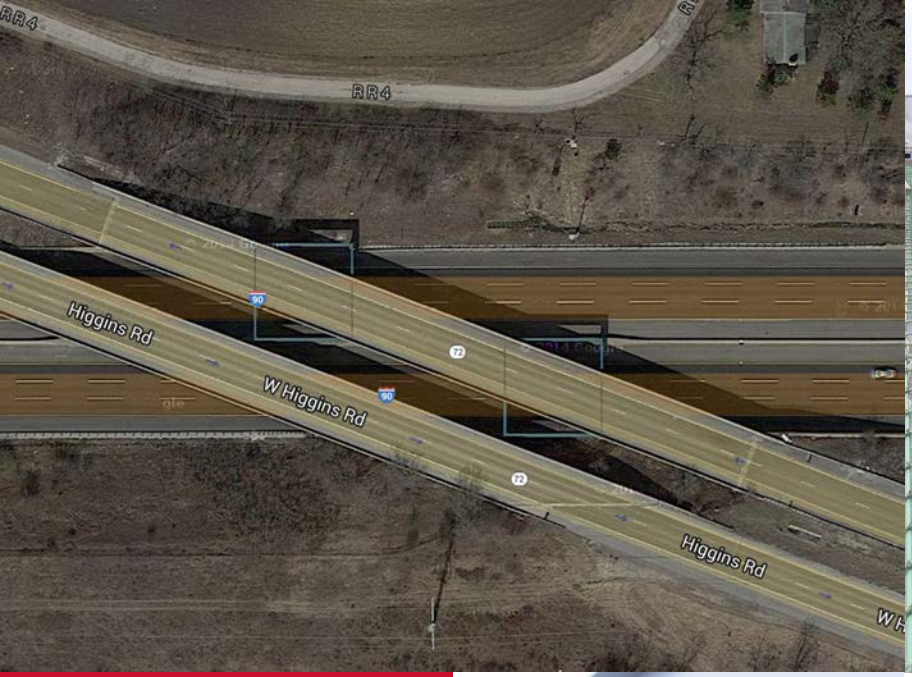
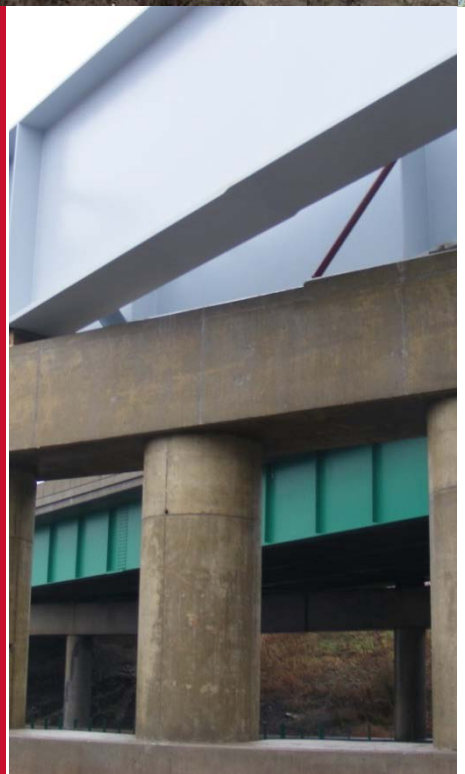
Illinois Tollway

Illinois Department of Transportation

HDR





That's No Ordinary Bridge

Ben Zeman, P.E.
Lance Peterman, P.E.,S.E.
Caahlen McAtee, P.E.

HDR

Presentation Outline

- Project Overview
- Design
  - Behavior of Skewed Structures
  - Framing Plan
  - 3D Finite Element Analysis
  - Detailing and Fit
  - Pier Design
  - Bearing Design
- Construction
- Summary

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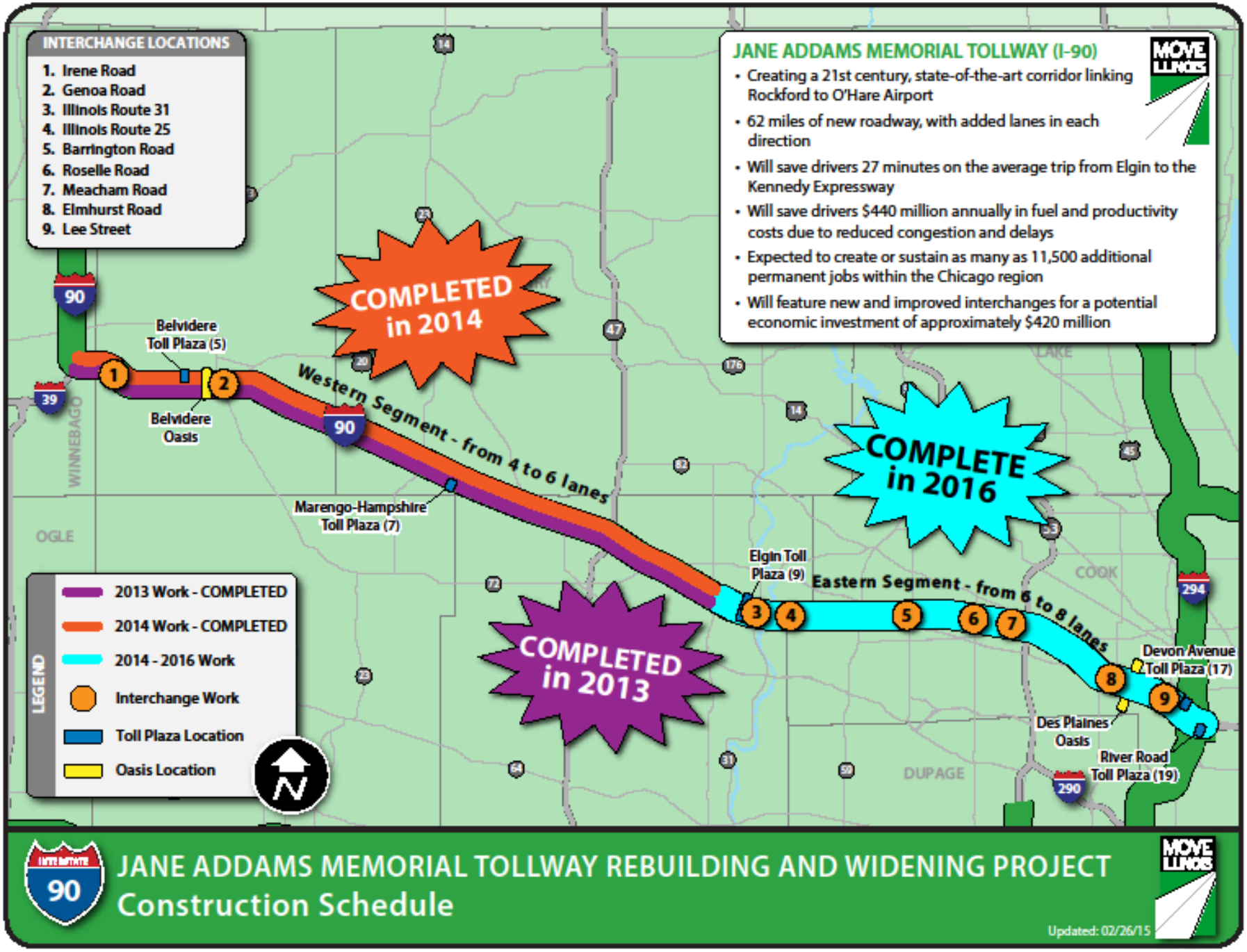
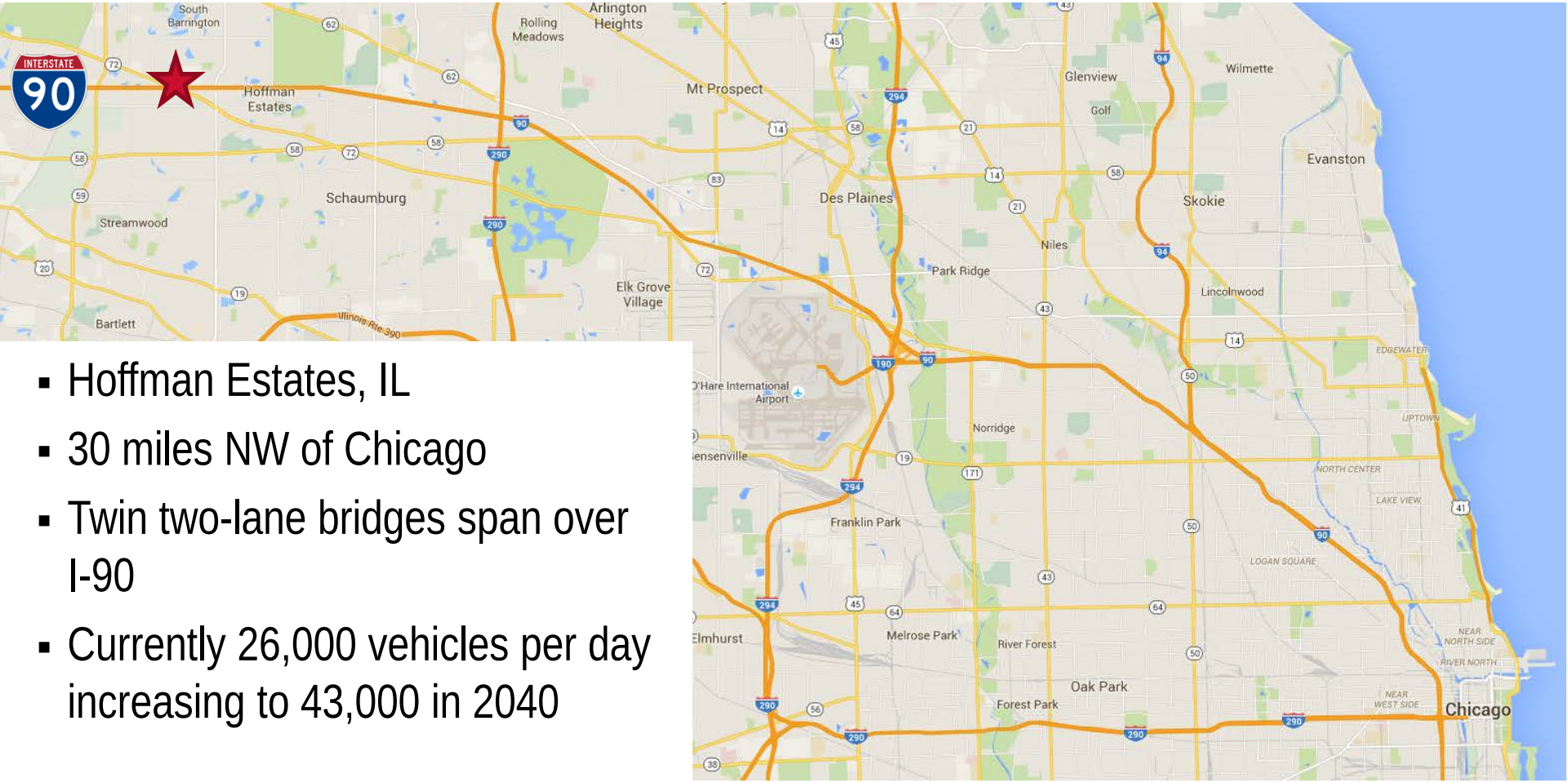

