69th Annual KU Structural Engineering Conference

The Gordie Howe International Bridge Project

Barry Chung, PE, SE, PhD, AECOM, Tampa, Florida

Dipal Vimawala, PE, SE, AECOM, Chicago, Illinois

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Agenda

- Introduction
- MAIN BRIDGE
  - Bridge Type and Layout
  - Foundations/Towers
  - Superstructure
  - Wind Design / Stay Cables
  - Erection
  - Durability
  - Key Dates
- MICHIGAN INTERCHANGE
  - Local Road and Connecting Ramps Bridges
  - LTPs and Gateway Towers
  - Unique Features
  - Redundancy Analysis
- Acknowledgements

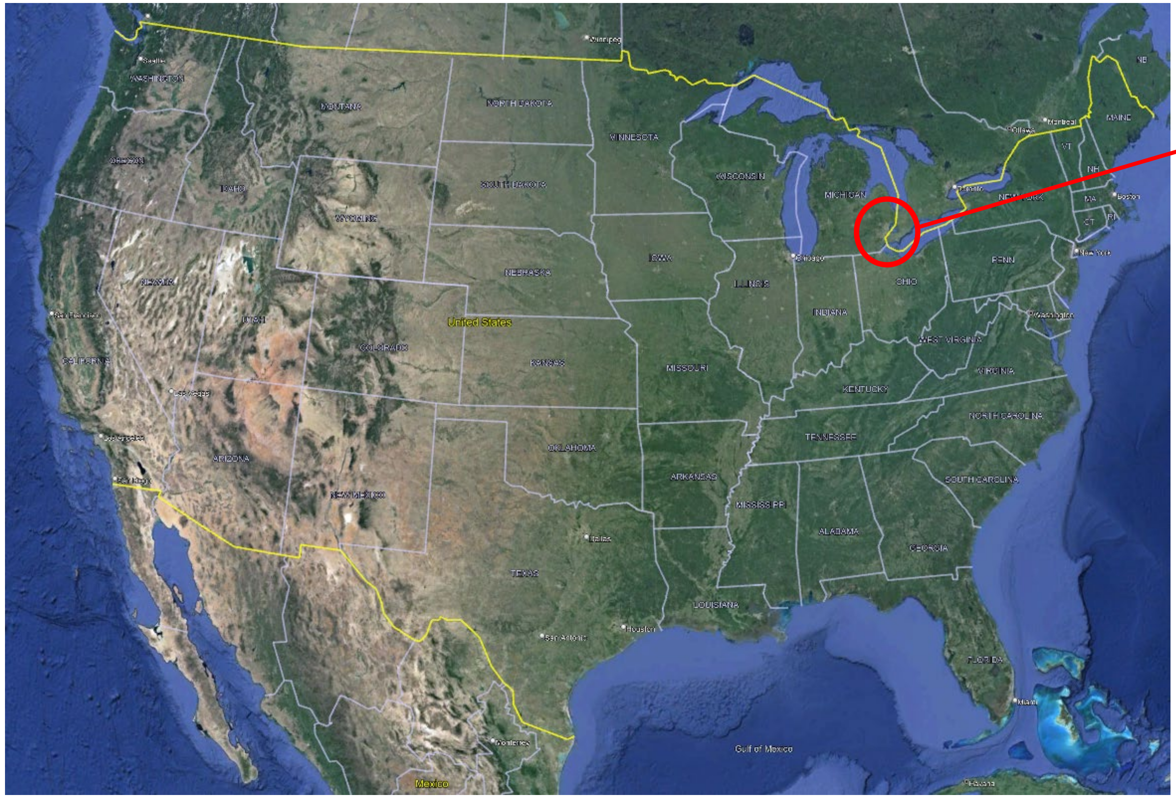
Introduction: Procurement Process

- Project Delivered as a Public-Private Partnership (PPP)
- RFQ released in July 2015
- Introductory Project Meetings and Industry Days were held in Windsor and Detroit in August 2015.
- 848 people representing 419 companies attended
- Six North American and international respondent teams submitted responses.
- WDBA announced three Shortlisted Respondents in January of 2016
- The RFP was released in November 2016
- CCM meetings held throughout 2017
- Technical Submissions Due April 2018
- Preferred Proponent announced in July 2018
- Financial close was in September 2018

Introduction: Bridging North America

Introduction: Location

Detroit, MI, USA

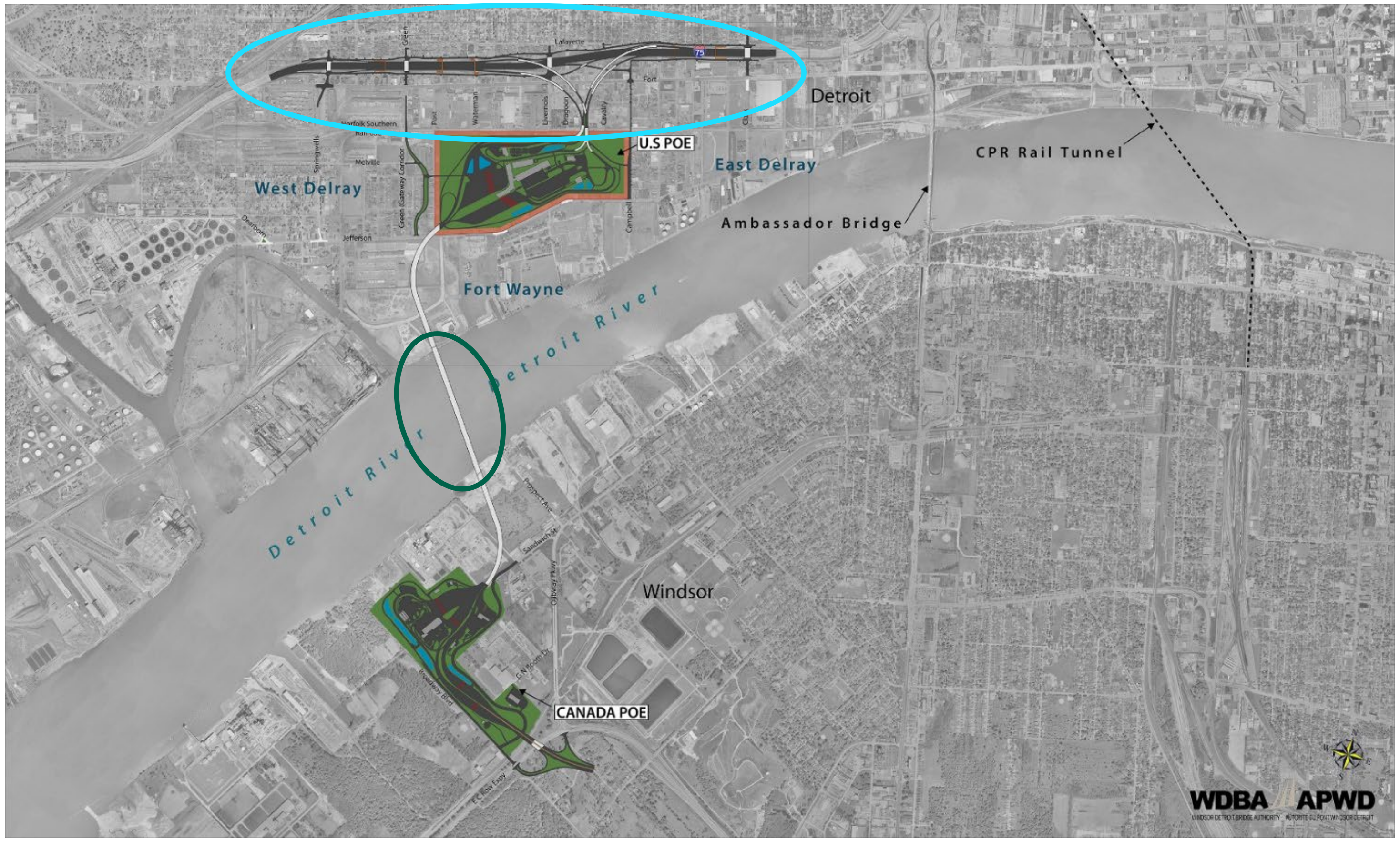


Windsor, ON, Canada

Introduction:

- Four major components:
  - Canadian POE
  - The Bridge
  - US POE
  - Michigan Interchange
- Contract Value: $5.7B update $6.4B
- Substantial Completion: Sept 2025
- OMR Period: 30 years after construction

Detroit, MI, USA

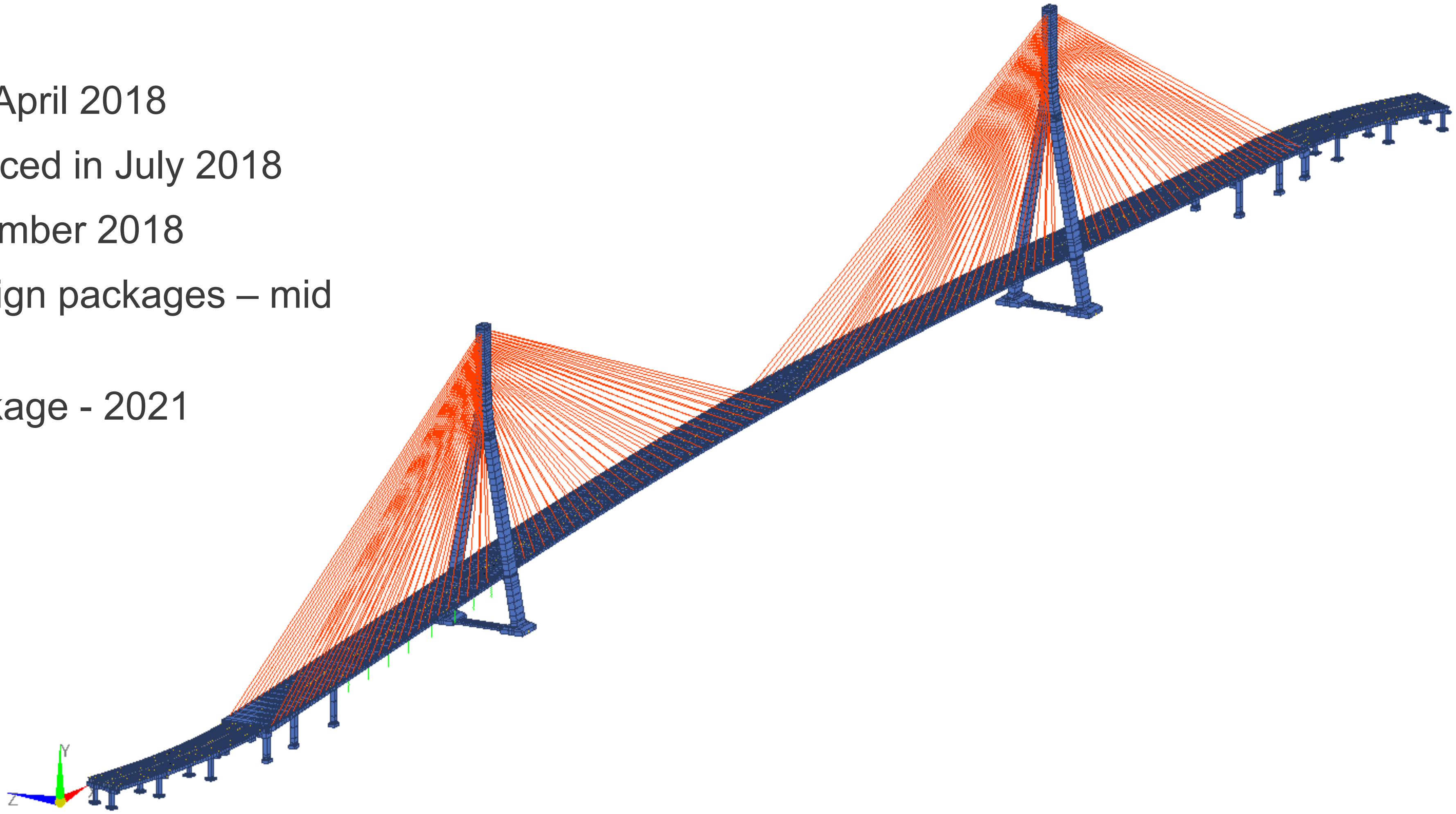


Windsor, ON, Canada

Introduction: AECOM Design Team Global Mobilization

Introduction: Design Timeline

- The RFP was released in November 2016
- Bid design start – early 2017
- Technical Submissions Due April 2018
- Preferred Proponent announced in July 2018
- Financial close was in September 2018
- Main Bridge early works design packages – mid 2019
- Main Bridge last design package - 2021



Bridge Type and Layout

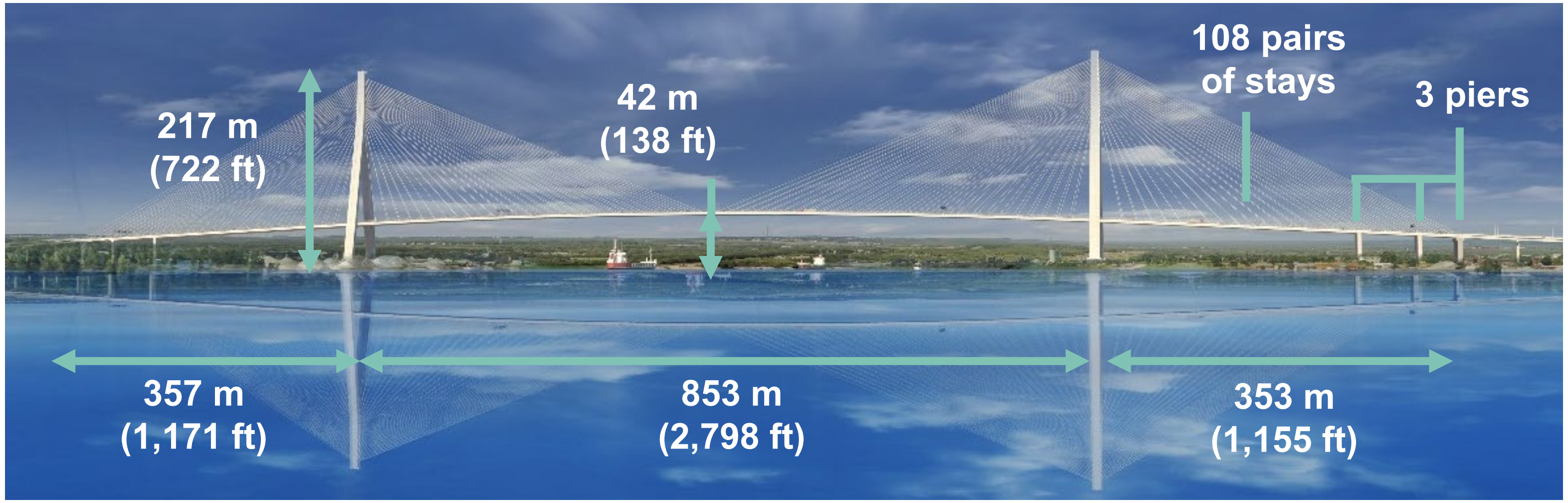
Cable Stayed Bridge

- 853m / 2,798ft main span
- 357m / 1,171ft US side span
- 352m / 1,155ft CAN side span
- 2 side span piers and 1 anchor pier
- 217m / 722 ft tower height
- 42m / 138 ft vertical clearance

