment loading
   - Obtain settlement value from the Contractor

Camber Estimation Parameters

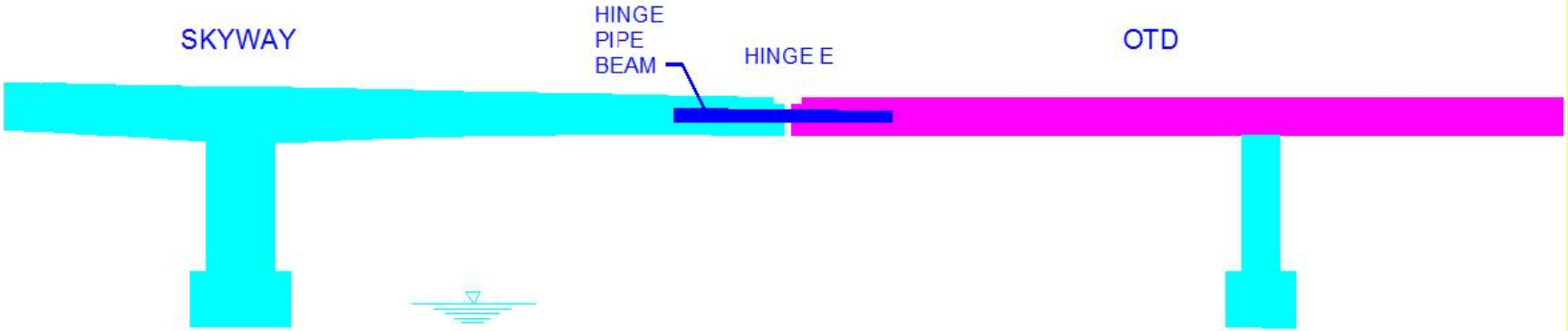
3. Construction Schedule
   - Work closely with the Contractor to determine realistic construction schedule
4. Skyway Deflection
   - Jacks supporting the Skyway were released to survey the Skyway elevation

Camber Adjustment Allowance

- Adjustment Allowance
  - Superstructure can be jacked up or weighed down to line up with Skyway, if necessary

Hinge E Construction Sequence

- Construction Sequence
  - Release Skyway jacks to establish elevation
  - Construct OTD superstructure to required camber
  - Post tension OTD frame (35 days delay)
  - Release falsework except for OTD temporary tower
  - Align OTD with Skyway, if necessary
  - Finish installation of pipe beam