INTERCHANGE LOCATIONS
1. Irene Road
2. Genoa Road
3. Illinois Route 31
4. Illinois Route 25
5. Barrington Road
6. Roselle Road
7. Meacham Road
8. Elmhurst Road
9. Lee Street
JANE ADDAMS MEMORIAL TOLLWAY (I-90)
MOVE ILLINOIS
• Creating a 21st century, state-of-the-art corridor linking Rockford to O'Hare Airport
• 62 miles of new roadway, with added lanes in each direction
• Will save drivers 27 minutes on the average trip from Elgin to the Kennedy Expressway
• Will save drivers $440 million annually in fuel and productivity costs due to reduced congestion and delays
• Expected to create or sustain as many as 11,500 additional permanent jobs within the Chicago region
• Will feature new and improved interchanges for a potential economic investment of approximately $420 million
COMPLETED in 2014
COMPLETE in 2016
COMPLETED in 2013
Belvidere Toll Plaza (5)
Belvidere Oasis
Western Segment - from 4 to 6 lanes
Marengo-Hampshire Toll Plaza (7)
Elgin Toll Plaza (9)
Eastern Segment - from 6 to 8 lanes
Devon Avenue Toll Plaza (17)
Des Plaines Oasis
River Road Toll Plaza (19)
WINNEBAGO
OGLE
COOK
DUPAGE
LAKE
LEGEND
2013 Work - COMPLETED
2014 Work - COMPLETED
2014 - 2016 Work
Interchange Work
Toll Plaza Location
Oasis Location
N
JANE ADDAMS MEMORIAL TOLLWAY REBUILDING AND WIDENING PROJECT
Construction Schedule
Updated: 02/26/15

Project Overview – Higgins Road



- Hoffman Estates, IL
- 30 miles NW of Chicago
- Twin two-lane bridges span over I-90
- Currently 26,000 vehicles per day increasing to 43,000 in 2040

Project Overview

WB: I957

EB: I978

Exist. WB Bridge:

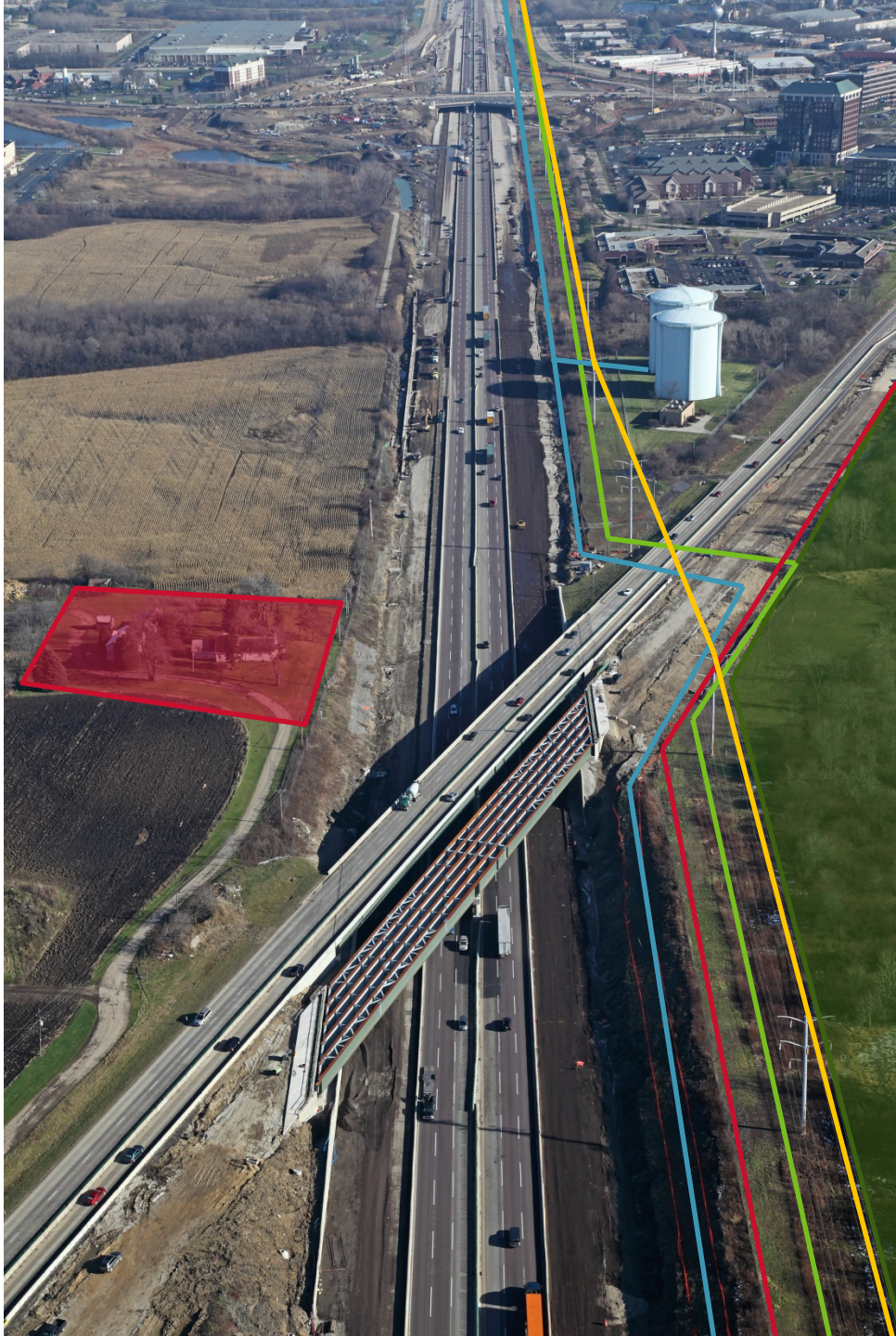
- 5 simple spans: 471 ft total length
- 60” deep plate girders
- WB fracture critical substructure
- WB no skew counterfort wall abut

Exist. EB Bridge

- 3 continuous spans: 503 ft total length
- 81” deep plate girders
- skewed counterfort wall abut

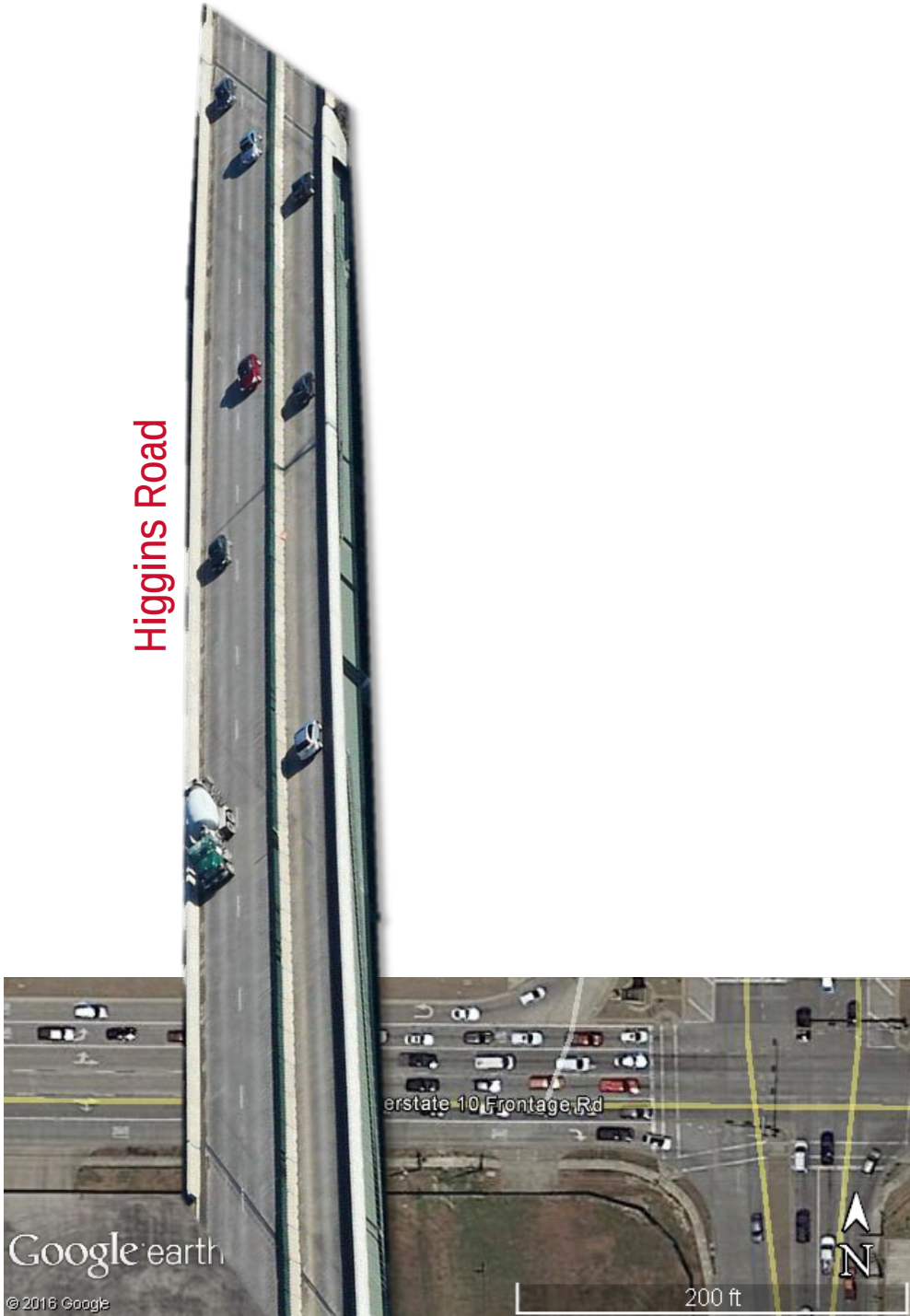
Project Overview

- High voltage power lines
- Large diameter water main
- Large diameter gas mains
- Oil pipeline
- Historic farm properties
- Forest preserve



Project Overview

- Two spans at 280 feet = 560 feet
- Long enough to cross
  - a 6-lane road
  - a 4-lane road
  - AND a 20-lane freeway…
  - With room to spare