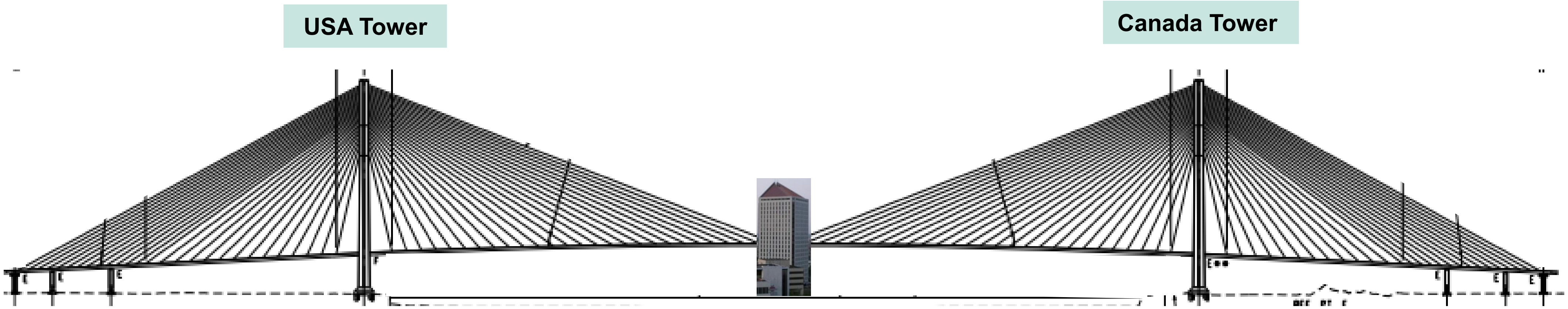
Longest CS Bridge in North America

10th Longest CS Bridge in World

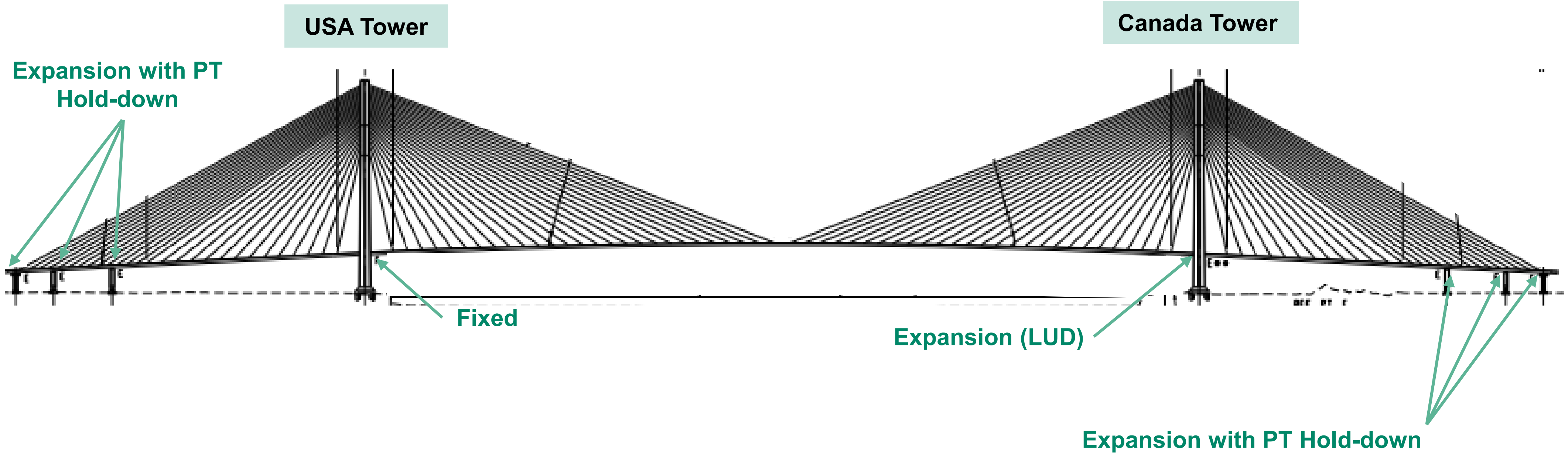
Longest Composite Deck CS bridge in the World



Bridge Type and Layout: Comparison to the Randolf Bridge and Epic Center



Bridge Type and Layout: Articulation



Bearings

- Vertical Bearings at Towers and Piers
- Longitudinally Fixed Bearing at US Tower
- Lateral Bearings at Towers

Hold-Downs

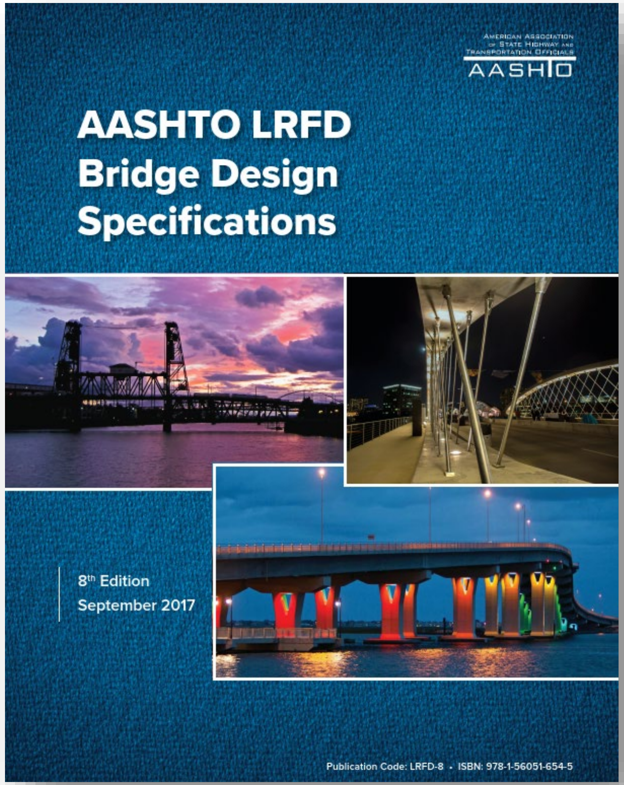
- Post Tension Hold Downs at Anchor and Side Span Piers

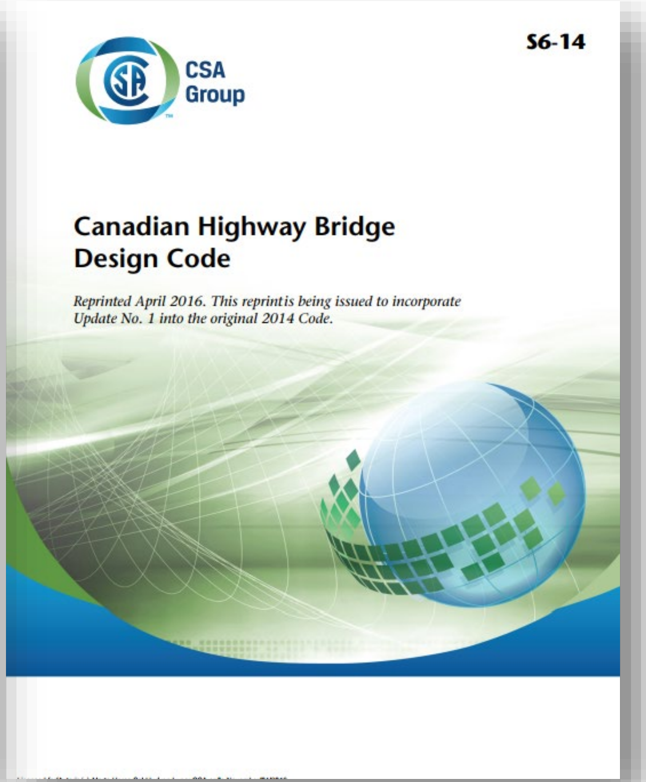
Lock Up Device (LUD)

- Longitudinal LUD At CAN Tower

Overall Design: Criteria

- Dual Track Design
  - US Track – AASHTO LRFD (English Units)
  - CAN Track – CSA S6 (Metric Units)
- Vertical Loads
  - Code and Project Specific Vehicles
  - Initial and Future Configuration
- Lateral Loads
  - Site Specific Wind Study (ULS wind speed of 228km/hr / 142mph)
  - Low-moderate Site Specific Seismic Study (PGA of 0.04g)





Overall Design: Tower Foundations

Drilled Shafts:

- Diameter = 3.0 m (10 ft)
- Length > 30 m (98ft) (down to bedrock)
- Ultimate strength at rock socket level (per shaft):
  - Compression → 15,100 tonnes
  - Tension → 730 tonnes
- Loading/construction method verified by Osterberg cell load test
- One footing per tower leg
- Post-tensioned tie between footings

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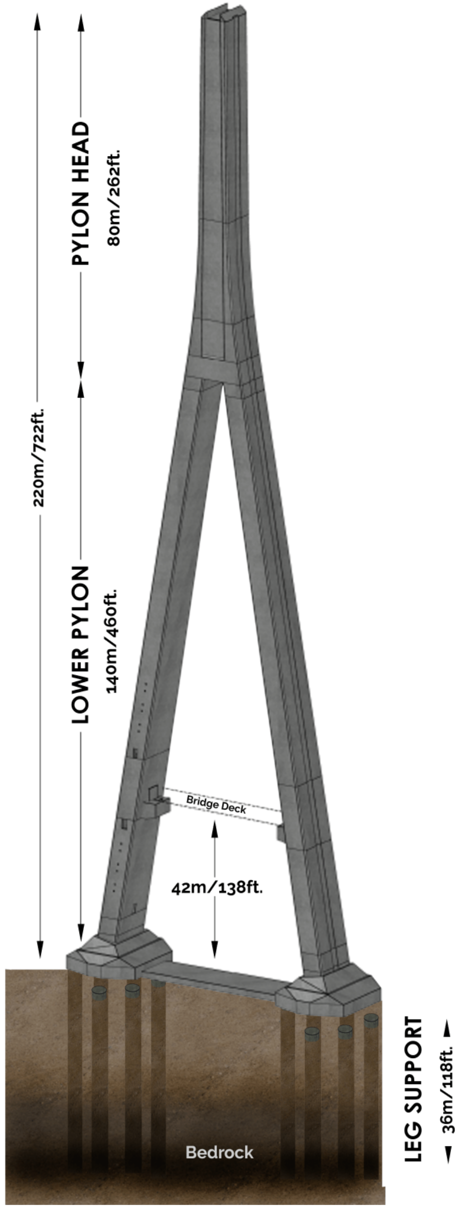
Overall Design: Towers

Inverted "Y" shape towers

- Conventionally reinforced concrete
- Hollow box section
- Steel anchor boxes for stay cable anchorage
- Corbels to support deck, no need for strut at deck level
- Uncoated reinforcing steel except stainless steel in the splash zone near deck level
- Completely accessible by ladders and elevators in all legs and upper part
- Transition room at legs' merging height



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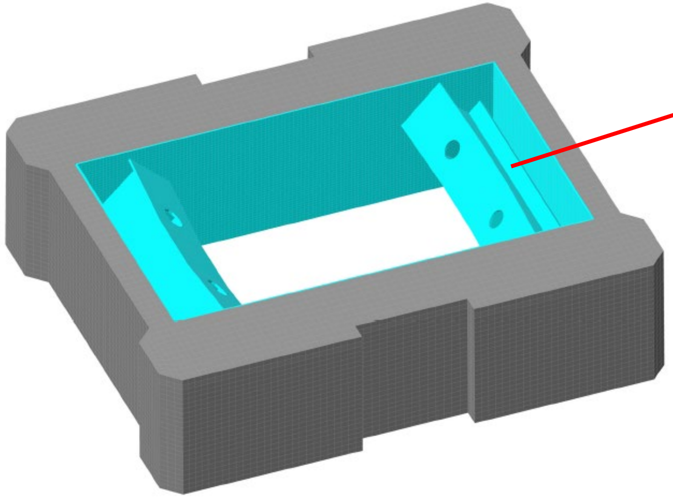
Overall Design: Tower Anchor Boxes

Anchor box for 4 stays at each level

- Composite action with concrete section
- Boxes not structurally joined together
- Max. lifting weight: 36 tonnes