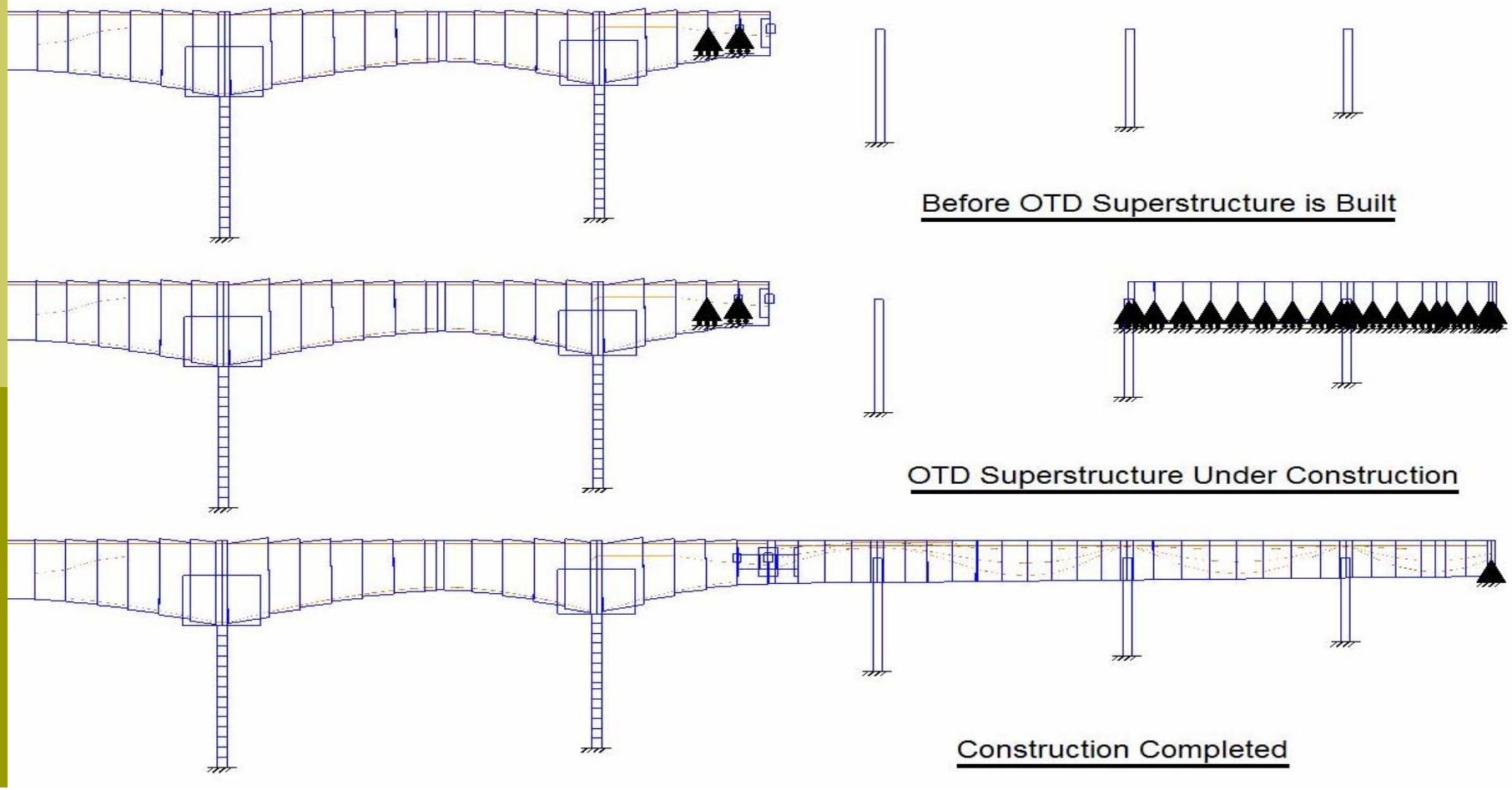


Hinge-E Key Analysis Items

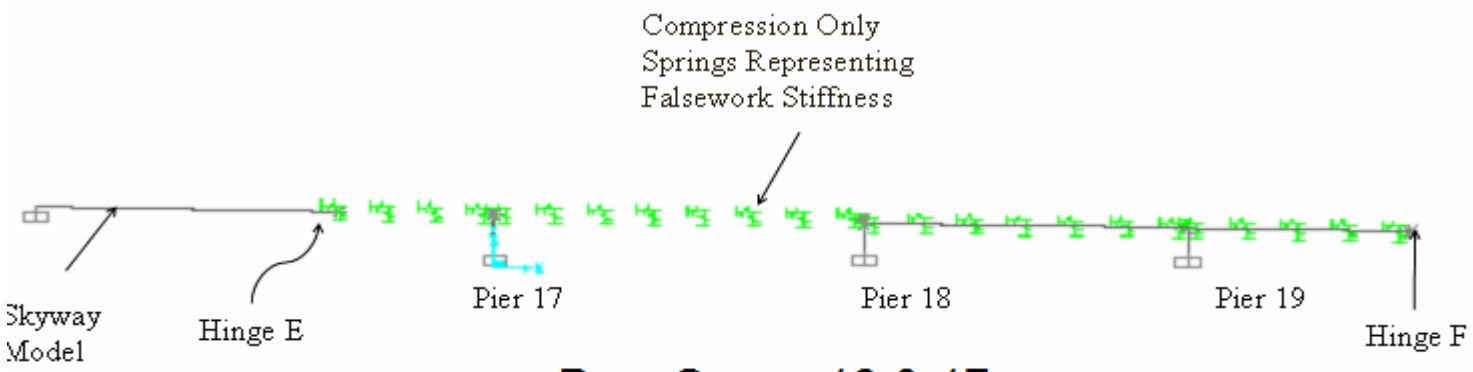
- OTD Hinge-E Deflection When P/S Is Completed
- OTD Hinge-E deflection When Hinge Pipe Beams Are Going To Be Connected
- OTD Hinge-E Deflection After P/S Long Term Losses (20yrs)
- Pipe Beam Forces After OTD Connected With Skyway
- Hinge-E Diaphragm Forces Due to Pipe Beam Reaction

Analysis Model

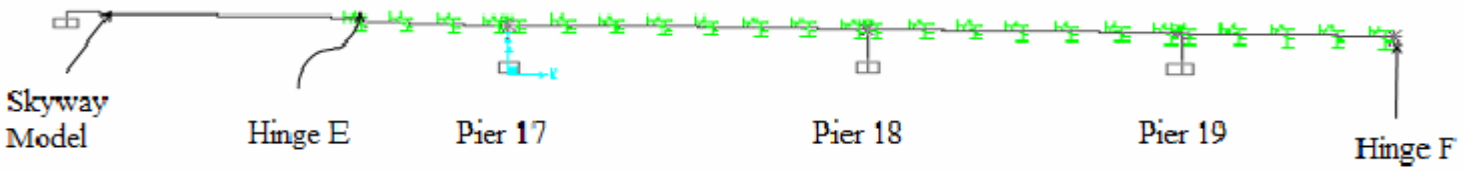
- Stage by Stage Time Dependent Analysis Based on Construction Schedule



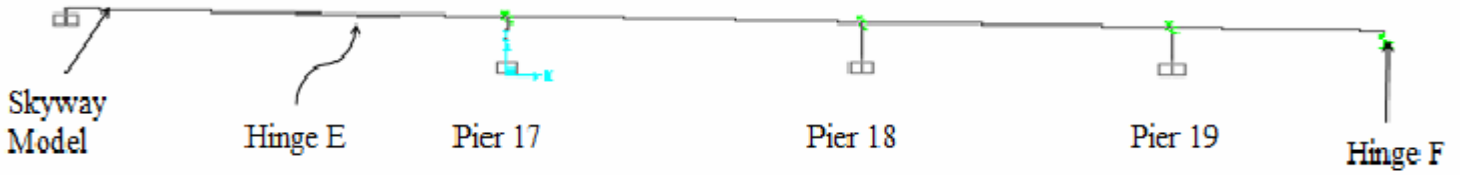
Analysis Model



Pour Spans 16 & 17



Pour Spans 18 & 19



Construction Completed

Analysis Model

- Model Geometry and Load Validation per Linear Elastic Dead Load Analysis

Hinge-E DL Deflection & Moment at P17 Comparison between Adapt & BDS Analysis Results