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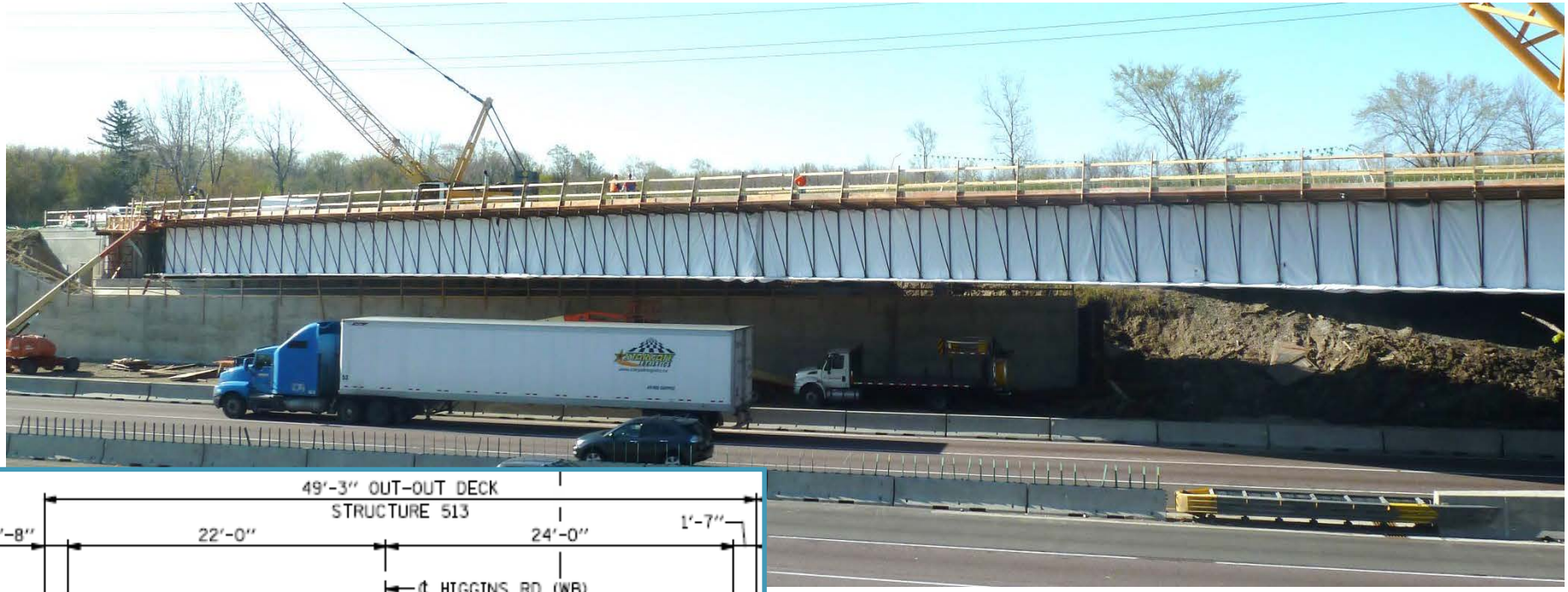
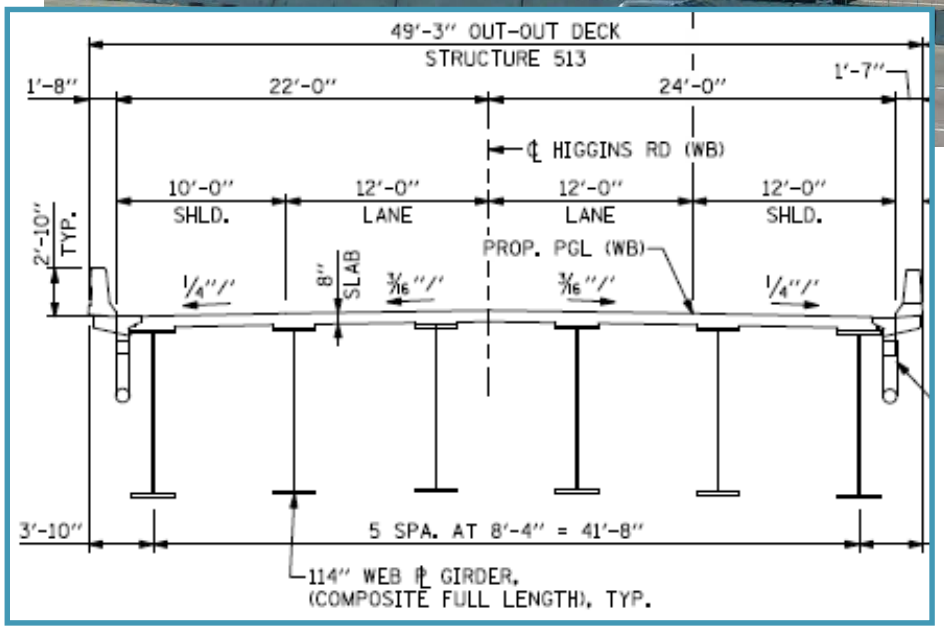
Design

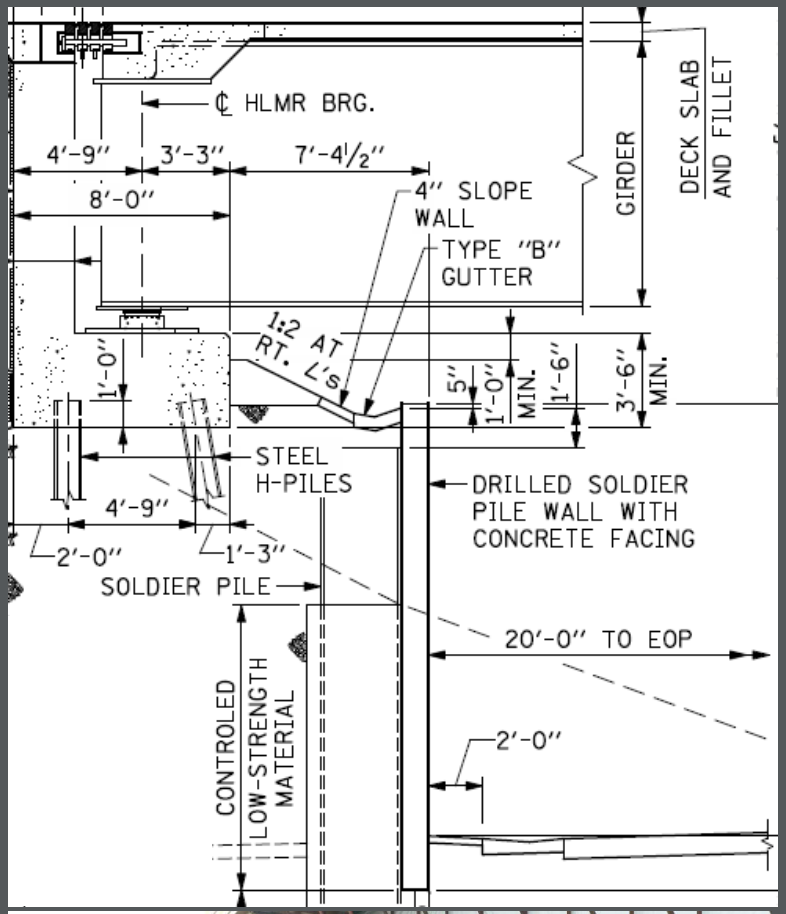




- 70-degree skew
- Two spans @ 280 ft = 560 ft total length
- Deck width: 49’-3” with three lanes
- 6 plate girders
- Webs: 13/16” x 9’-6”
- Flanges: 1.5”x26” to 3”x34”
- X-type intermediate cross-frames
- Full-depth abutment diaphragm along skew
- Full-depth pier diaphragm normal to girders

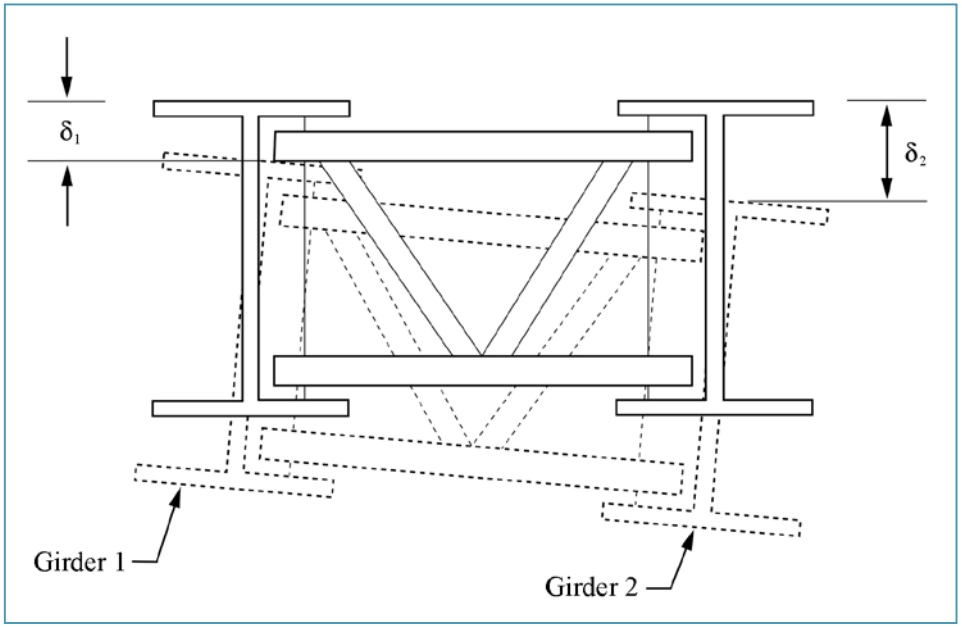
Design

- Stub abutments behind 600 ft long soldier pile walls
- Modular swivel type expansion joints at each abutment
- Multi-column pier supported on 4 rows of battered piles



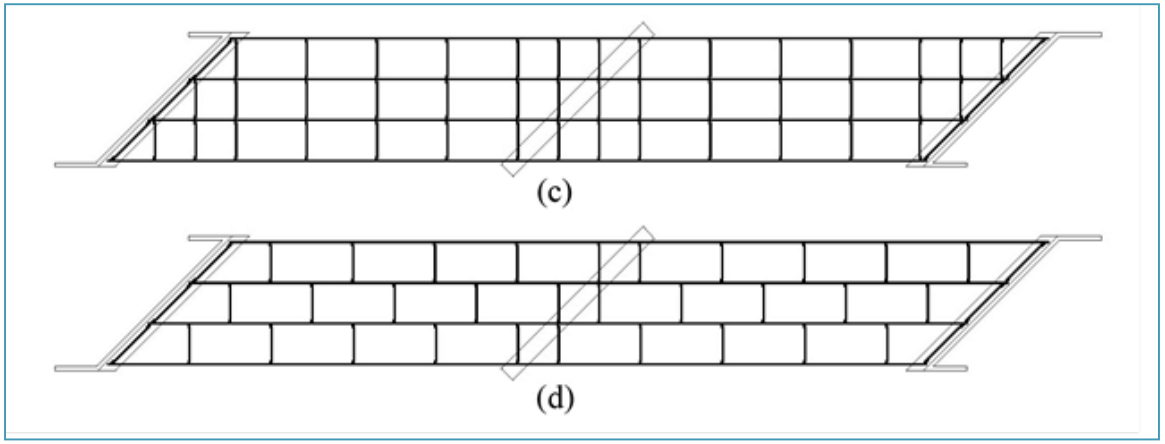
Behavior of Skewed Structures

- Girder differential vertical deflection causes lateral deflections and twist
- Shifting of load between girders creates torsion and changes the vertical and horizontal reactions
- Cross-frames attempt to equalize adjacent girder deflections