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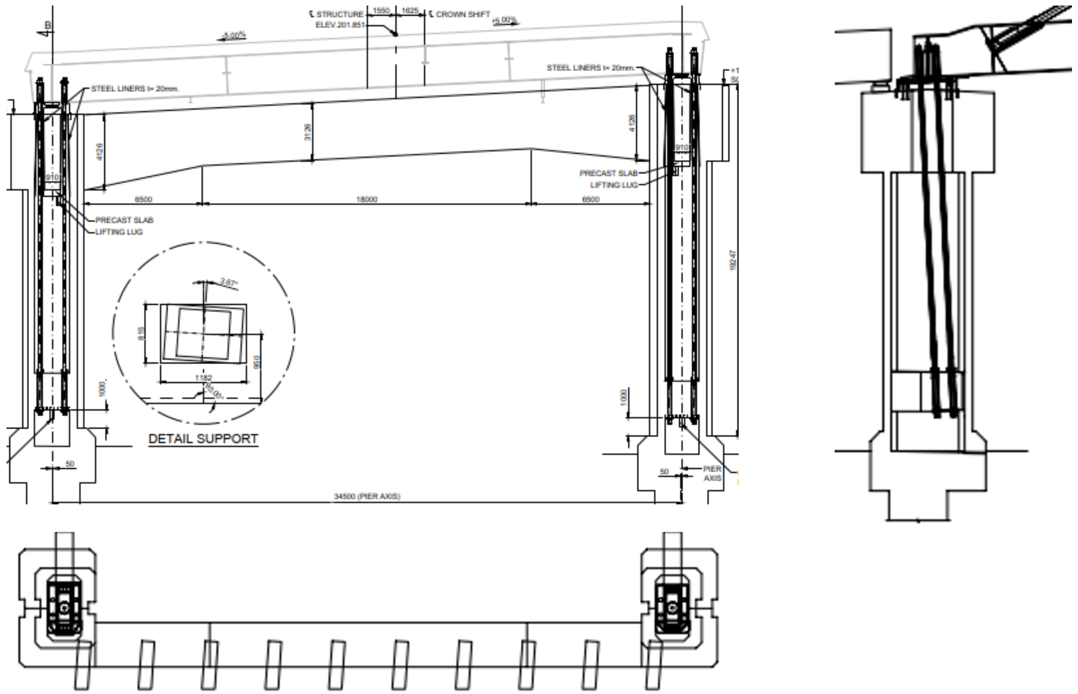
Overall Design: Piers

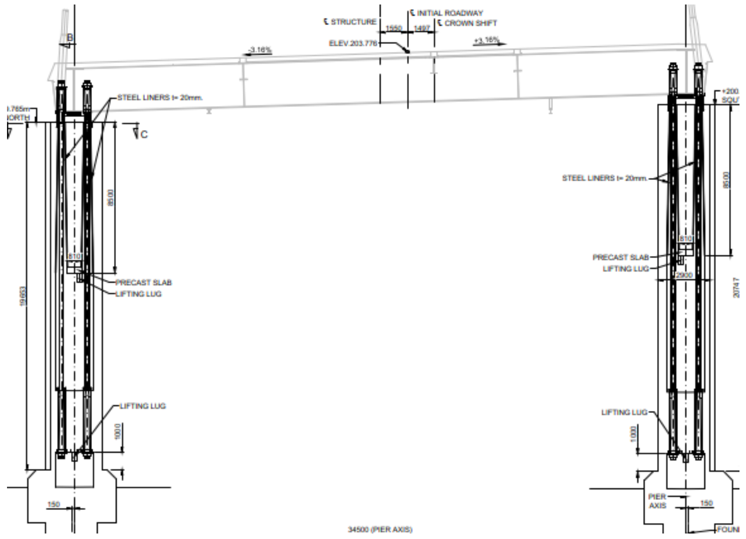
Anchor piers

- 2 columns with prestressed cross-beam
- Hollow-box reinforced concrete columns
- They support main and approach bridges
- 4 tie-downs per column provide net compression
- Single drilled shaft foundation → D=3.0 m (10 ft)



Side span piers

- 2 single columns both with guided bearings
- Hollow-box reinforced concrete columns
- 4 tie-downs per column provide net compression
- Single drilled shaft foundation → D=3.0 m (10 ft)

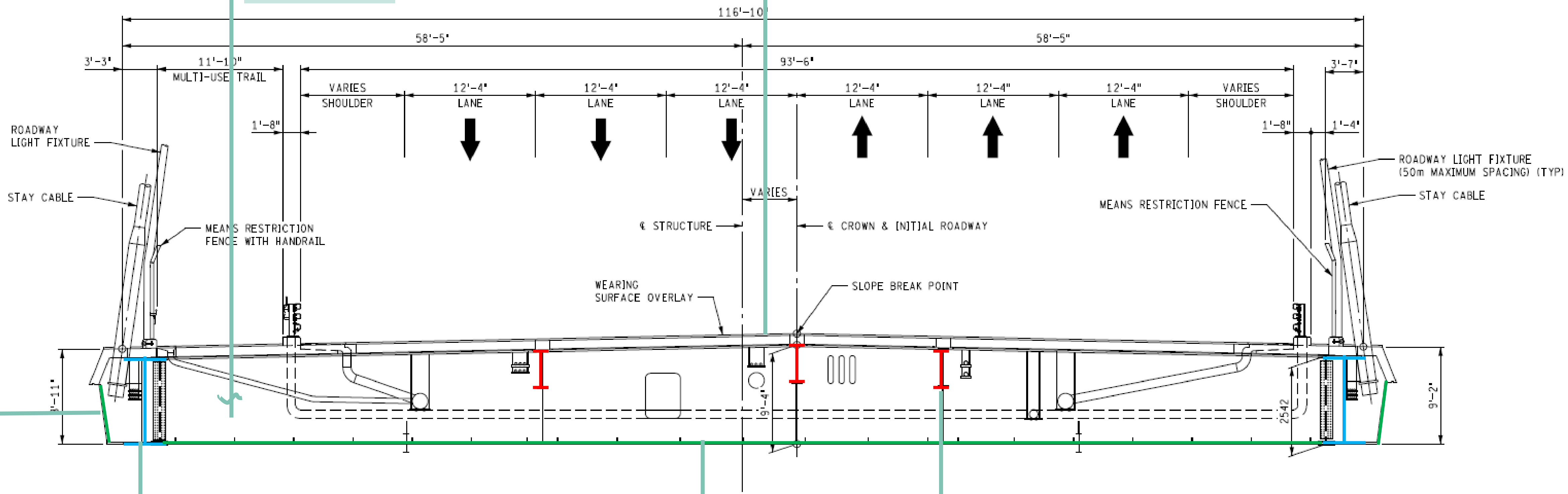


Overall Design: Superstructure Cross Section (Initial traffic configuration)

- 37.50 m (11.43 ft) wide, asymmetric
- Multiuse trail + 2 x 3 lanes

Floorbeams

Concrete deck: constant depth 0.25 m (9.8 in)



Edge girders → depth 2.50 m (8.2 ft)

Redundancy girders → Structural

Cladding panels → Non structural: aerodynamics + aesthetics

Soffit panels → Non-structural: aerodynamics + aesthetics

Overall Design: Superstructure Cross Section (Initial traffic configuration)

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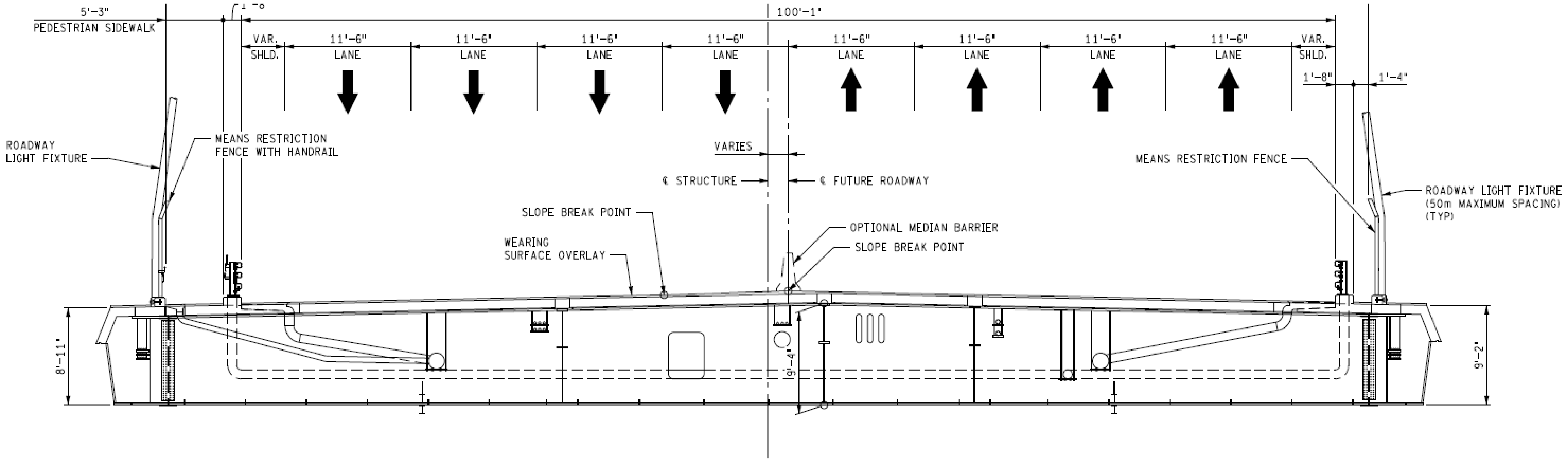
Redundancy girders → Structural

Cladding panels → Non structural: aerodynamics + aesthetics

Soffit panels → Non-structural: aerodynamics + aesthetics

Overall Design: Superstructure Cross Section (Future traffic configuration)

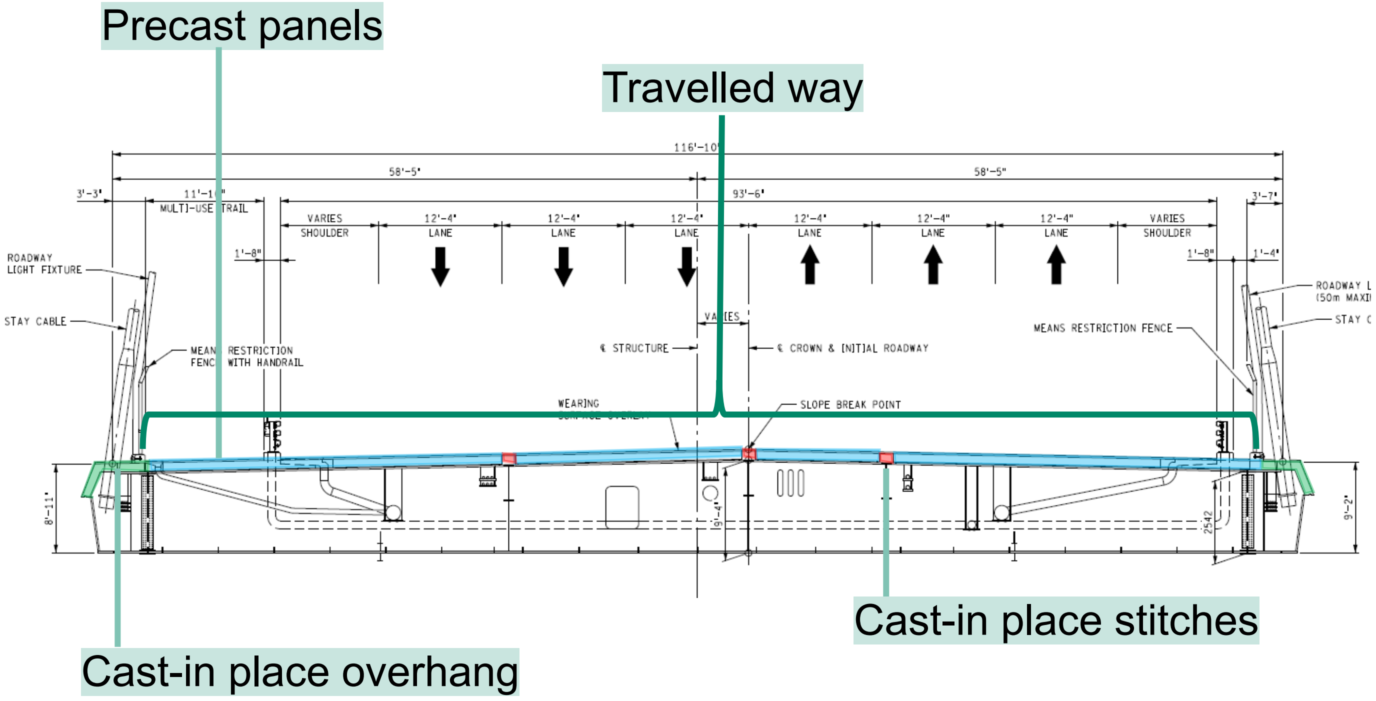
- 2 x 4 lanes

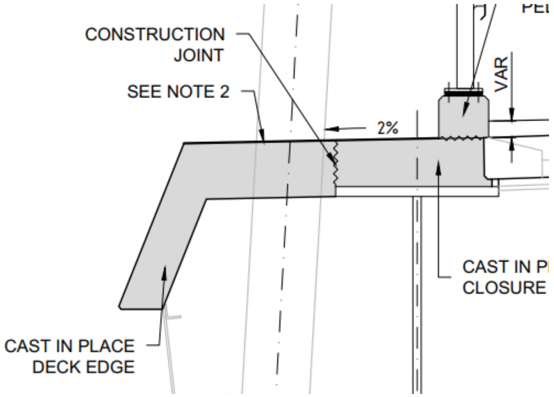


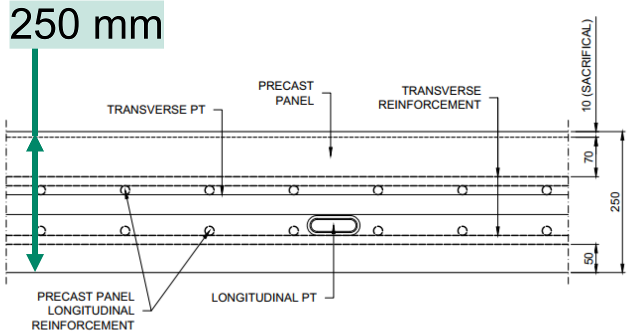
Superstructure Design

Precast concrete deck

- Precast slabs + stitches + overhang
- Zero tension under SLS in travelled way
- Longitudinal post-tensioning
  - Next to anchor piers
  - Center of main span
- Transverse post-tensioning
- Stainless steel reinforcement and embeds
- 240 mm (9.4in) + 10 mm (0.4in) (sacrificial)
- 70 mm cover at top reinforcement
- Local + global demands → Non-linear analysis