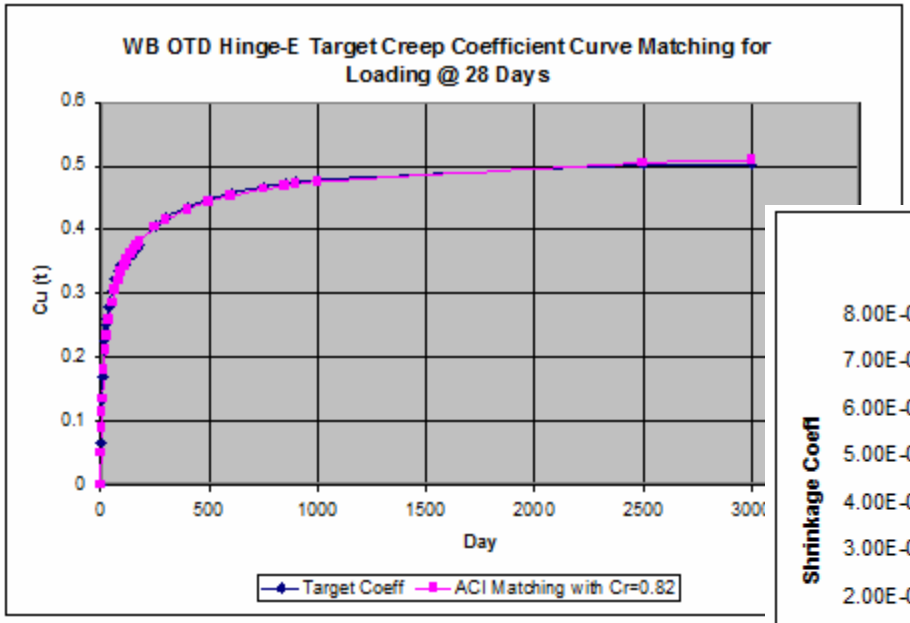
Program	Case	Def at Hinge-E				M at P17			
		Try-0 (ft)	Try-0 (mm)	Try-1 (ft)	Try-1 (mm)	Try-0 (k-ft)	Try-0(KN-m)	Try-1 (k-ft)	Try-1(KN-m)
Adapt	90k @ tip	0.31	96.14	0.02	6.74	-1.79E+05	-2.43E+05	-2.08E+04	-2.81E+04
BDS	90k @ tip	0.32	96.01	0.02	6.71	-1.79E+05	-2.42E+05	-2.08E+04	-2.81E+04

Analysis Model

- Concrete Properties Adjust from Lab Test Data of the Field Concrete Mix
  - Test Data (Test Performed by Prof. Al-Manaseer – SJSU)
    - Concrete cylinder 6in x 12in
    - Relative Humidity = 50%
    - Notional Size = 3”
  - Site Conditions
    - Relative Humidity = 70%
    - Based on Average Section Properties: Notional Size = 14”
  - Adjustment Factors
    - Applied to transform the test results to reflect the actual site conditions

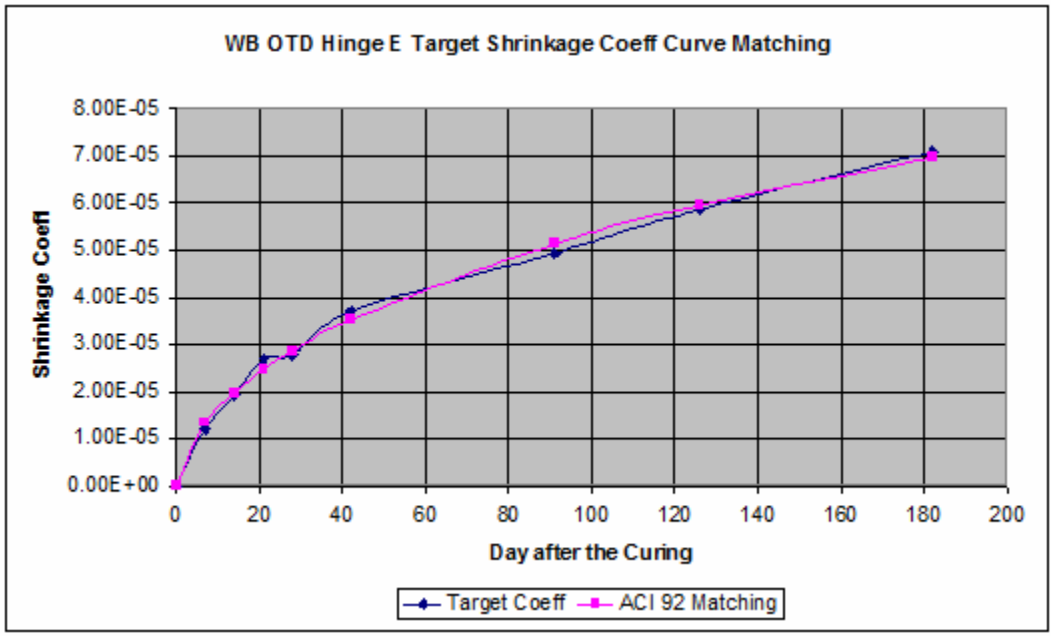
Analysis Model

- ACI 92 & CEB-90 Time Dependent Concrete Models to Match Adjusted Lab Test Data & Used in the Analysis Model