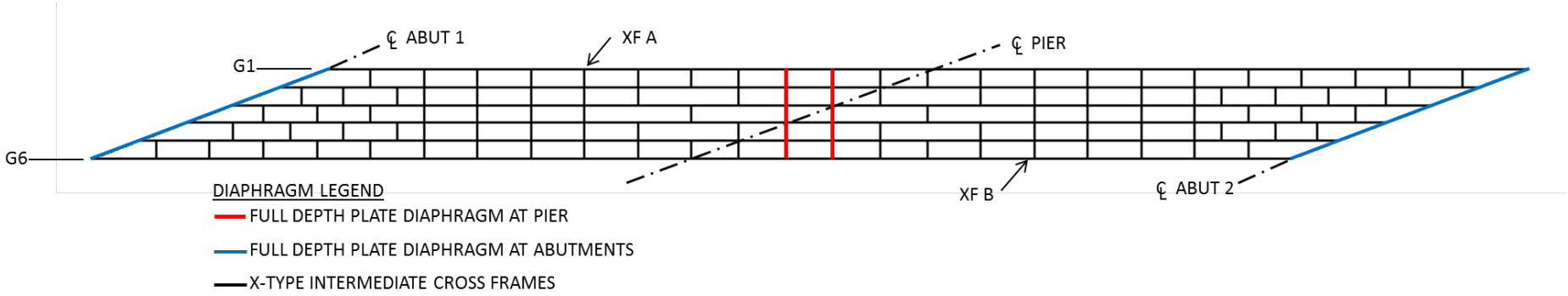
Framing Plan

- Integrated system behavior is recognized with framing plan arrangement
- Continuous versus staggered diaphragms
  - Manage Uplift
  - Flange Lateral Bending



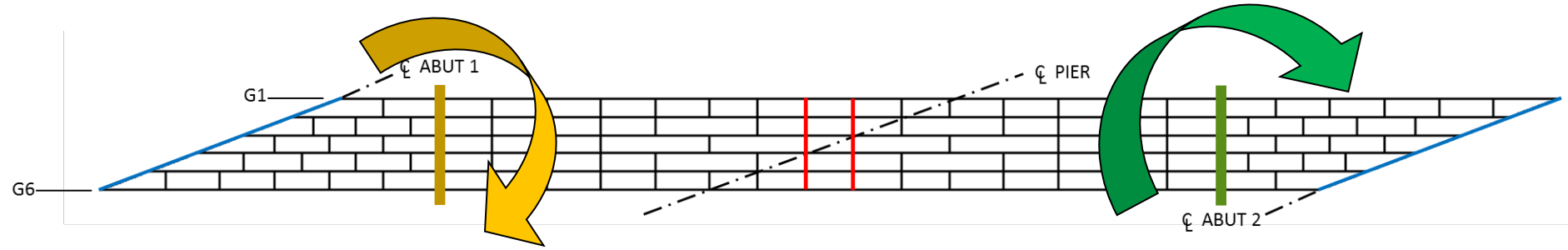
Framing Plan

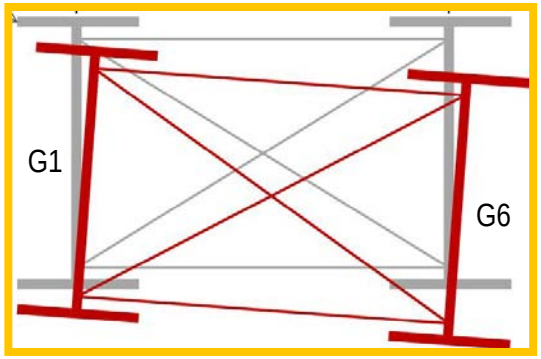
- Selectively remove cross-frames near the pier
  - Nuisance stiffness, reduce transverse load paths
- Use full-depth diaphragms at interior pier location
  - Attract load at two distinct locations
- Use staggered cross-frame pattern at skewed ends
  - Eliminate the transverse load paths



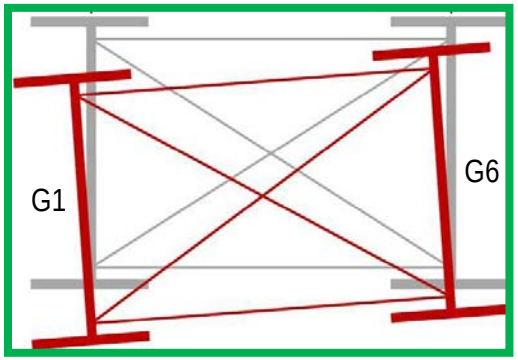
Framing Plan

- Opposite direction of rotation between span 1 and 2

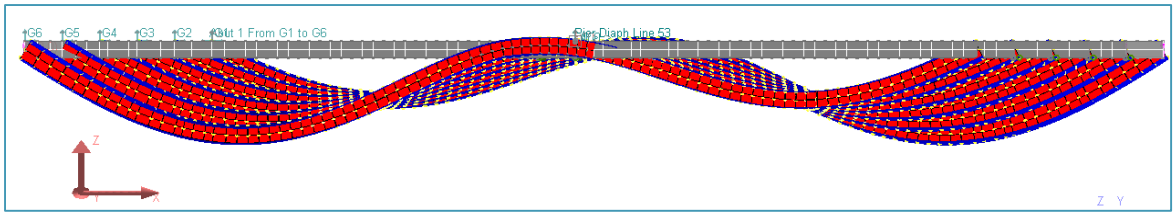




SPAN 1 – LOOKING TOWARDS ABUT 2



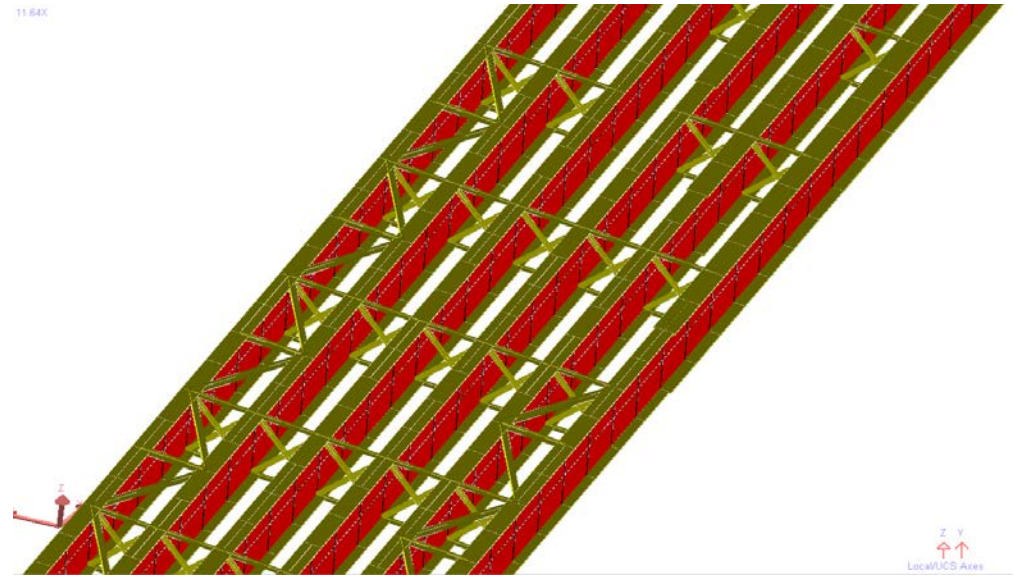
SPAN 2 – LOOKING TOWARDS ABUT 2

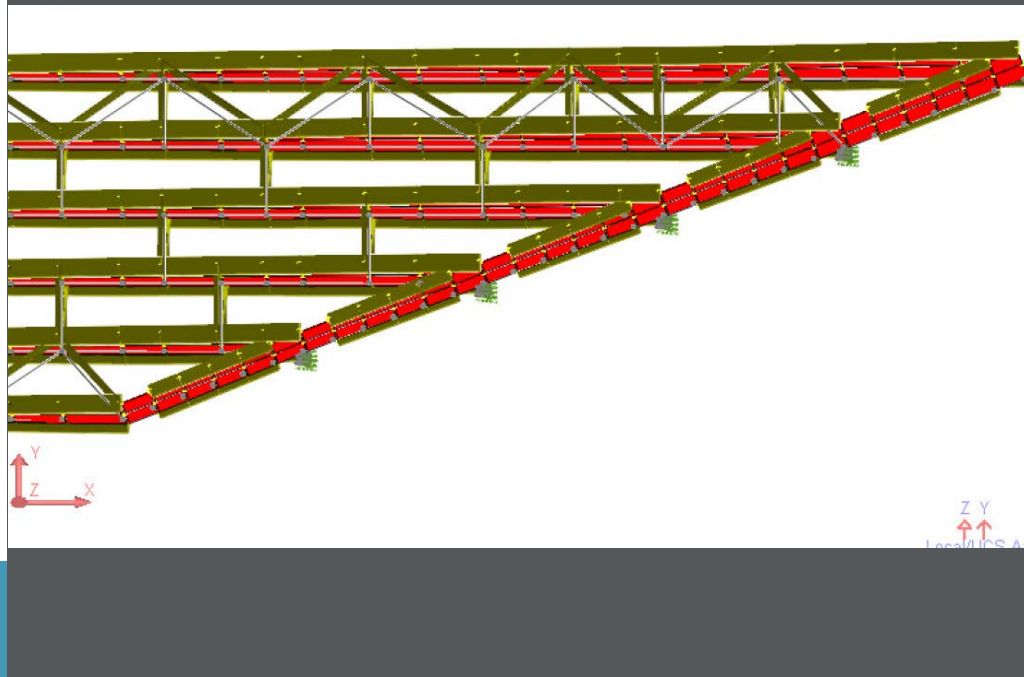


3D Finite Element Analysis

- Properly model girder torsional stiffness and warping stiffness
- Can account for load shifting between girders
- Explicitly model all cross-frame members and full-depth diaphragms