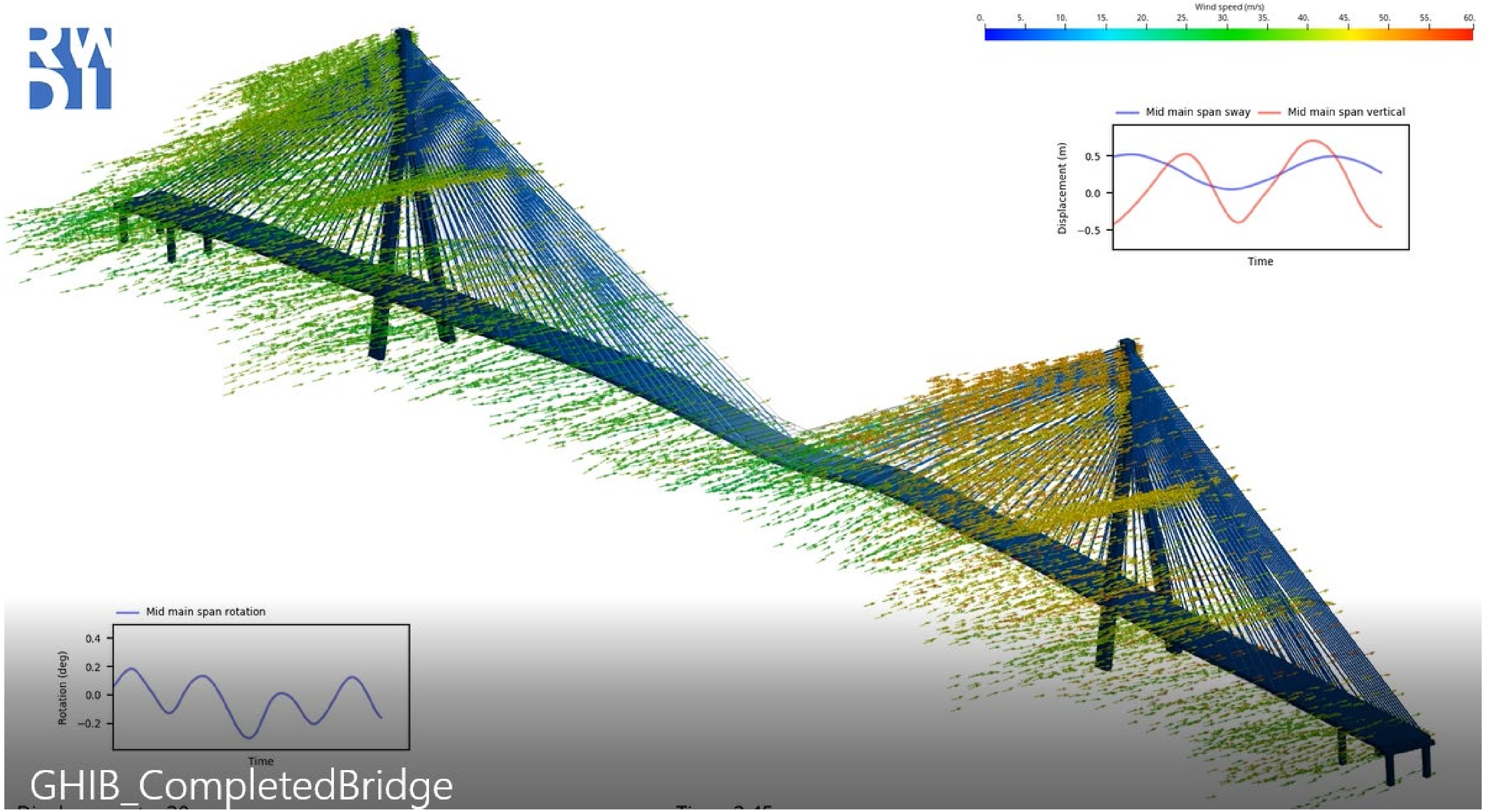






Aerodynamic Considerations

Wind buffeting analysis



Aerodynamic Considerations

Wind tunnel testing

Section model testing

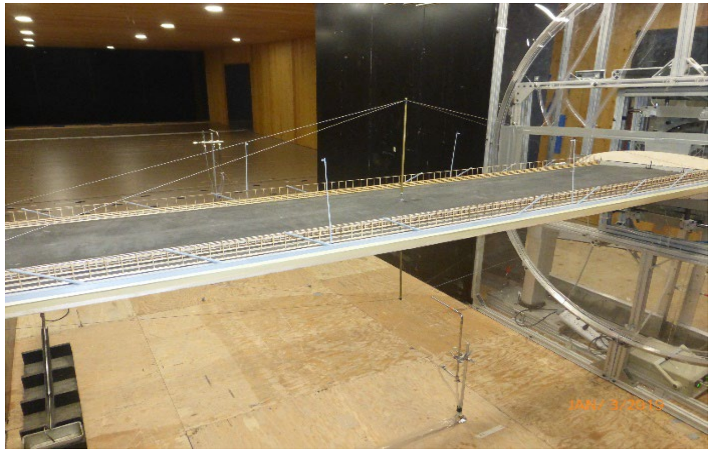
- Static Drag
- Flutter Stability
- Vortex induced oscillations
- Buffeting
- Erection stages
- Iced barriers/railings
- Vehicle Overturning

Full Aeroelastic Model

- Flutter
- Vortex Shedding
- Buffeting
- Construction stages

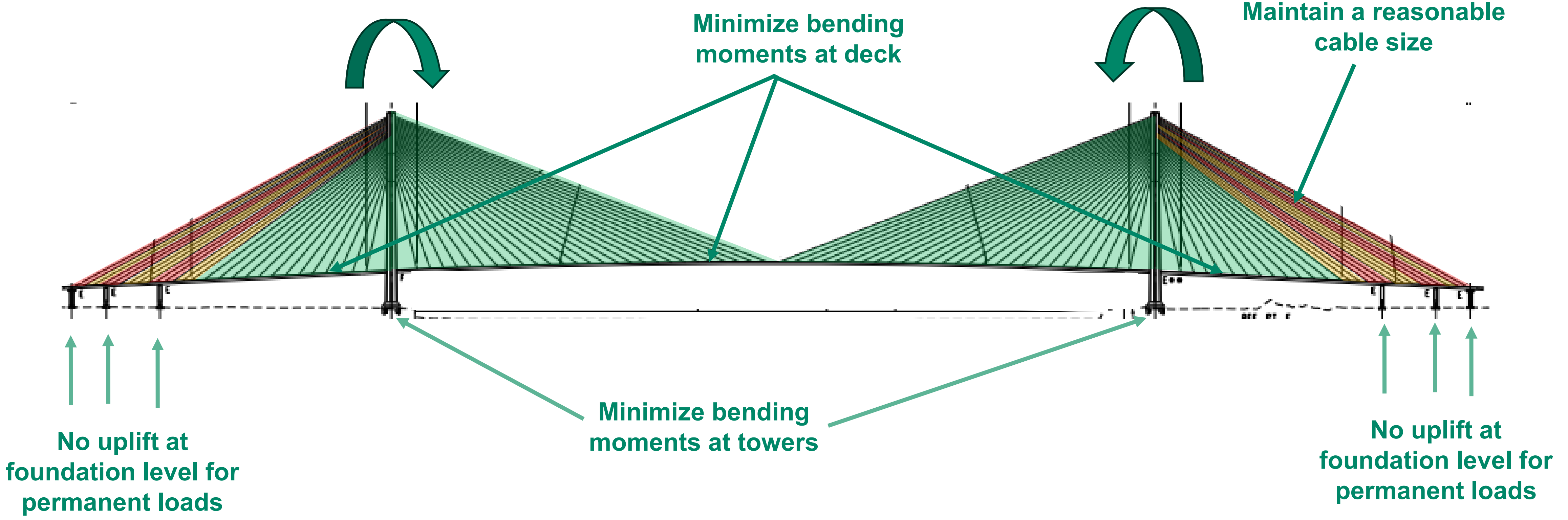
Tower Model

- Static drag
- Final and erection stages
- Aerodynamic Stability
- Interaction with Tower Crane



Stay Cables

Cable tuning

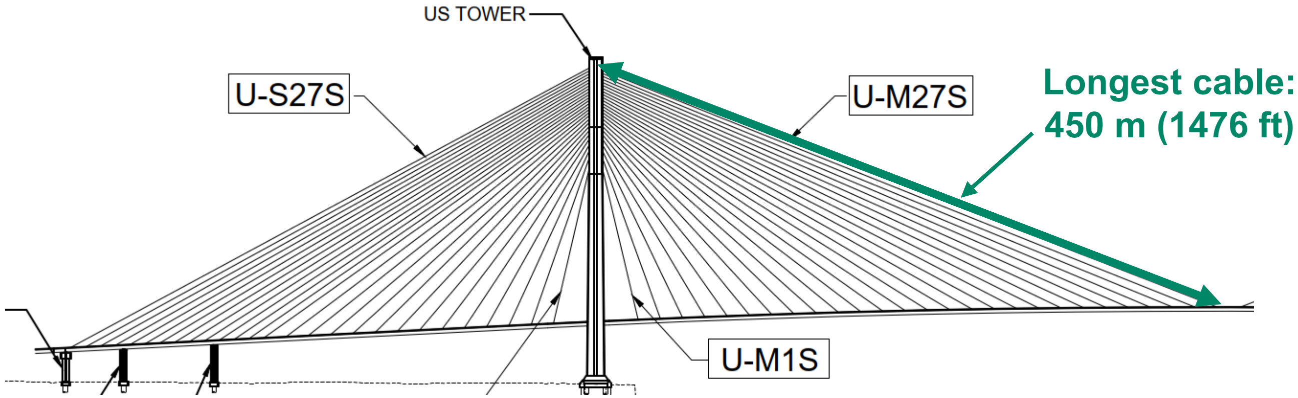


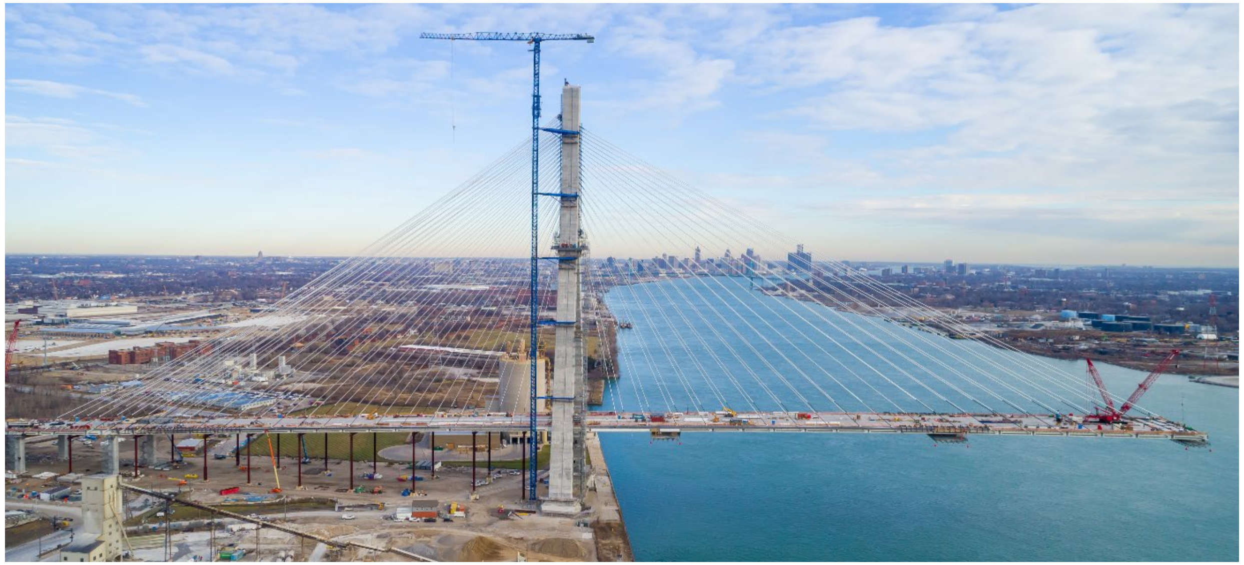
OBJECTIVE: Compensating the lower weight in the side span with tie-down forces at piers

Stay Cables

Parallel sheathed strands

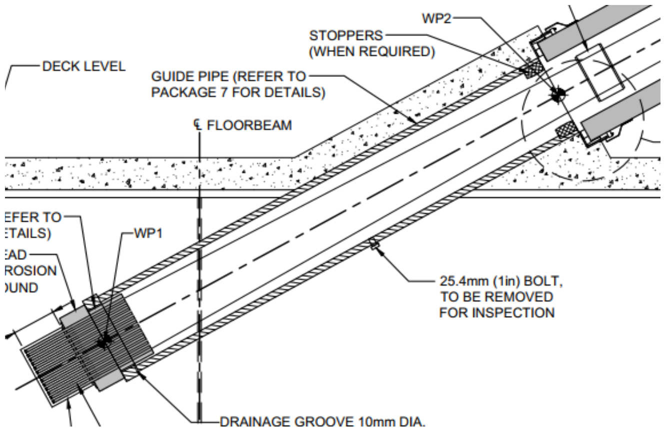
- Parallel 0.6” diameter grade 270 post tensioning strand
- Sizing: from 38 to 121 strands per cable
- Greased and sheathed strand, encased in outer polyethylene sheath
- Design for passive and future active ice control measures