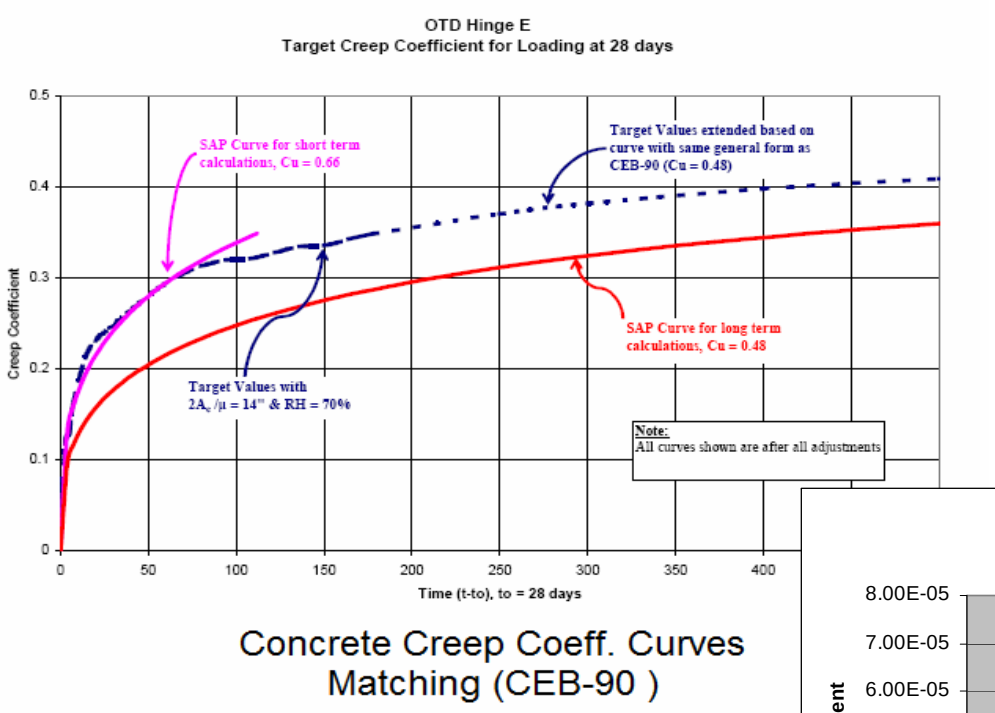


Concrete Creep Coefficient Curves Matching (ACI 92)

Concrete Shrinkage Coefficient Curves Matching (ACI 92)