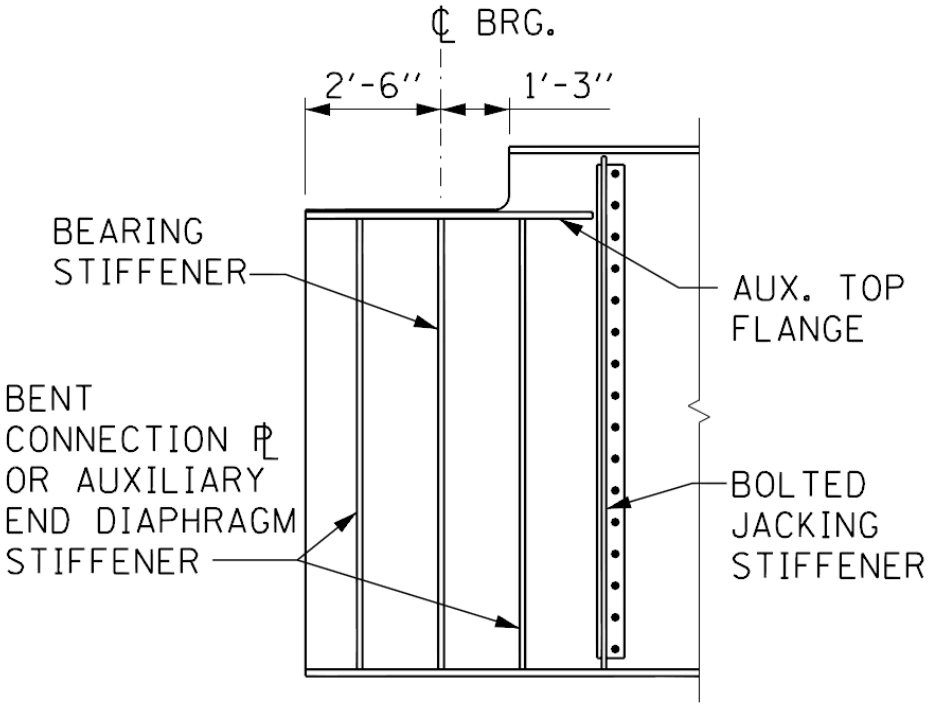
- 2D grid analysis inaccurate results:
  - Cross-frame forces
  - Bearing Reactions
  - Girder displacements





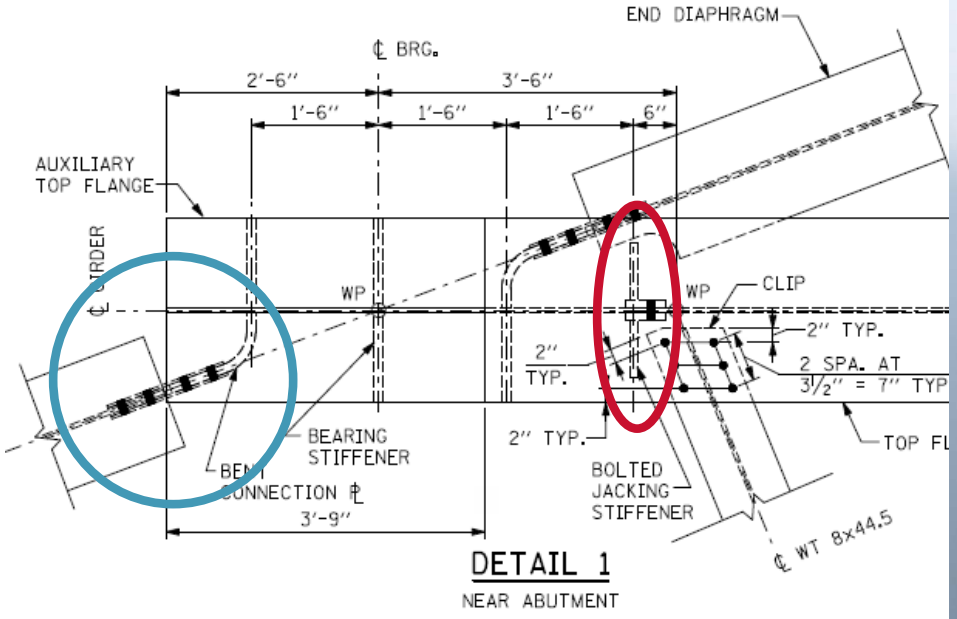
Steel Details

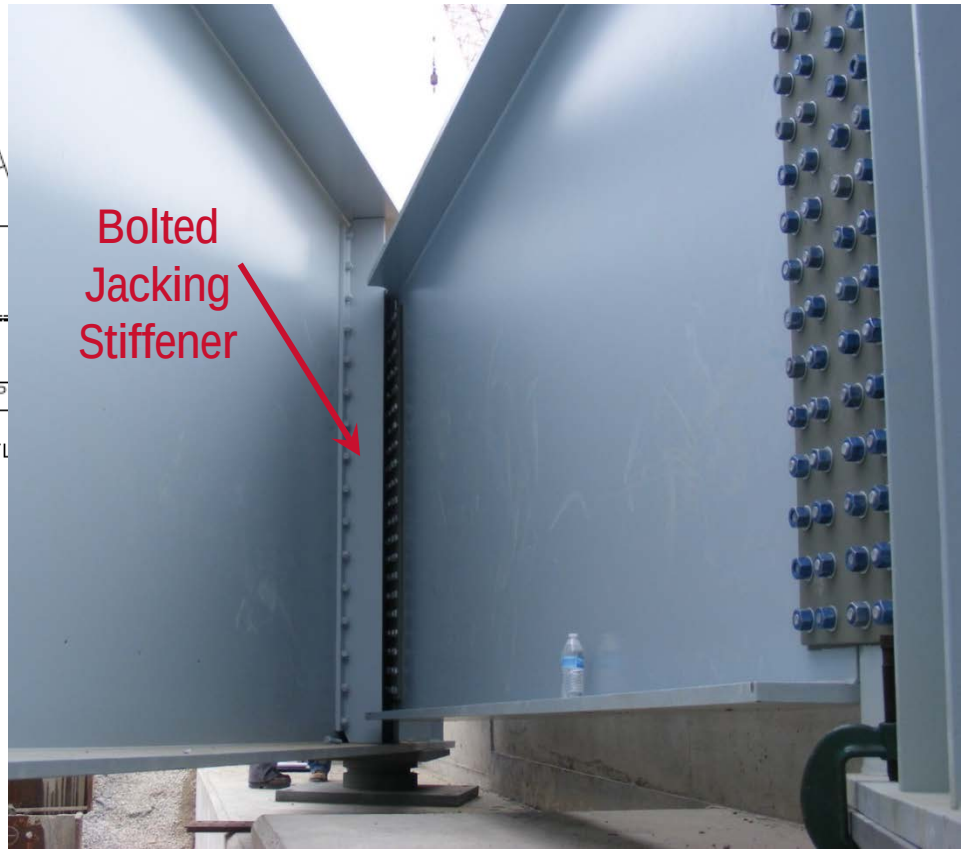
- Full-depth end diaphragm (length ~ 23.5 ft)
  - Too long for a K-type cross-frame
- Auxiliary stiffeners (back-up stiffeners)



End Diaphragm

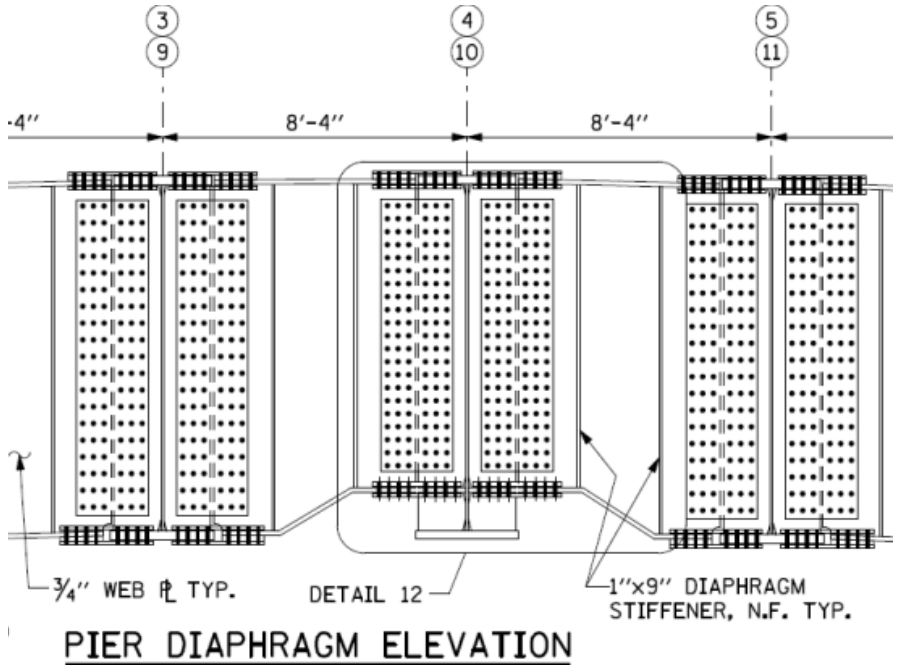
- Full-depth diaphragm connected to bent stiffener plate
- Bolted jacking stiffener installed after end diaphragm due to conflict





Full-Depth Diaphragm at Pier

- Detail to avoid interference with fixed bearing at skewed pier



PIER DIAPHRAGM ELEVATION

Fit Condition

- Severe skew leads to:
  - Out-of-plumb webs after dead load is applied
  - Excessive bearing rotation
  - Try to control this rotation via detailing
- AASHTO Article 6.7.2
  - Fit condition to be specified in the plans
- 3 choices:
  - No load fit (NLF)
  - Steel dead load fit (SDLF)
  - Total dead load fit (TDLF)

Cross-frames connect to girder locations that have different dead load deflections (differential).

For SDLF and TDLF the cross-frames are forced into place and the girders are twisted out of plumb during the erection.