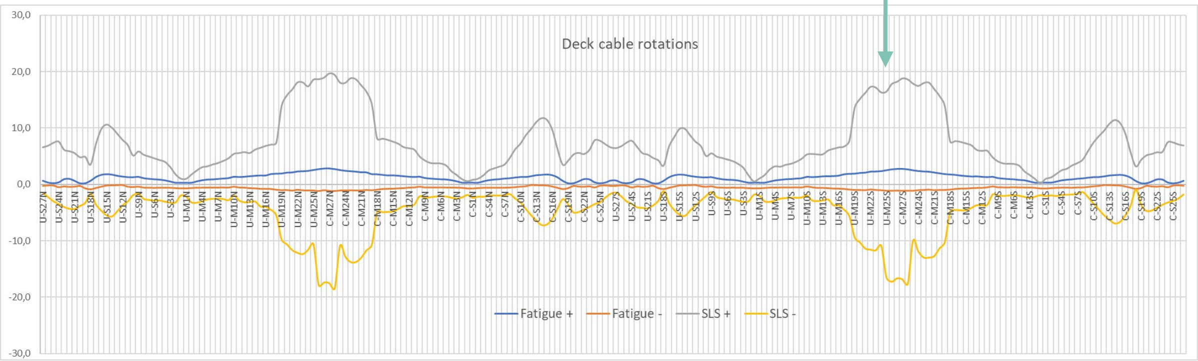


Stay Cables

Deck anchorages

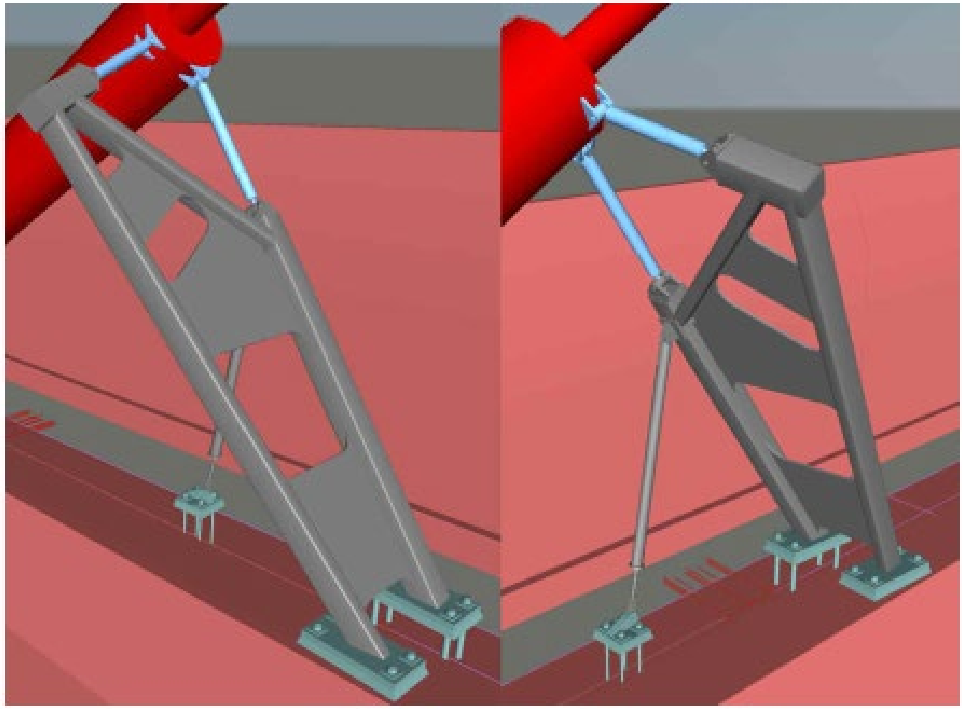


- Significant rotations → rotational offset
  - SLS < 25 mrad
  - Fatigue < 10 mrad



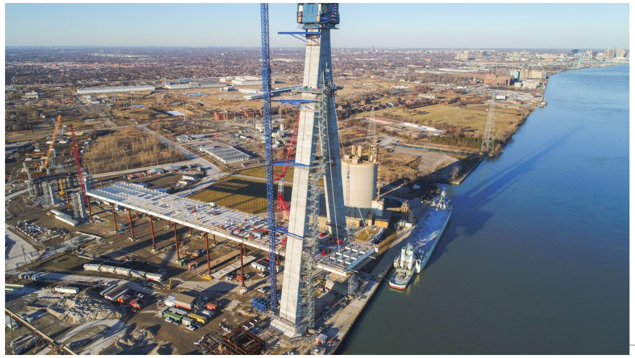
Damper frames

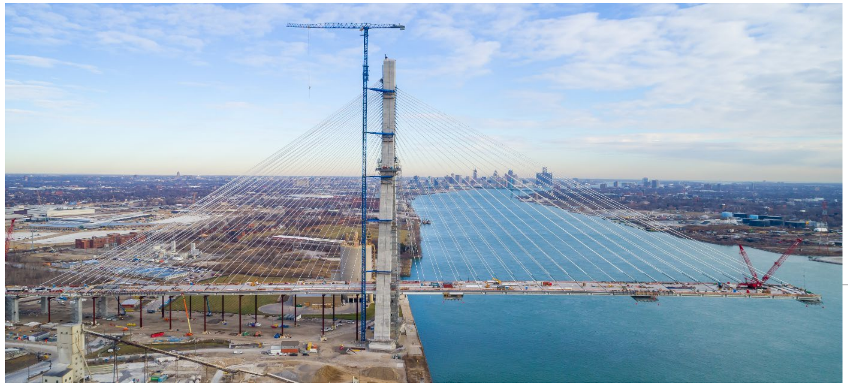
- All cables incorporate DYWIDAG external hydraulic dampers



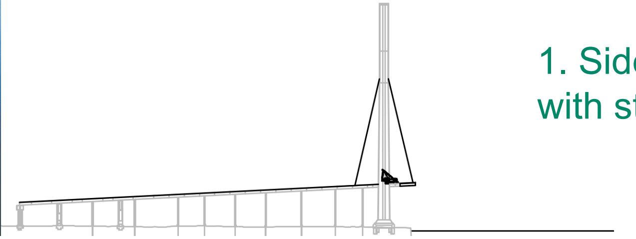
Erection: Outline

Shored side span + cantilevered main span

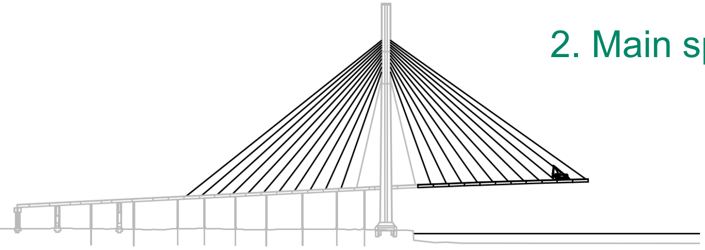




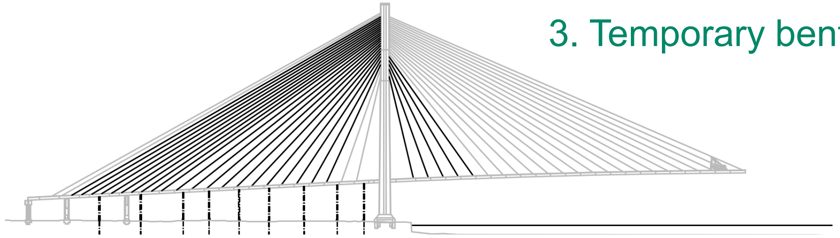
- Side span over temporary bents every ~30 m (98 ft)



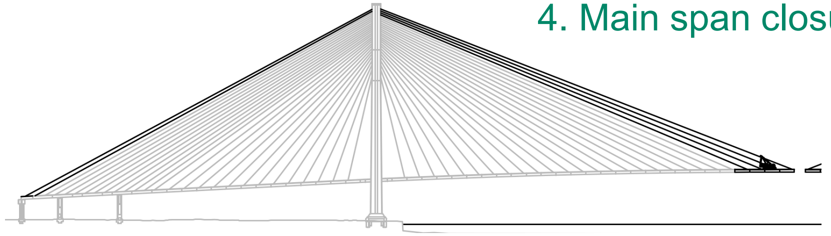
1. Side span (steel + concrete) with steel temporary bents



2. Main span: no river erection



3. Temporary bents removal



4. Main span closure + finishings

Erection: Main Span Segment

Stick Assembly

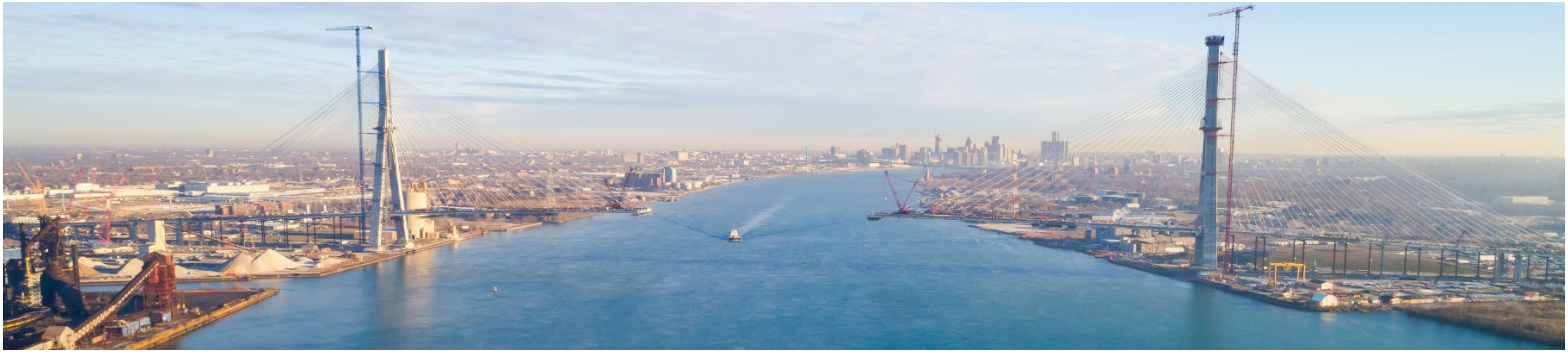
- Main span segment:
  - Piece-by-piece steel assembly
  - First cable stressing
  - Precast panel installation
  - Second cable stressing
  - Stressing of side span cable

Durability

Service life: 125 years

- Excepting replaceable elements:
  - Cable stays → 100 years.
  - Bearings & expansion joints → 50 years
  - Others → 30 – 60 years
- Concrete durability based on fib Bulletin 34 “Model code for Service Life Design”
- STADIUM analysis software
- Maintenance painting → CAPP System® (Coating Assessment and Painting Priority)
- Comprehensive Durability Plan including assessment of all materials incorporated into the bridge

Key dates: Main Bridge



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- Current focus is on Main Span Segment Erection Across the River, Stay Cable Installation
- Superstructure Side Span Erection Began 1st Quarter 2022
- Superstructure Main Span Erection Began January 2023
- Mid Span Closure – Mid 2024
- Construction Completion: Sept 2025
- 30 Year Handover 2055

Michigan Interchange

I-75 Improvements

4 Local Road Bridges

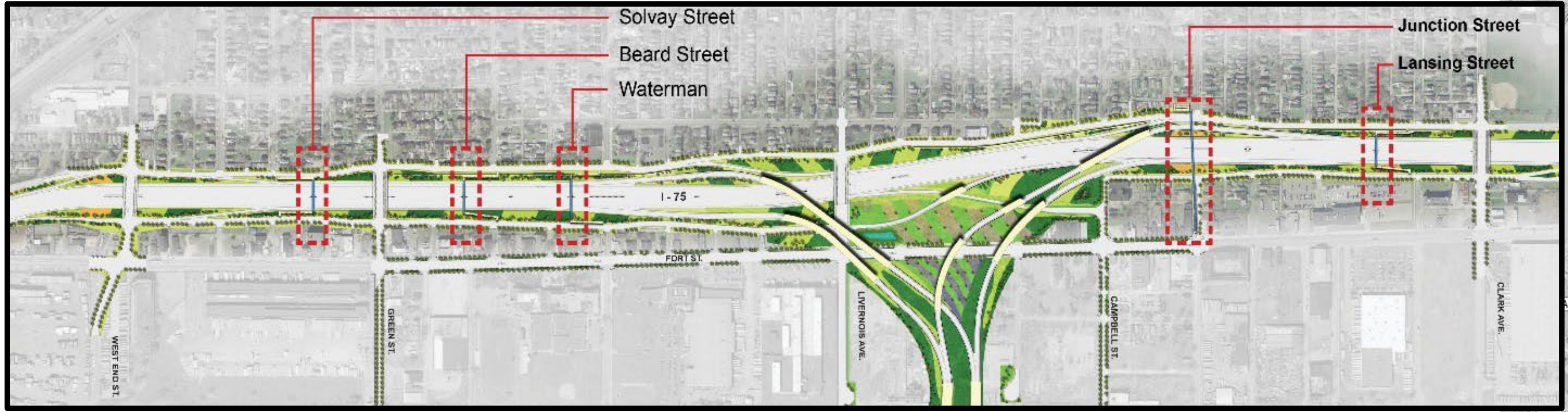
5 Pedestrian Bridges

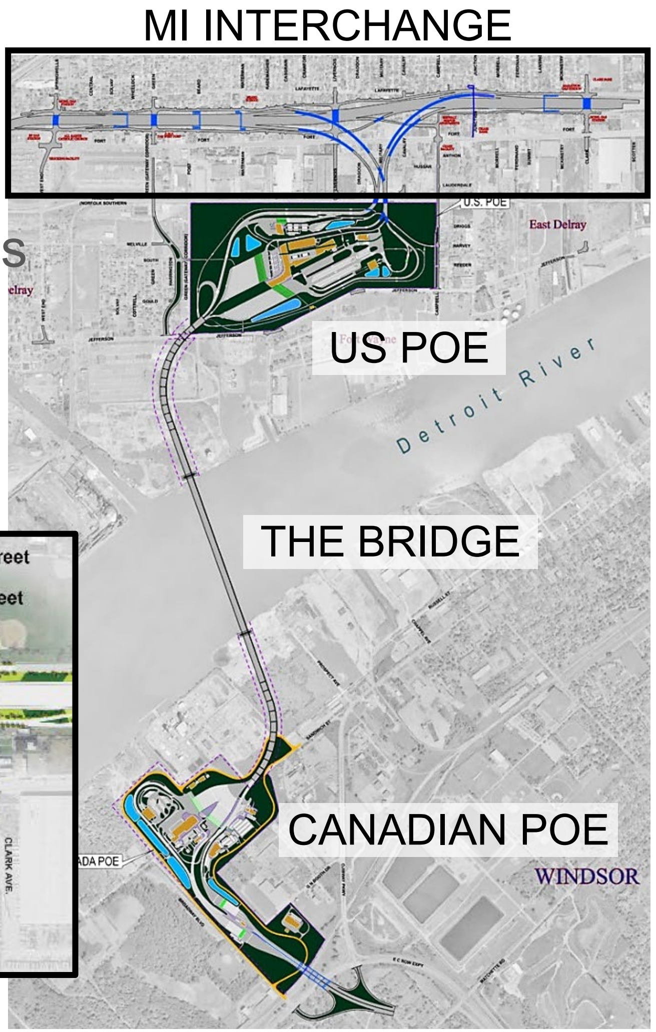
Noise Barrier Walls

Connecting Ramps

- 5 Steel Superstructure Flyover Bridges
- 5 Concrete Superstructure Ramp Bridges
- 8 Load Transfer Platforms
- 4 Gateway Towers –