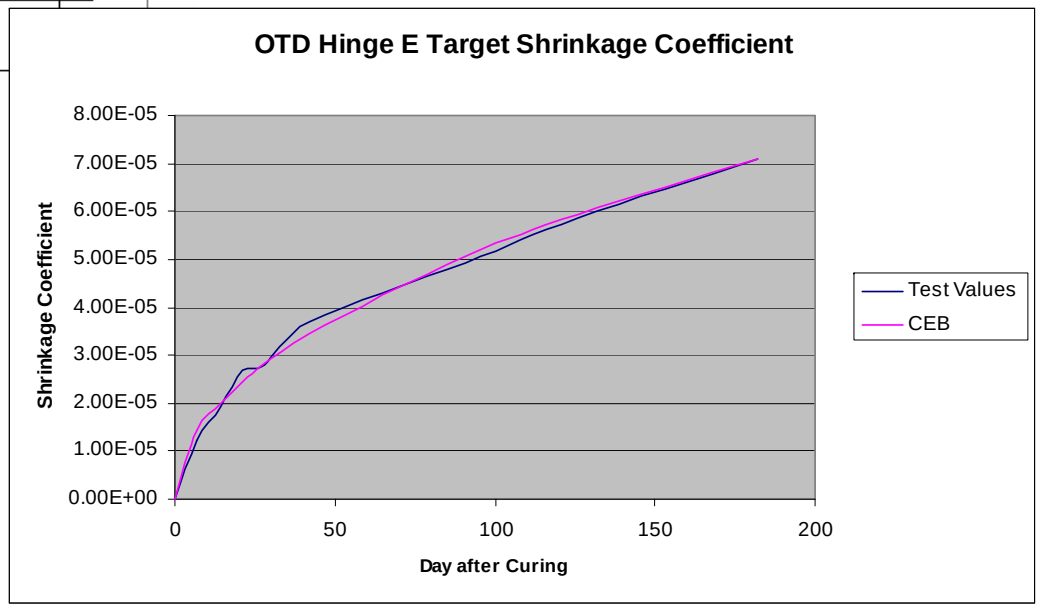


Analysis Model

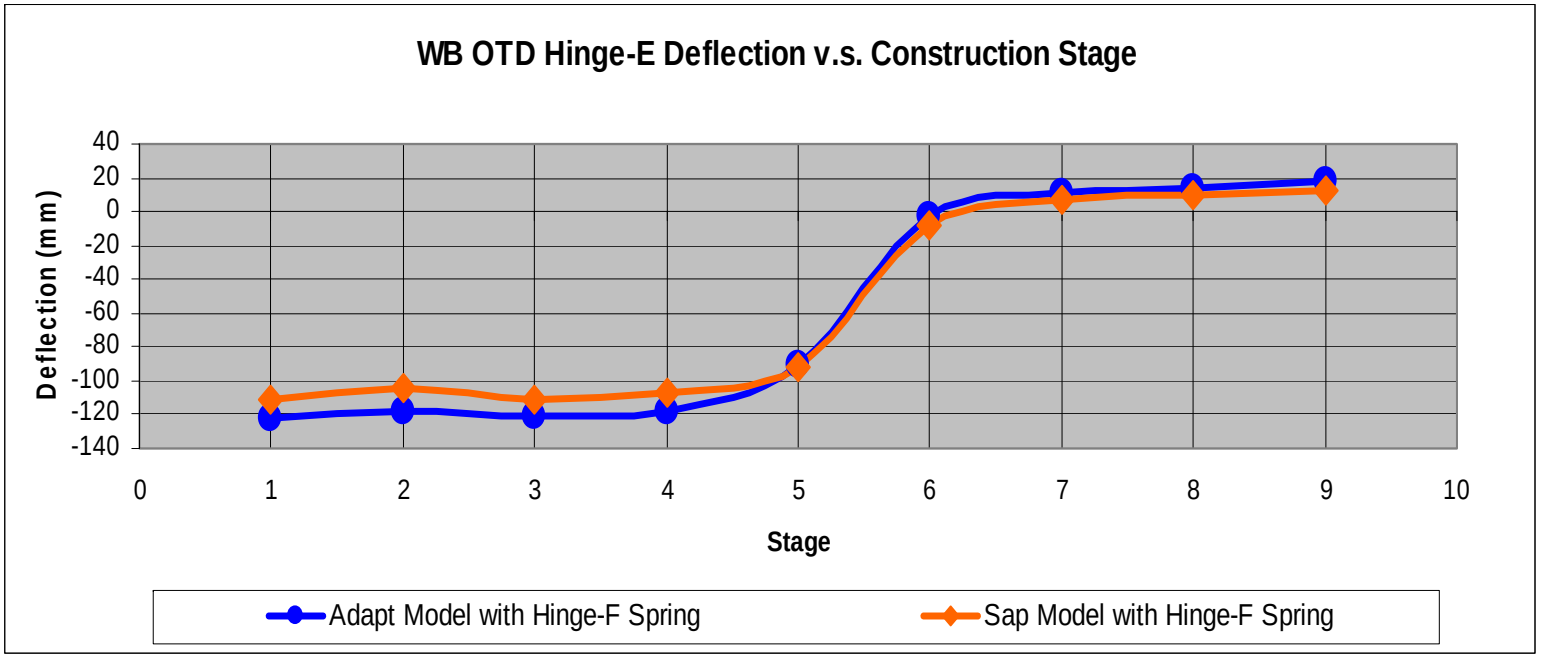


Concrete Creep Coeff. Curves Matching (CEB-90)

Concrete Shrinkage Coefficient Curve Matching (CEB-90)



Analysis Model

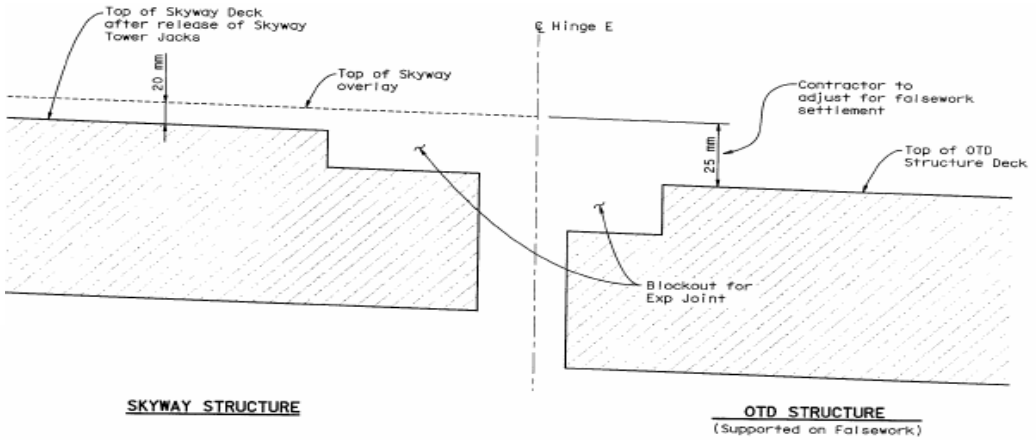


Stage v.s. Day in Construction

Day	110	110	115	120	127	128	131	135	150
Stage	1	2	3	4	5	6	7	8	9
Note	Before P/S	Grd 25% P/S	Grd 50% P/S	Grd 75% P/S	Edger Grd 100% P/S	Deck P/S	Grd 100% P/S	Portion ADL Applied	Before Pipe Connect

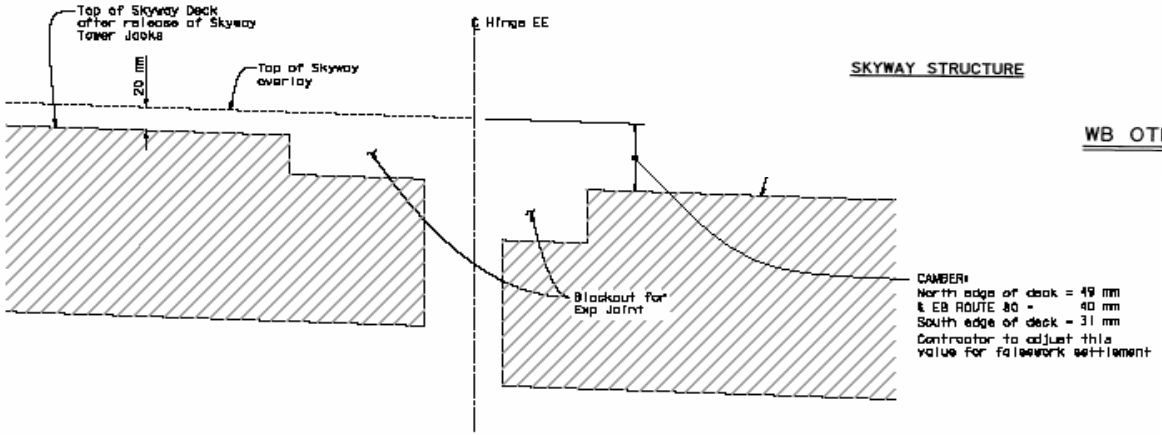
Analysis Results

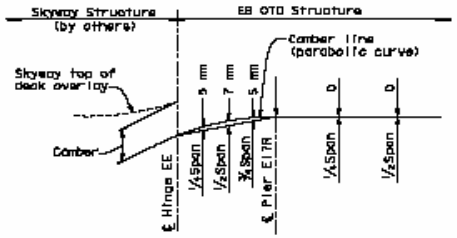
- Hinge-E Deflections - used for determination of the construction camber