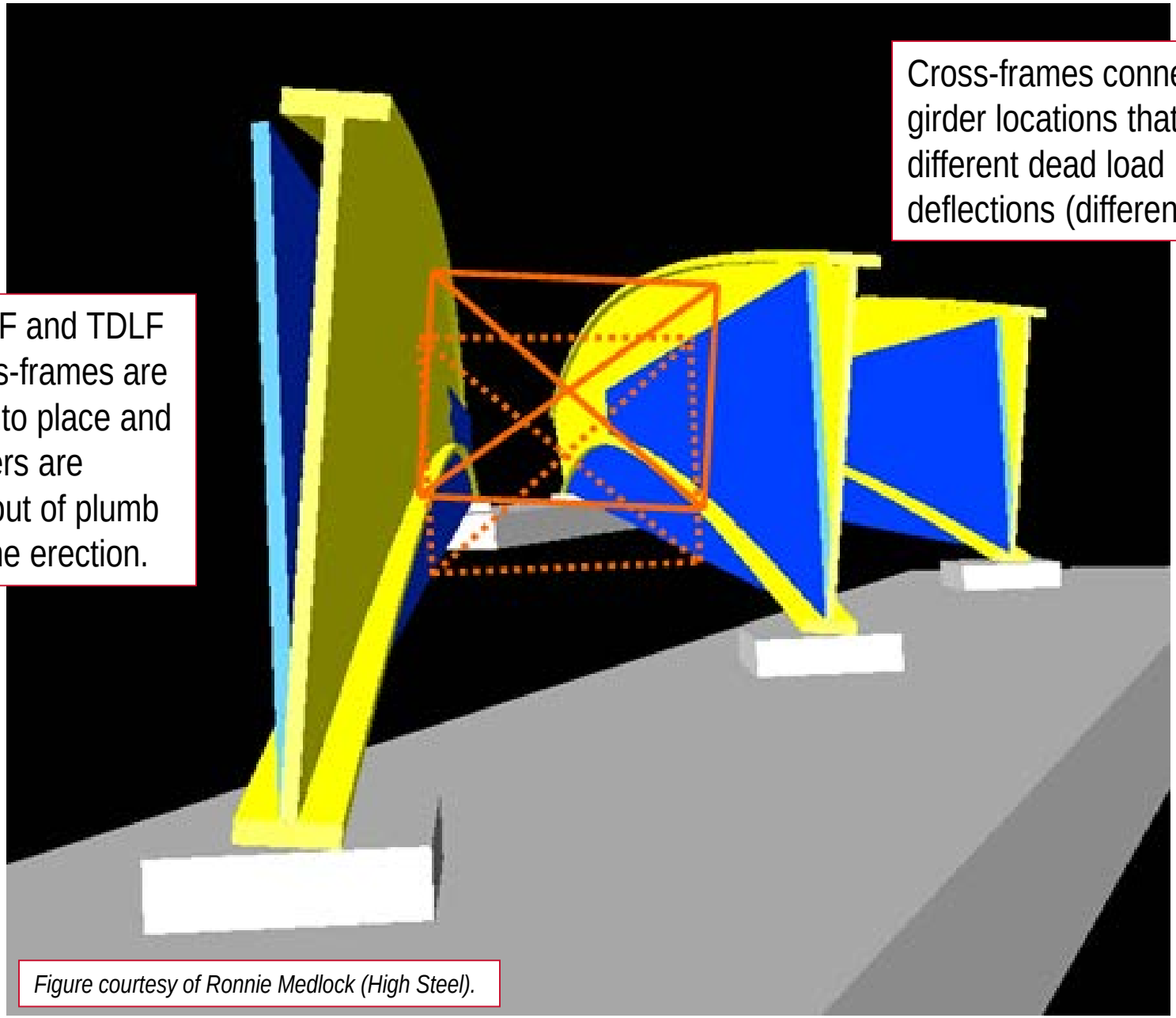


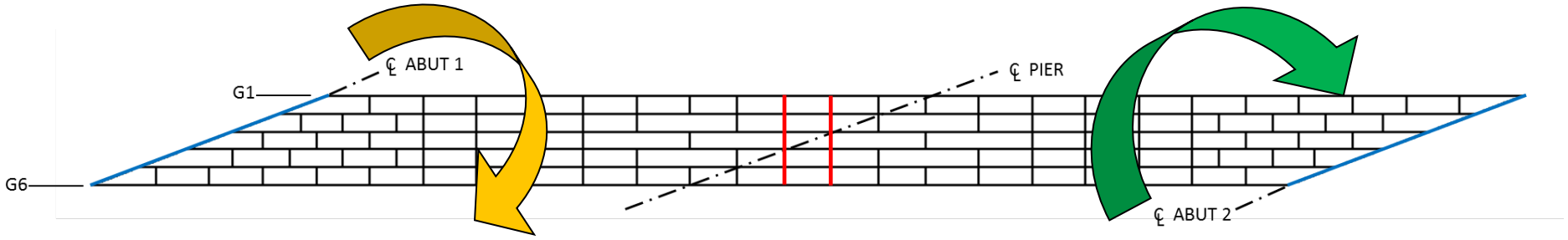
Figure courtesy of Ronnie Medlock (High Steel).

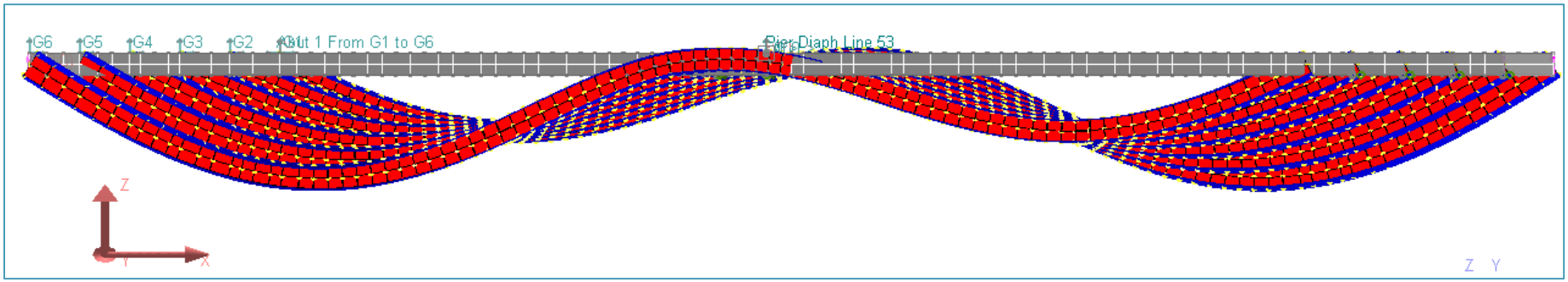
Detailing and Fit

- For SDLF and TDLF the cross-frames are forced into place and the girders are twisted out of plumb during the erection
- Steel Dead Load Fit (SDLF) chosen
  - Disc bearing can accommodate rotations
    - Concrete dead load
    - Live load
  - Erection simpler and faster than TDLF
    - Due to larger girder size
  - Limited construction windows

Pier Design: Effect of Skew

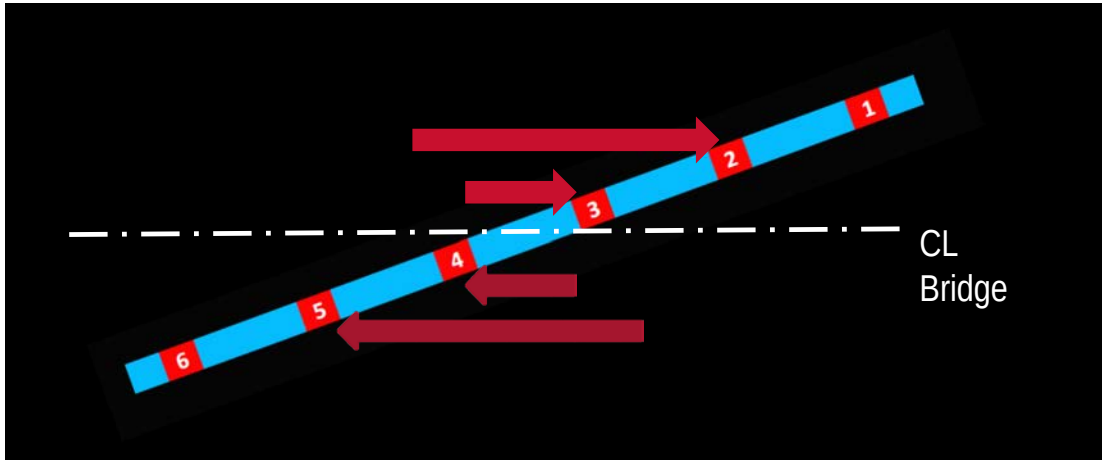
- Opposite direction of rotation between span 1 and 2

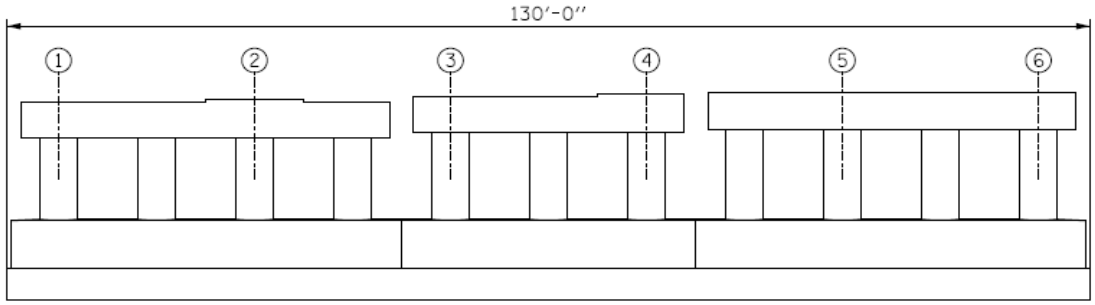




Pier Design

- Severe skew and fixed bearing condition led to high lateral forces in opposite directions
- Segmented pier:
  - Better accommodate internal thermal force demands
  - Reduce torsion in pier cap
- Circular columns directly under girders to effectively carry vertical reaction
- Intermediate circular columns to effectively resist fixed horizontal bearing reactions



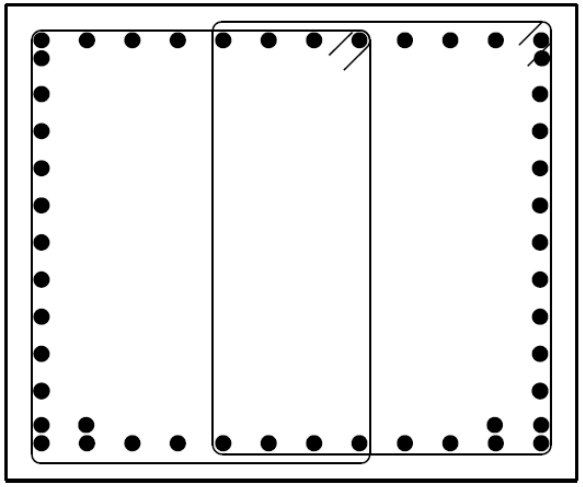


Pier Cap Design

- End Result:

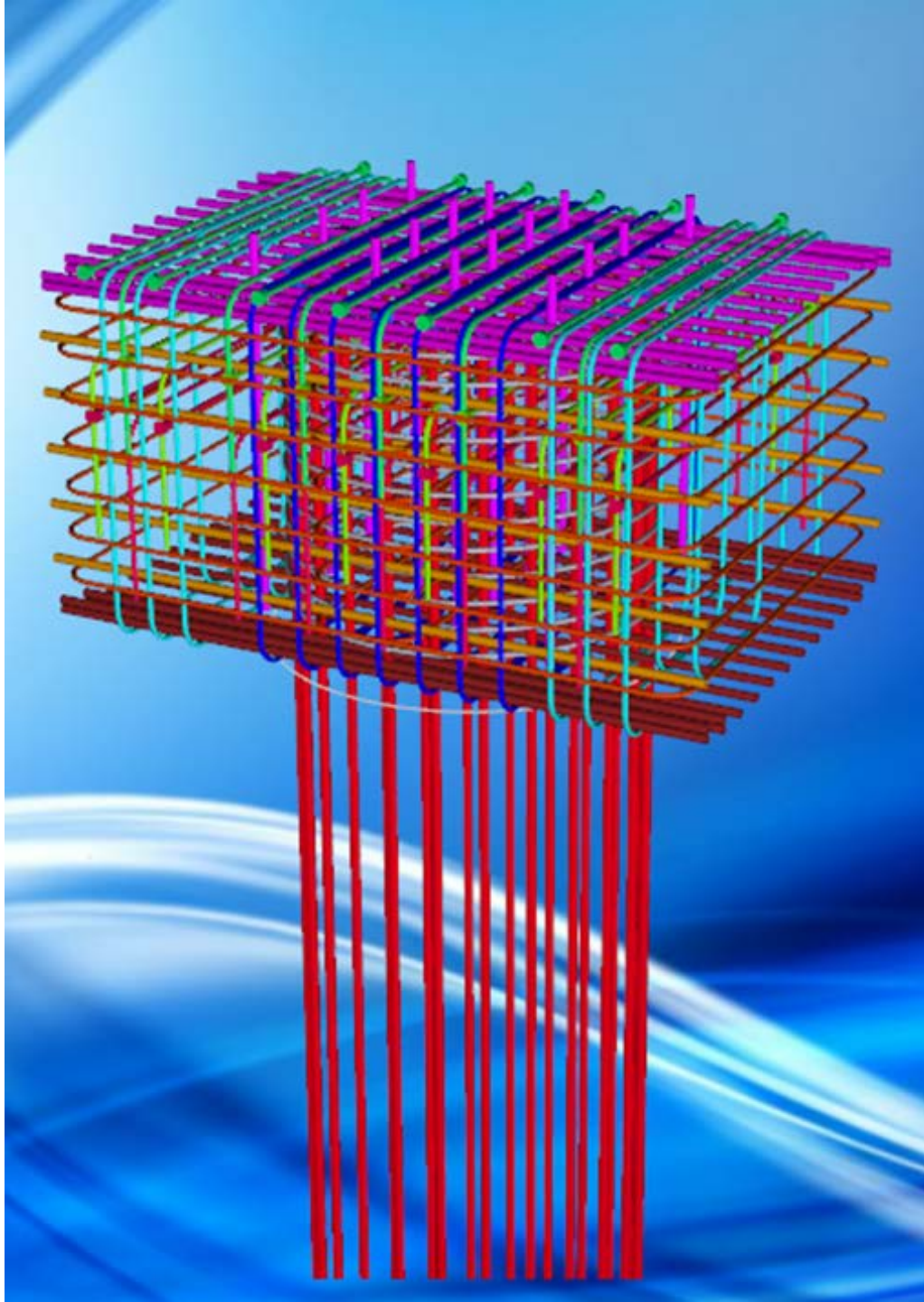
  Horizontal bearing reactions approximately equal to vertical reactions