  Transition from Steel to Concrete





MI Interchange – Pedestrian Bridges

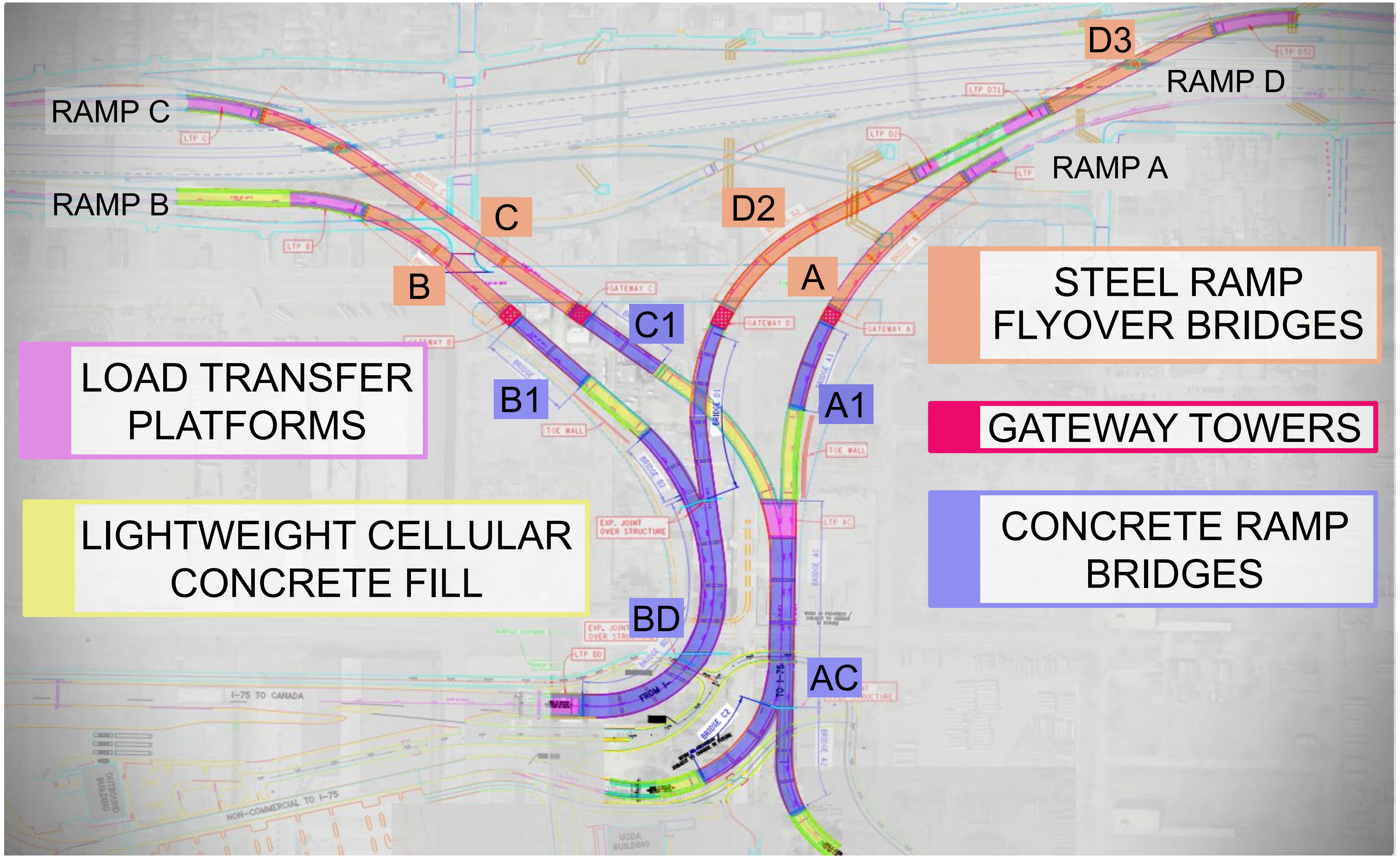
MI Interchange – Structures along I-75

Pedestrian & Local Bridges

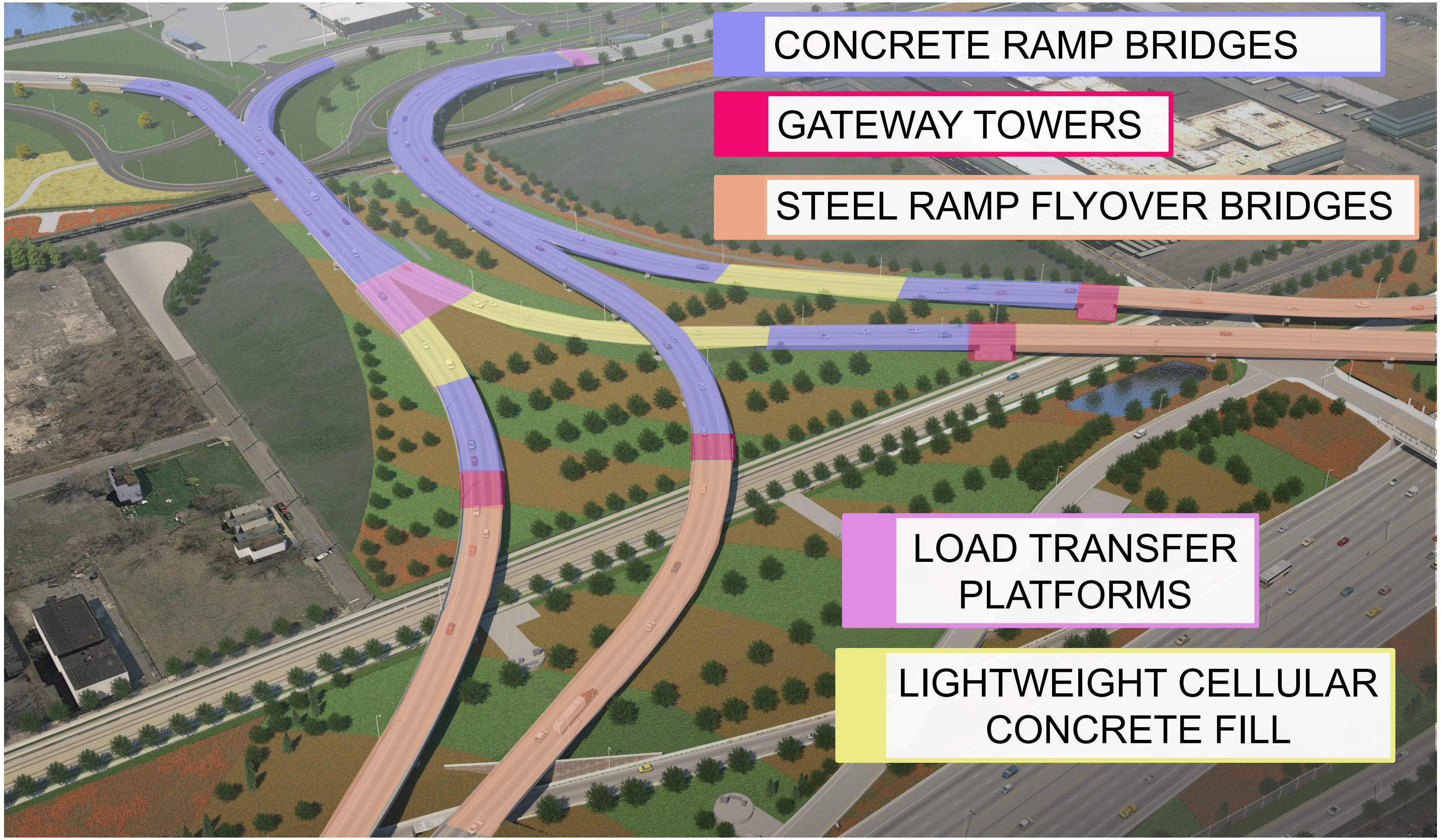
Arch was chosen option by the community

Aesthetic treatments for local road bridges

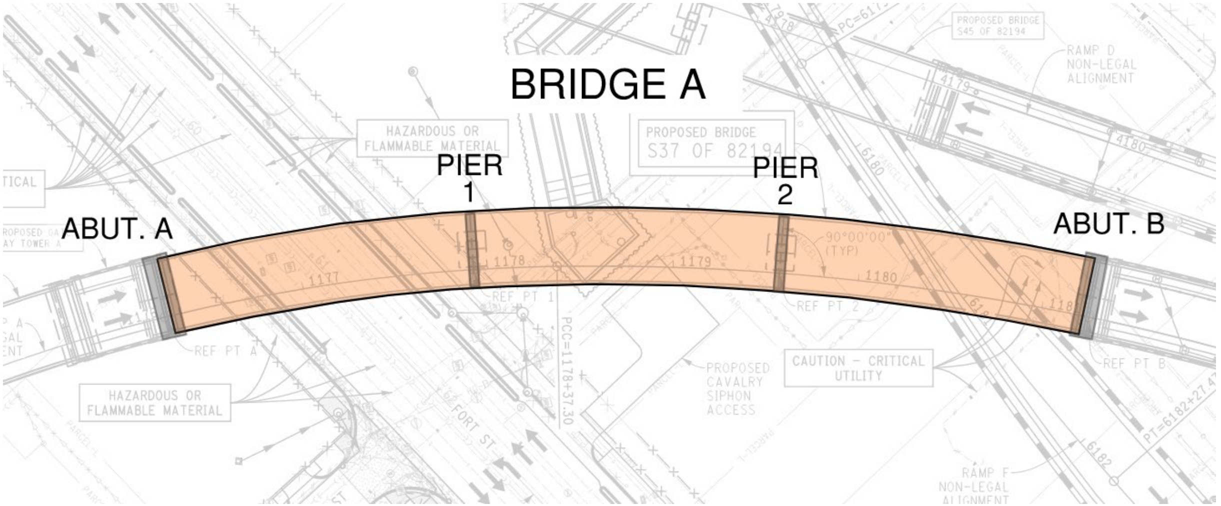
MI Interchange – Connecting Ramps

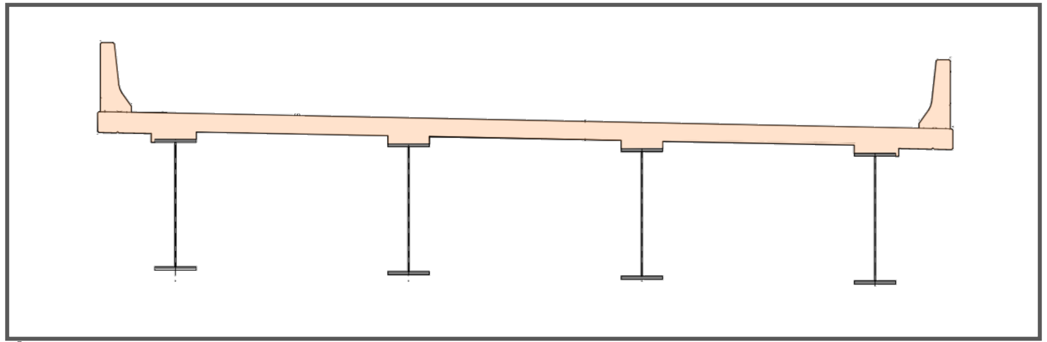


MI Interchange – Connecting Ramps



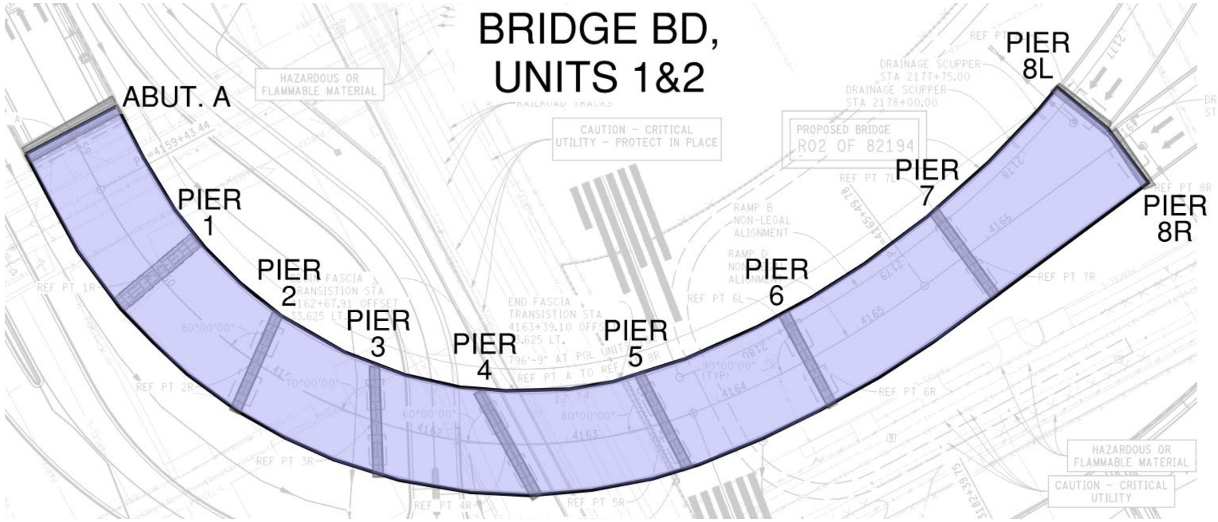
MI Interchange – Typical Flyover Bridges