WB OTD CAMBER AT HINGE E

NOT TO SCALE



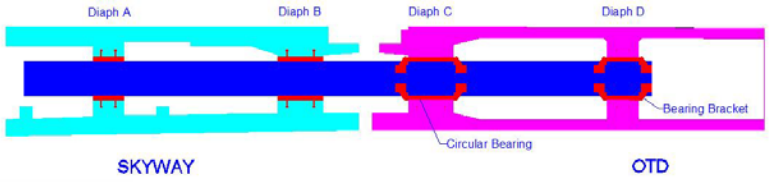


EB OTD CAMBER AT HINGE EE

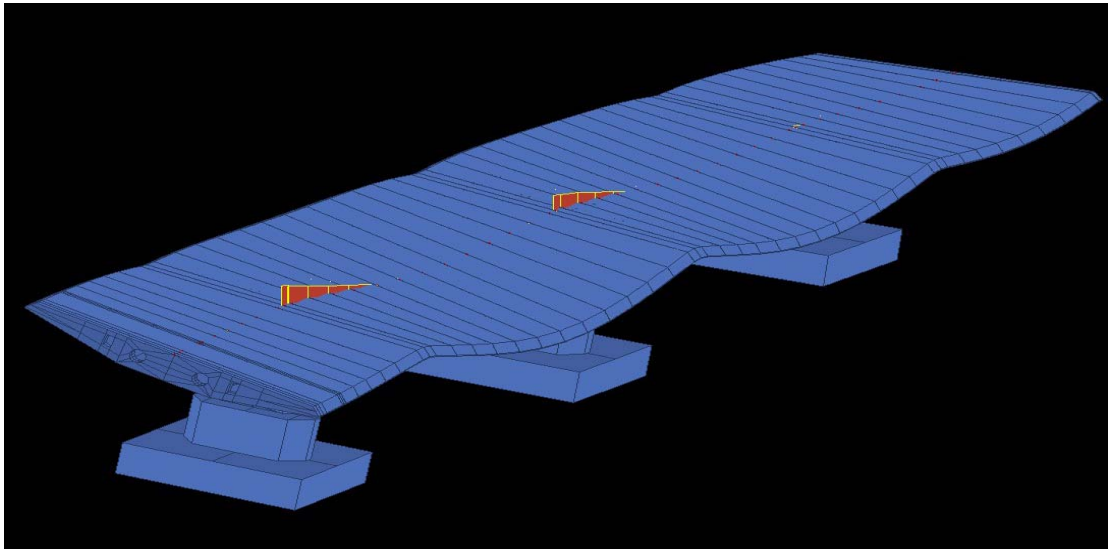
NOT TO SCALE

NOTE:

Just after alignment locking EB OTD Structure top of deck should be 6 mm higher than top of Skyway overlay. Skyway should rise by this amount when pipe beam is moved into OTD.