- High torsional demand
  - No. 10 bars all around
- Special design considerations at fixed bearing locations



Concrete Anchorage Design

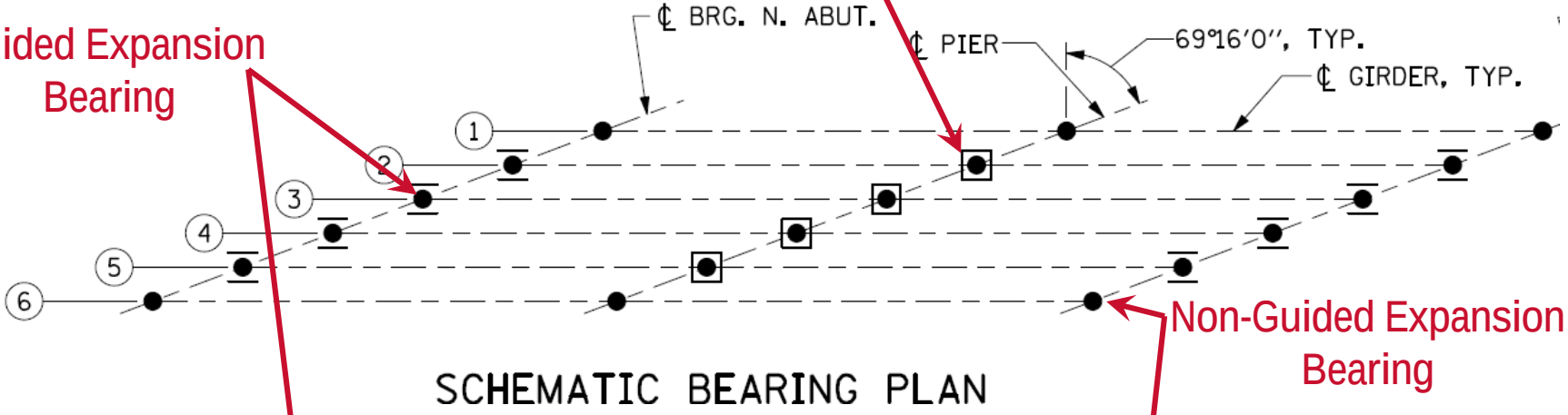
- Specialized approach with seismic-like detailing
  - Supplemental horizontal and vertical stirrups
  - Welded hoop bars
  - Embedded anchor bolts
  - Bar terminators
- Use of parametric tools
  - Clash detection
  - Verify sequence



Bearing Design

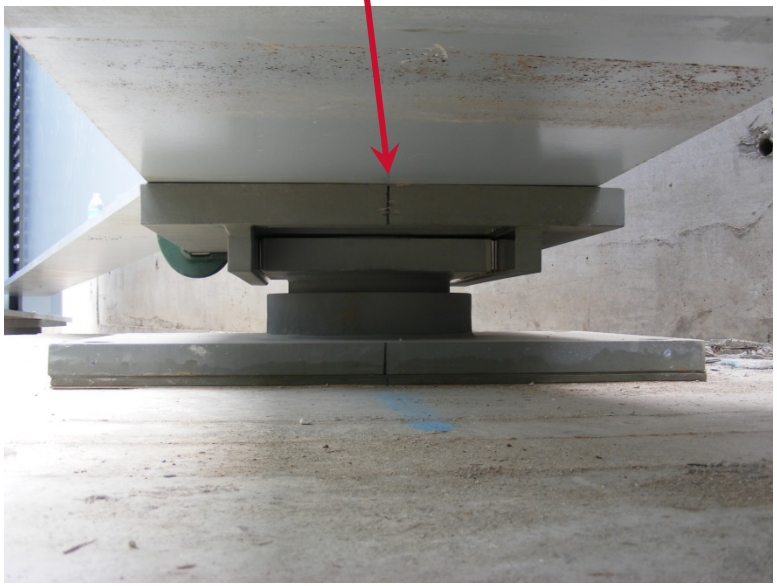
Fixed Bearing

Guided Expansion Bearing



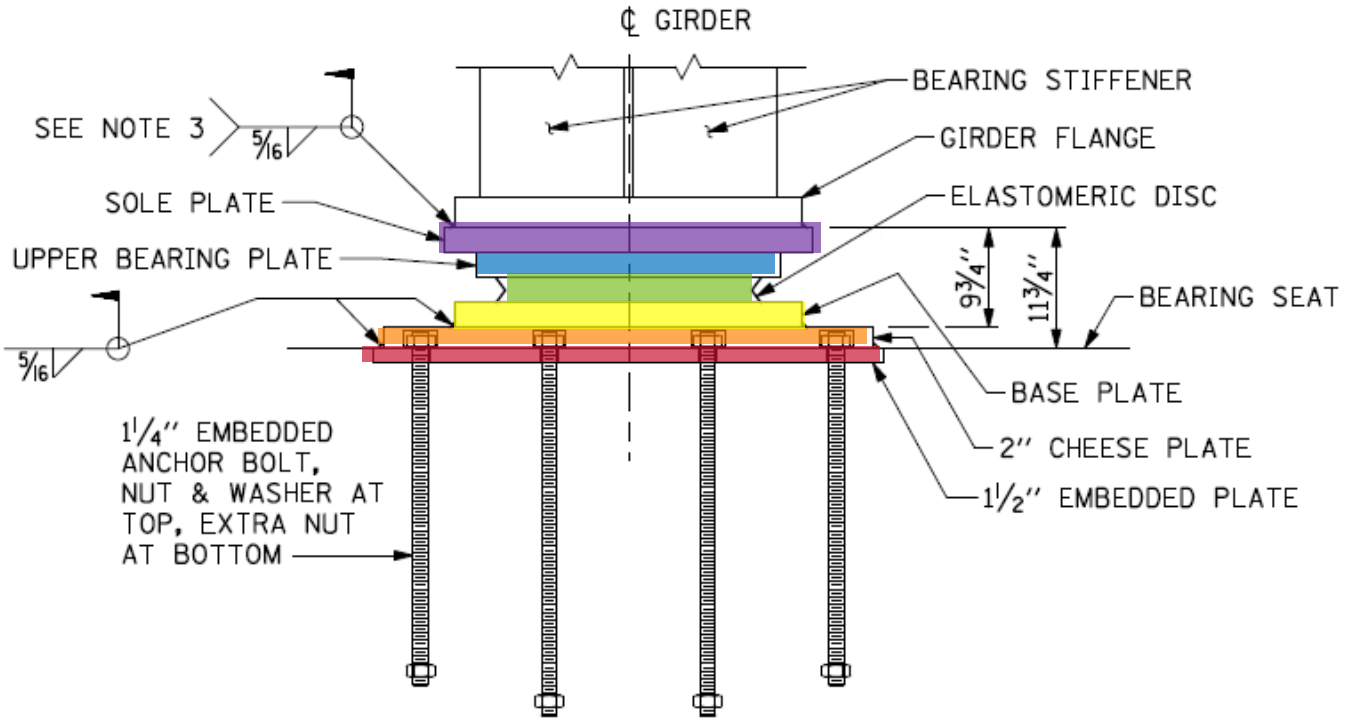
SCHEMATIC BEARING PLAN

Non-Guided Expansion Bearing



Bearing Design

- High Load Multi-Rotational Bearings
- Disc bearings were specified (rotation at abutments > 0.05 radians)