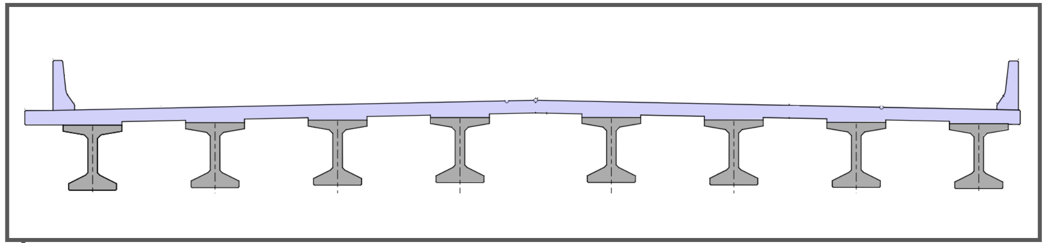




Four Curved Steel Plate Girders

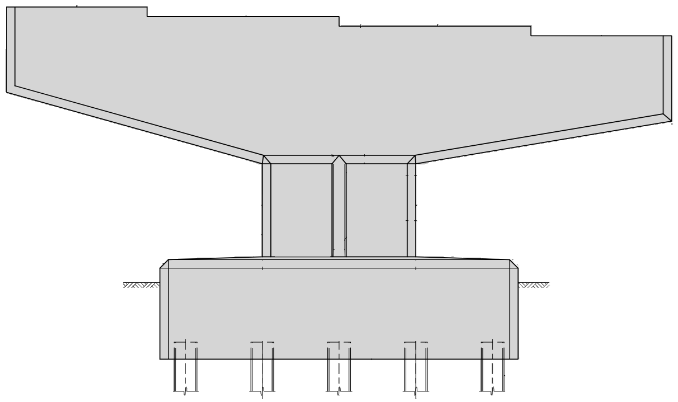
72” & 96” Webs

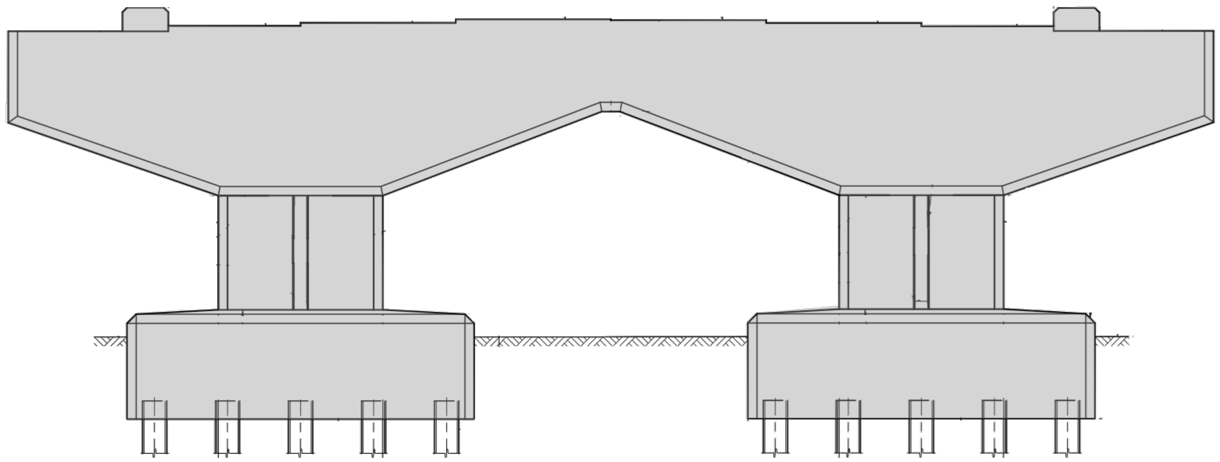


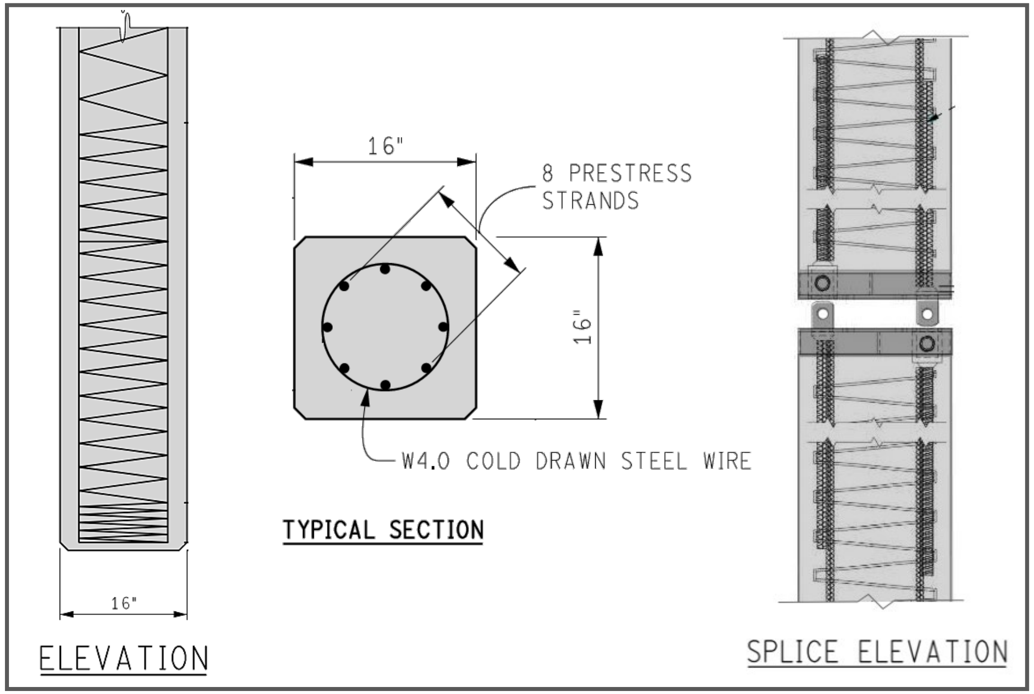


- Eight Prestressed Concrete Bulb-Tee Beams
- 54” Depth

MI Interchange – Typical Flyover Bridges

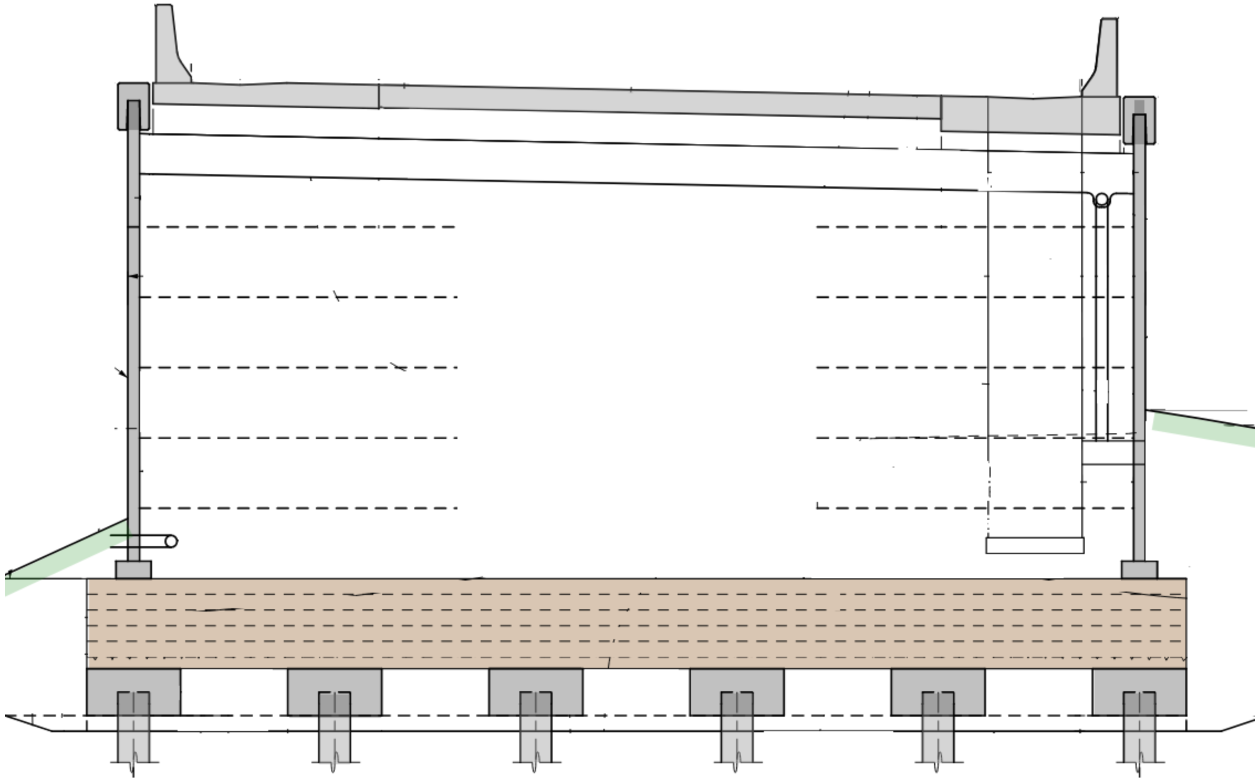






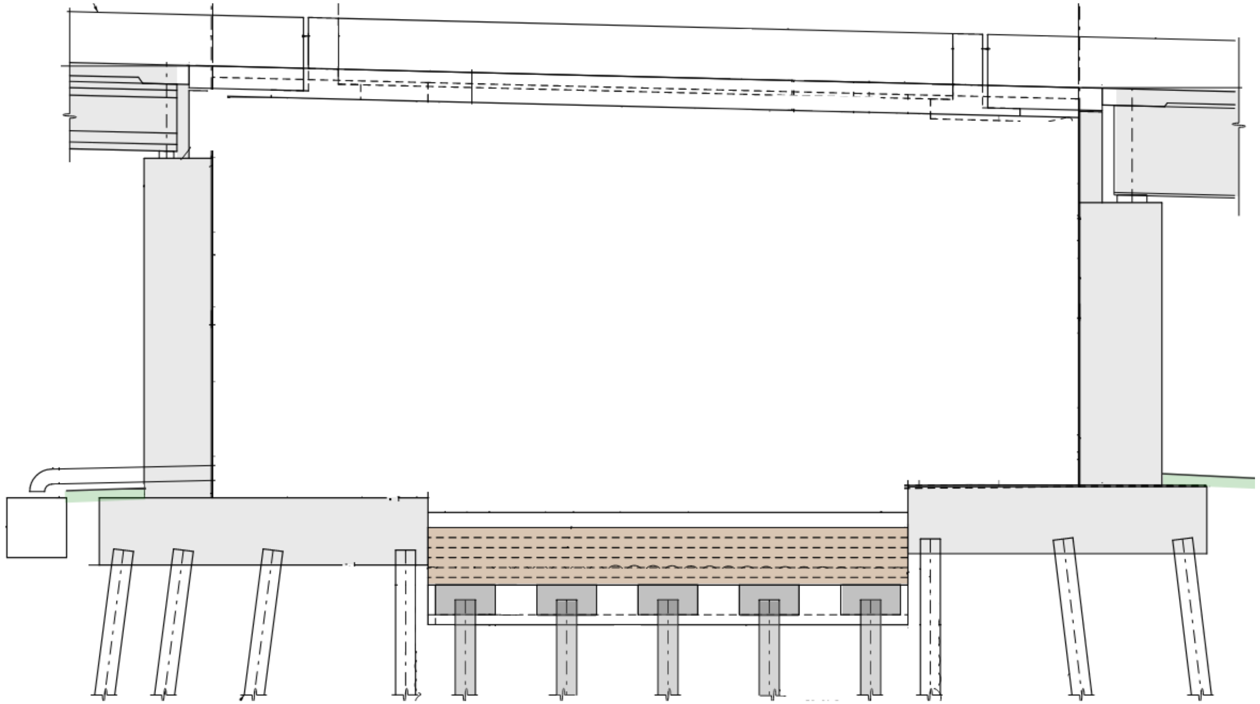
- Post-Tensioned Hammerhead Caps
- Single-Column Piers
- Prestressed Precast Concrete Piles

MI Interchange – Load Transfer Platforms (LTP)



- Piles @ 8' centers, both ways
- Geosynthetic Grid – 8" lifts
- Dense-Graded Aggregate fill
- 4' x 4' Pile caps
- MSE walls supporting fill

MI Interchange – Gateway Towers



- Transition between different bridge types and varying superstructure heights
- Consists of LTP with MSE wall to support fill between high wall abutments

MI Interchange – Connecting Ramps

MI Interchange – Unique Features

- 125 years of design service life for the Connecting Ramp bridges
- AASHTO LRFD (HL-93 MOD) and WDBA specific live loads
- Minimize expansion joints
- Project specific reports:
  - Bridge Design Criteria report
  - Bridge Access report
  - Durability plan
  - **Redundancy report**
  - Erection Procedure report