Analysis Results

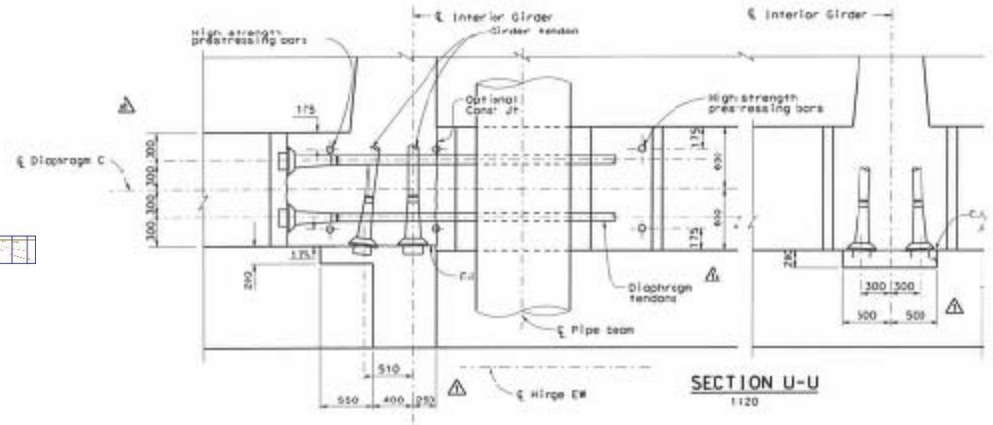


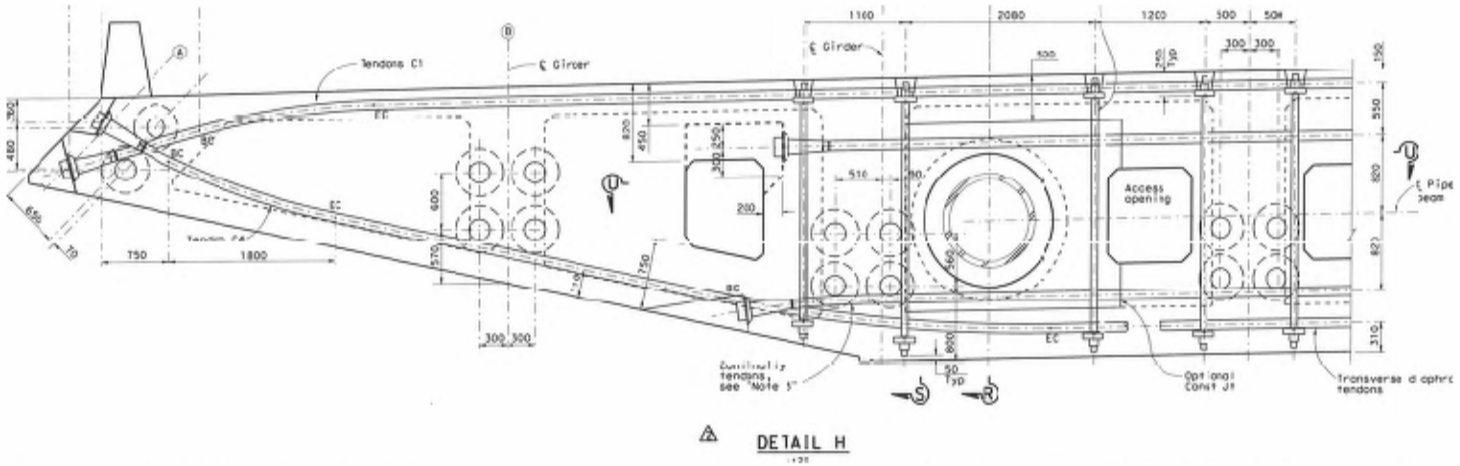
EB OTD Tilted Deflection Due to Bike Lane Loading

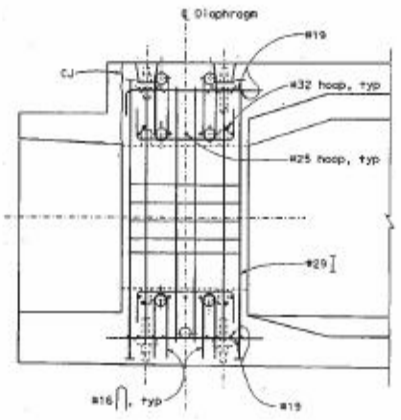
- Pipe Beam Forces – verified the pipe beam capacity is adequate for field condition
- Pipe Beam Reaction – for Hinge-E Diaphragm design

Hinge-E Diaphragm Design

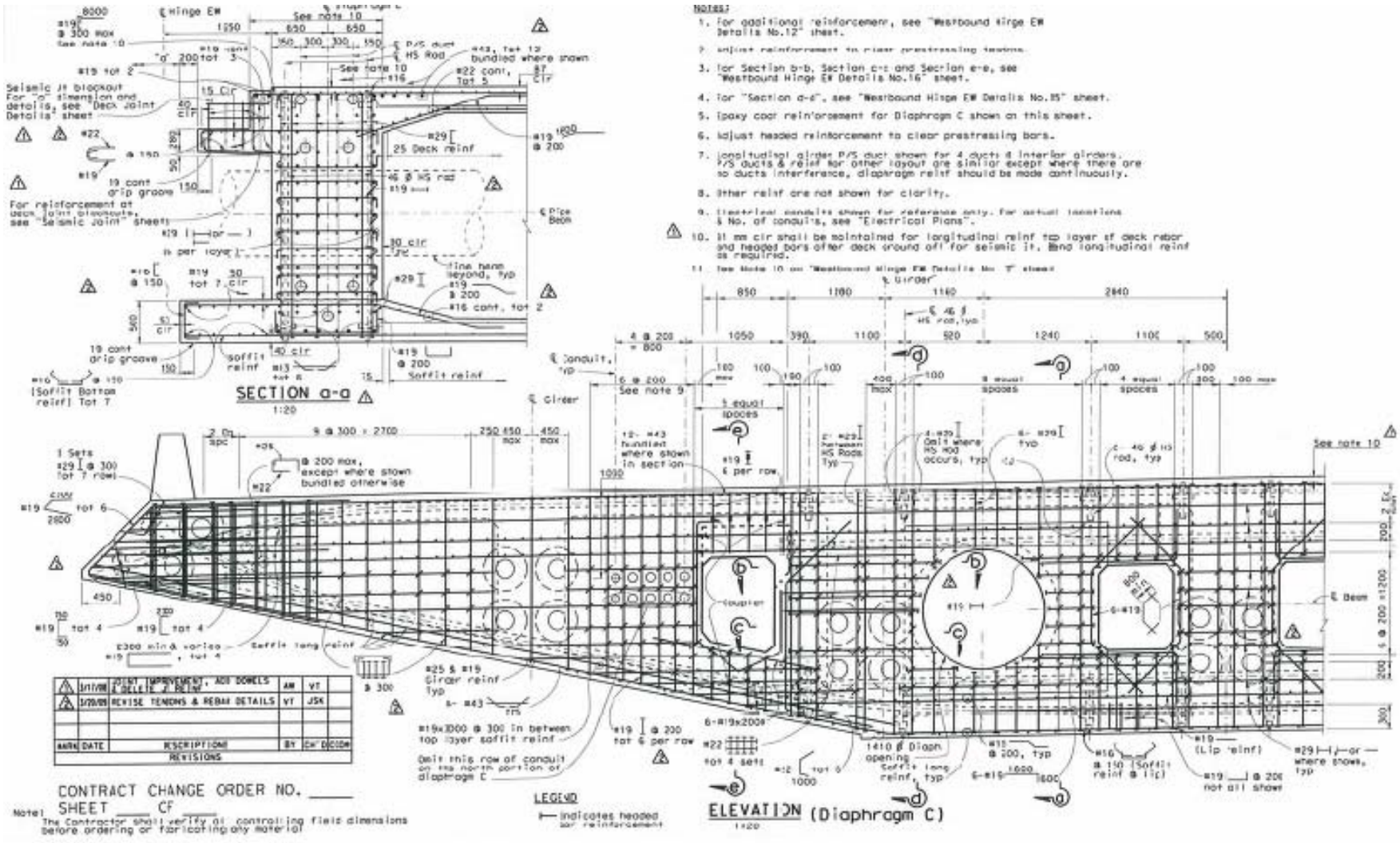
- Limited Cross Section Area & Member Size
- Large Concentrated Load
- Complicated Stresses Distribution
- 3-way Pre-stressing
- Detailing