MI Interchange – Redundancy Analysis

Design-Build Specifications

Load Path Redundancy

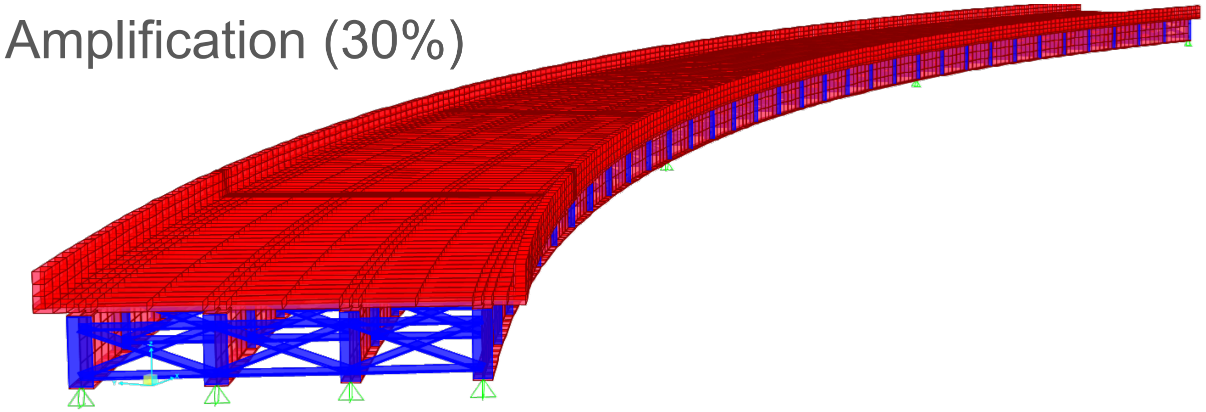
Positive & Negative Moment Fractures

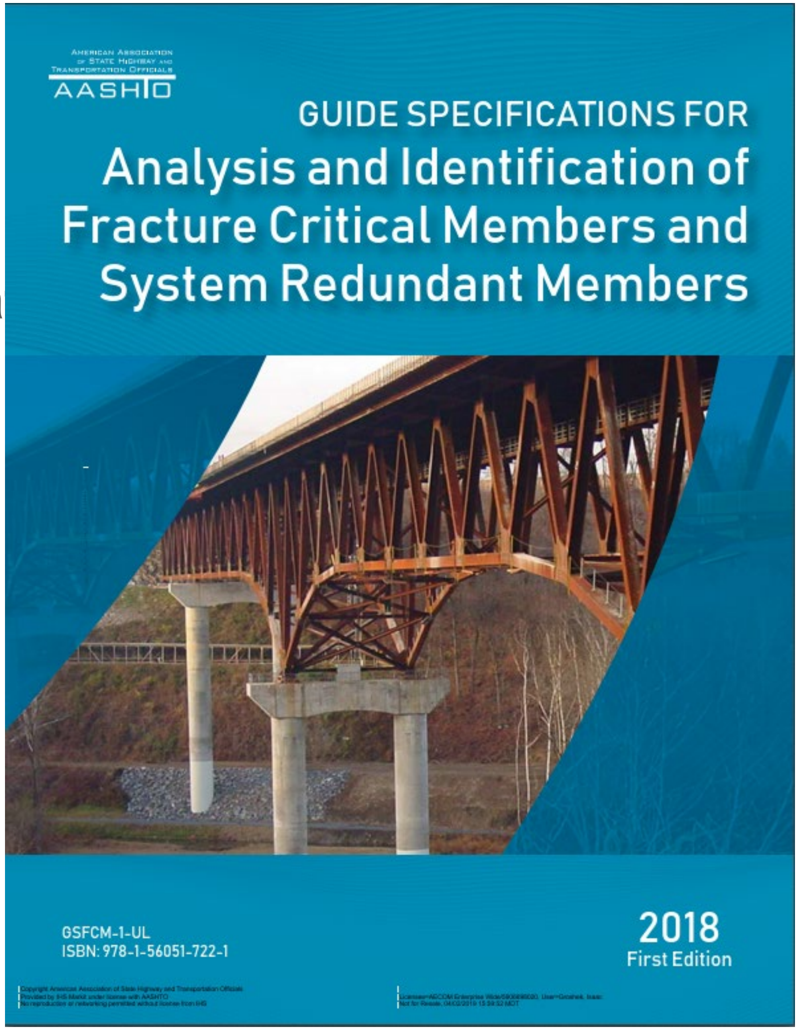
AASHTO Guide Specifications for Analysis and Identifica of Fracture Critical Members and System Redundant Members

Nonlinear Analysis Guidance

Strain-based Failure Criteria

Dynamic Amplification (30%)



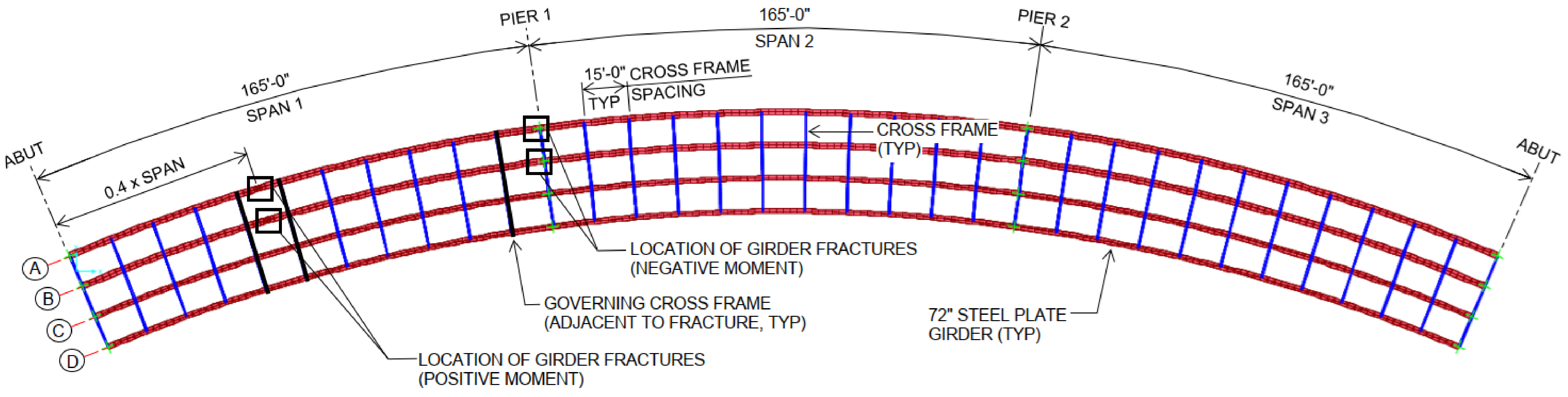


MI Interchange – Redundancy Analysis Fracture Locations

Positive Moment Fractures

Negative Moment Fractures

Governing Cross Frames

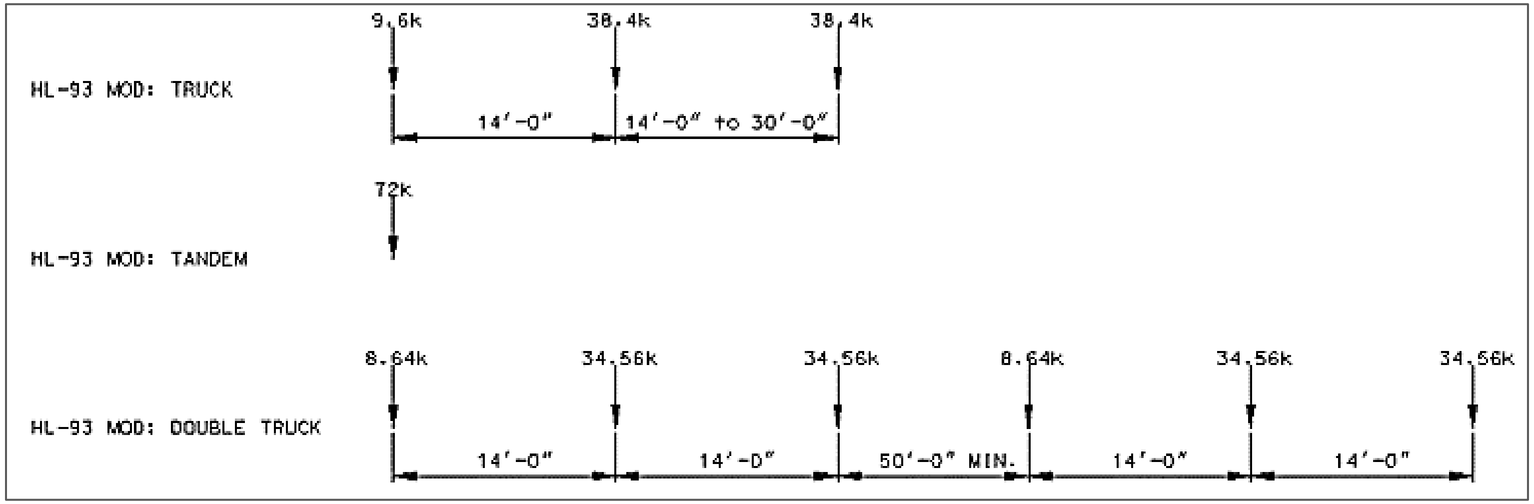


BRIDGE D1 - FRACTURE LOCATIONS

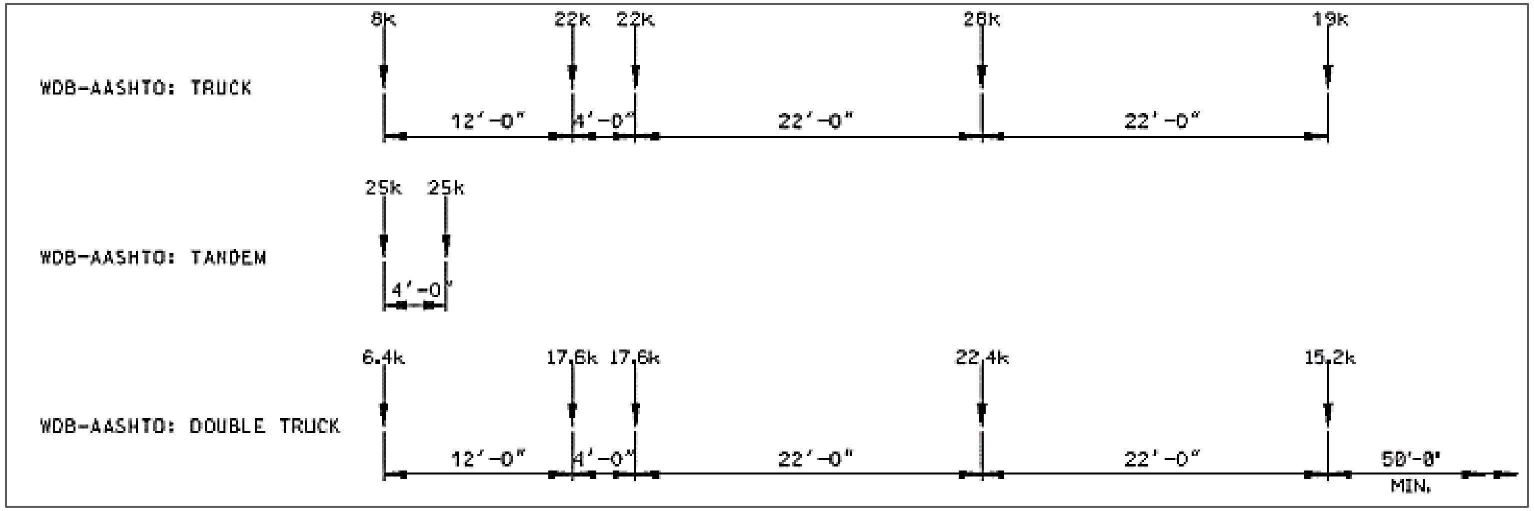
MI Interchange – Redundancy Analysis Vehicular Loading

HL-93 (MOD) Vehicular Loading

- 20% greater loading than standard HL-93 Loading



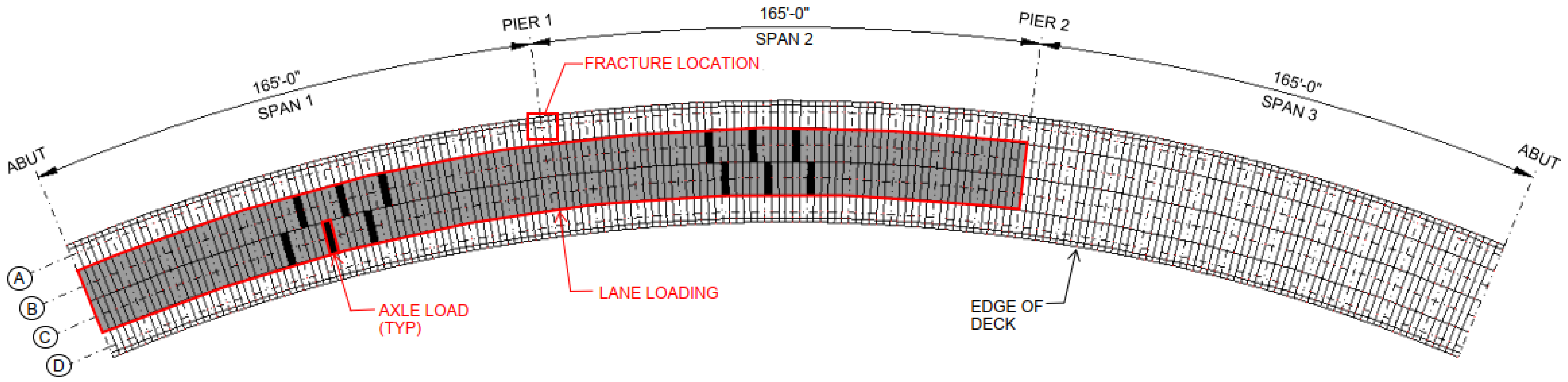
WDBA Vehicular Loading



MI Interchange – Redundancy Analysis Loading Application

Specific Loading Configurations for each fracture case determined by linear analysis.

Area loads used to apply truck and lane loads.



BRIDGE D1 - LIVE LOAD PATTERN - EXTERIOR GIRDER FRACTURE

MI Interchange – Redundancy Analysis
Redundancy Load Combination

Importance Factor, ηI = 1.05

- Required by D-B Specification
- Applies to all loading types

Dynamic Amplification Factor, DAR = 0.30

- Accounts for bridge oscillation after fracture
- Based upon research at University of Austin, TX

Static Force Amplification

- DC Loading = 1.05 x 1.30 x 1.25 = 1.71
- DW Loading = 1.05 x 1.30 x 1.50 = 2.05
- LL + IM Loading = 1.05 x 1.30 x 1.30 x 1.33 = 2.36!!!

Redundancy Load Combination:

$\eta_I \times (1+DA_R) \times [1.25DC + 1.5DW + 1.30(LL+IM)]$, IM = 33%

Reminder: HL-93 (Mod) is 20% heavier than HL-93 Loading

- 1.2 x 2.36 = 2.83

MI Interchange – Redundancy Analysis Challenges & Solutions

- Challenges:
  - Deck Crushing Failure – Positive Moment Fracture
  - Unacceptable Tensile Strains in Flanges
  - Unacceptable Strains in K-Style Cross Frames

- Solutions:
  - Confinement Reinforcement for Deck & Haunches
  - Ensure Flange Size for Increased Tensile Strains
  - X-Frame Style Cross Frames

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WDBA APWD
WINDSOR-DETROIT BRIDGE AUTHORITY | AUTORITÉ DU PONT WINDSOR-DETROIT

Bridging North America

- Private sector partner responsible for design, build, finance, operate and maintain the facility
    - ACS Infrastructure
    - DRAGADOS
    - Fluor
    - AECON

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- KTA Group — KTA a Bowman company
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