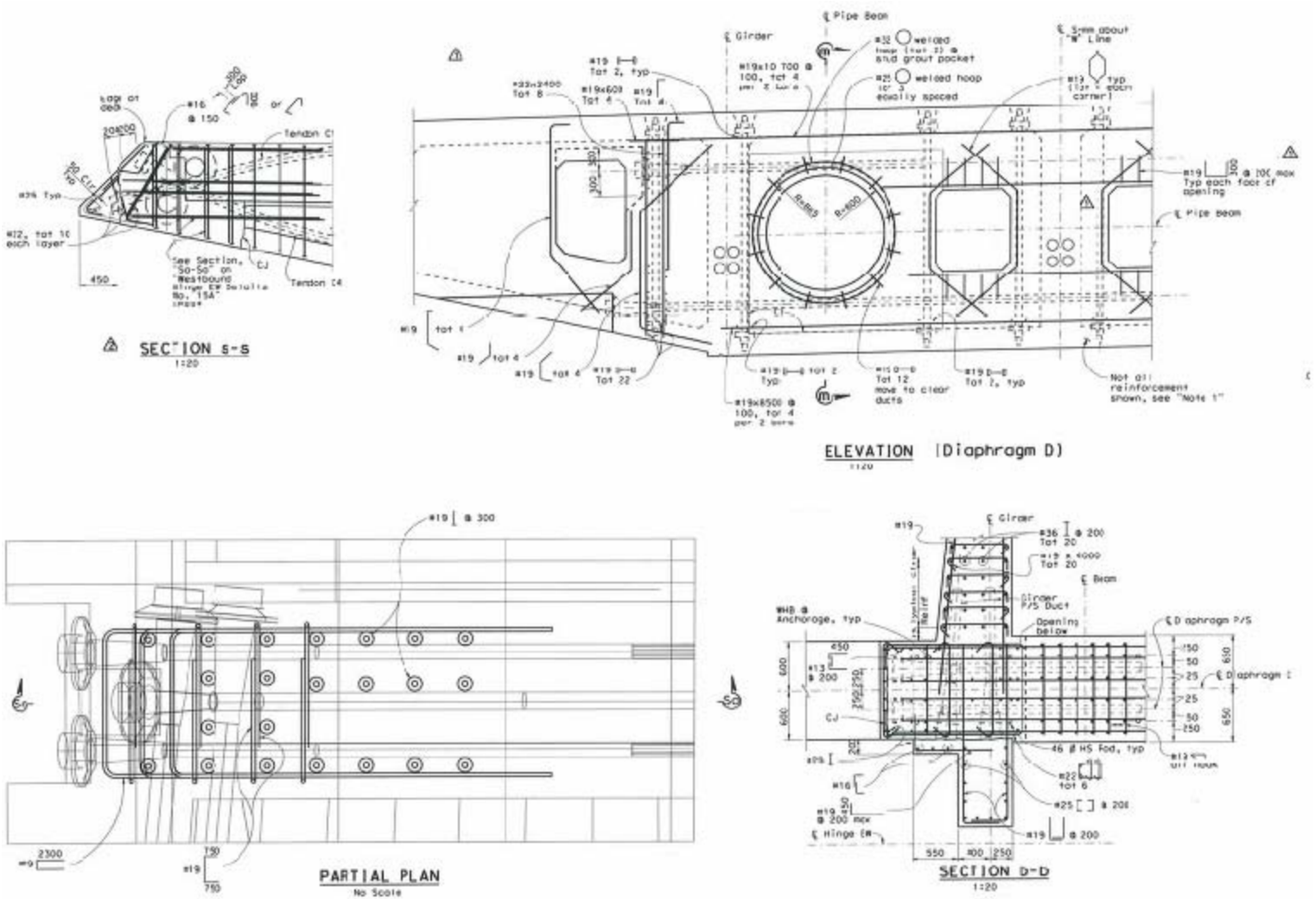


Hinge-E Diaphragm Design



Partial Diaphragm Detail

Hinge-E Diaphragm Design



Conclusion

- Pre-cast Segmental & CIP Box Girder mid-span connection hinge is feasible.
- By special analysis with field test material properties, boundary conditions and carefully scheduled construction stages, a reasonable camber value can be set to enable smooth operation for the pipe hinge beam coupling installation.
- Aesthetic architectural design effect can be always achieved by thoughtful structural design & detailing

  In this case:

  → Moment connection at Hinge-E for LL is used to reduce the maximum moment demand at relatively shallower cantilever support

  → 3-way P/S is designed to provide maximum section capacities and reduce rebar congestion

  → High compressive concrete strength (8.5 ksi) is used to provide compatible compression capacity for matching the large volume of the reinforcement.


THANK YOU
We Also Appreciate
Caltrans' Support for This OTD Project