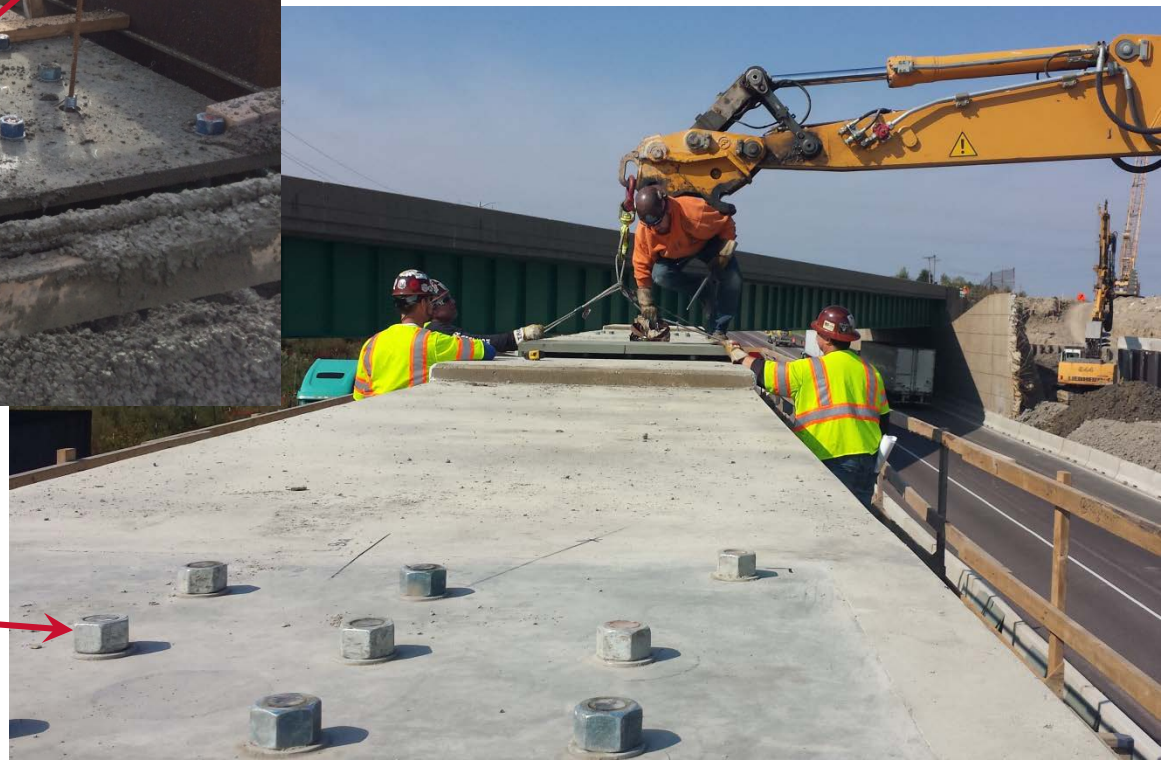


FIXED DISC BEARING ASSEMBLY

AT PIER - GIRDERS ②, ⑤, ⑧, ⑪

Bearing Design

Concrete
Placement Hole



Anchor bolts
threaded through
embedded plate

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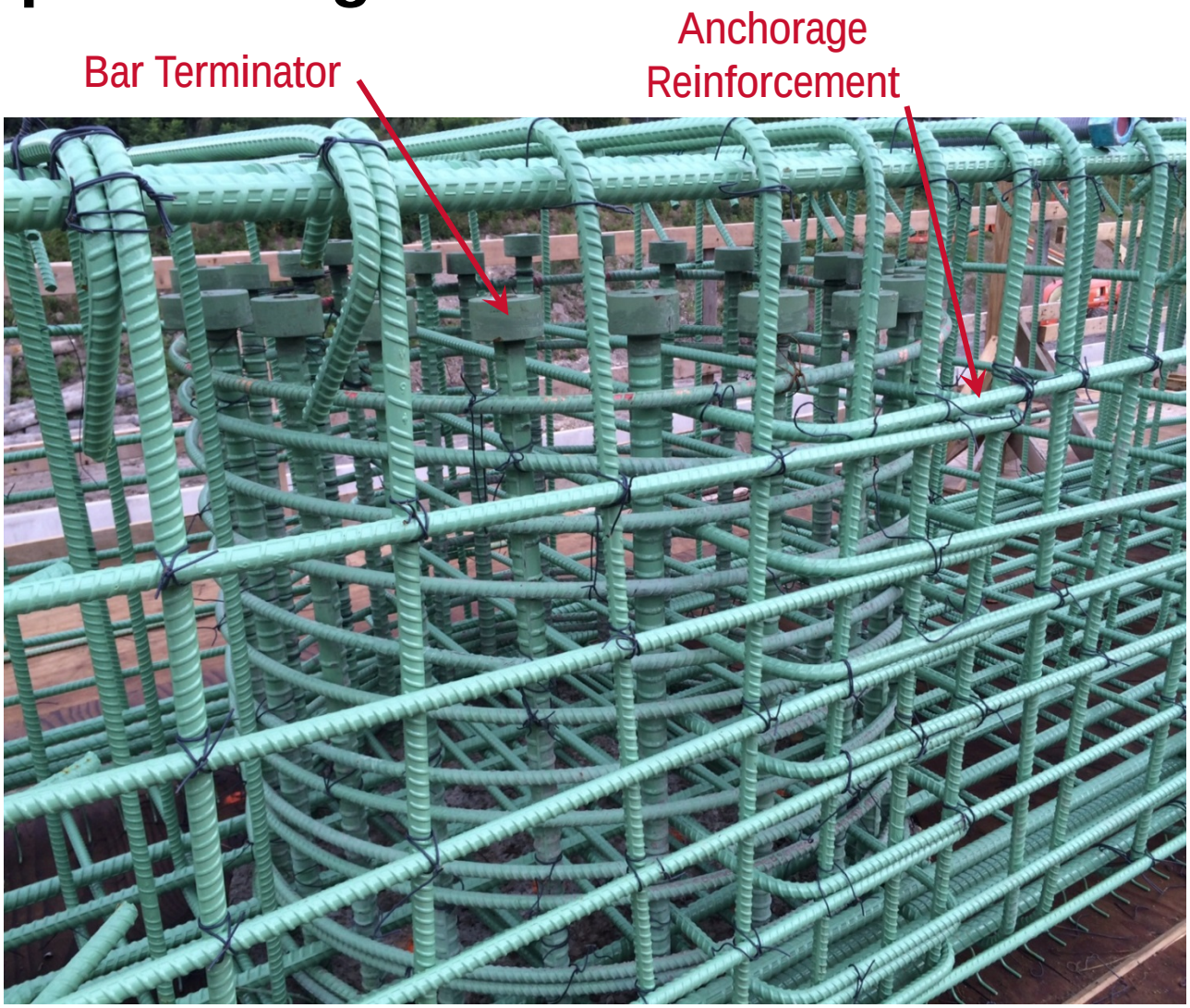
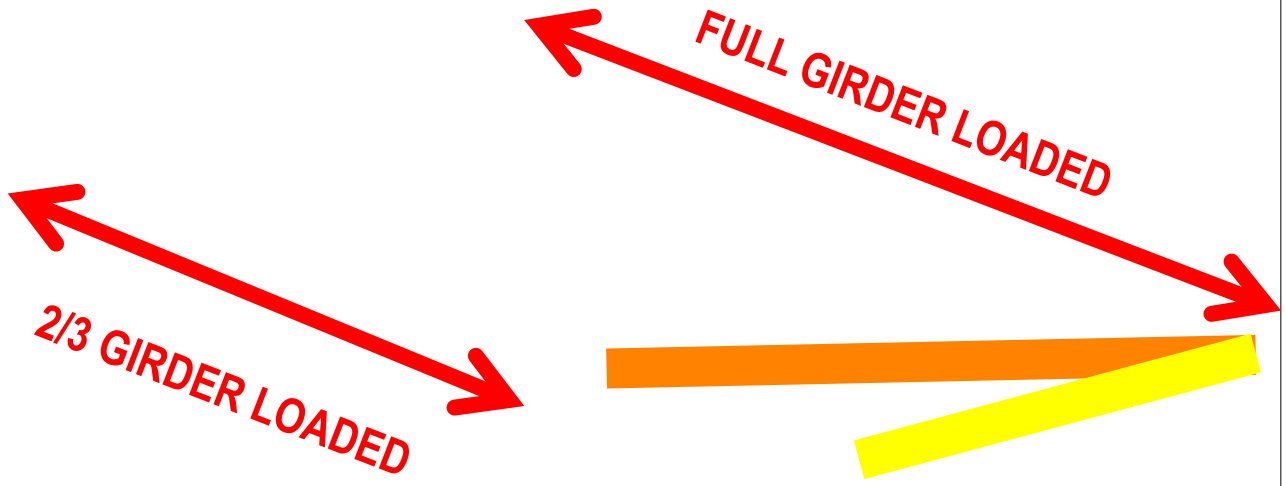
Shop Fit-Up

Pier

- Welded hoop bars to confine core for anchorage

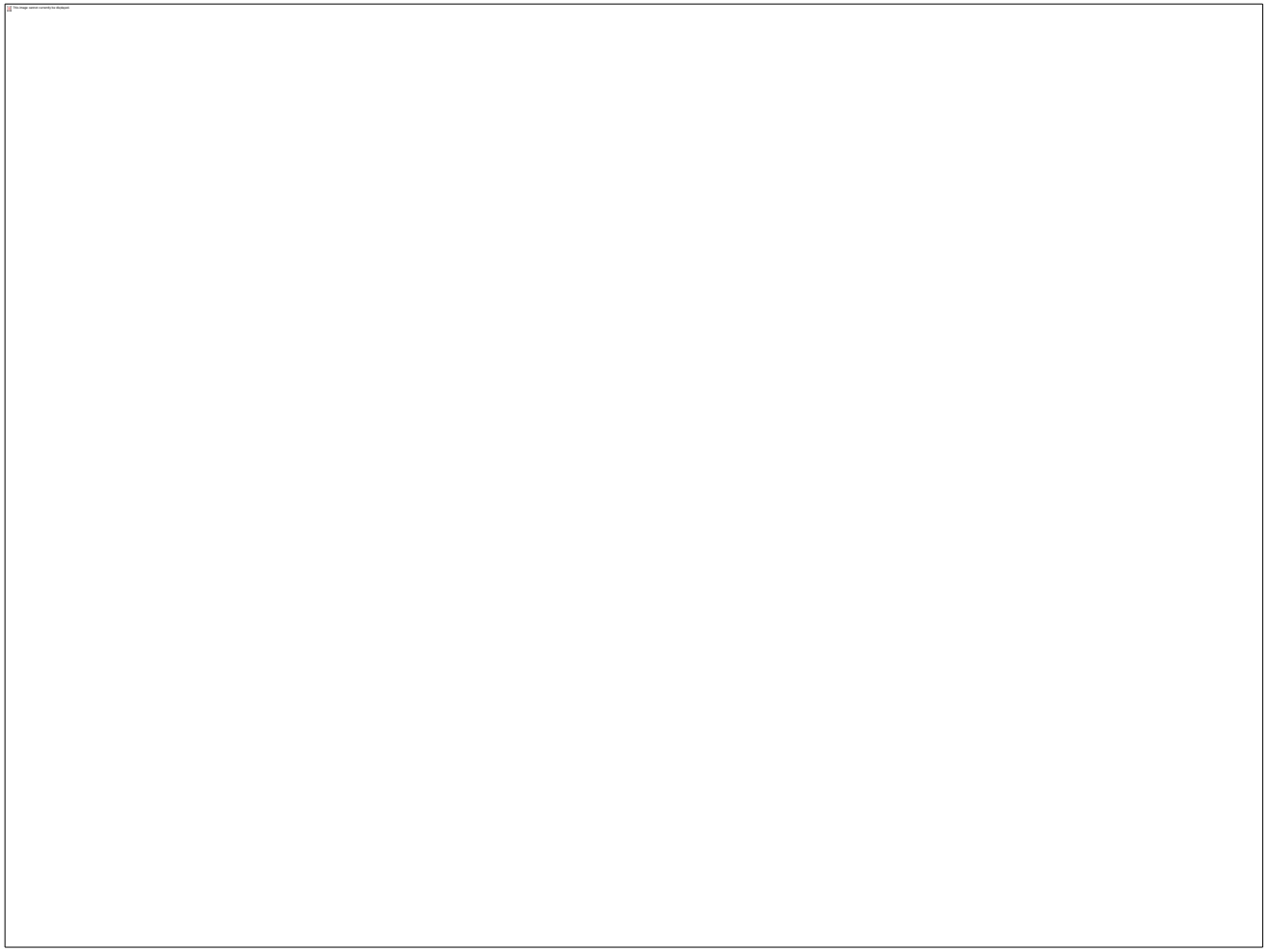
Pier Cap Detailing

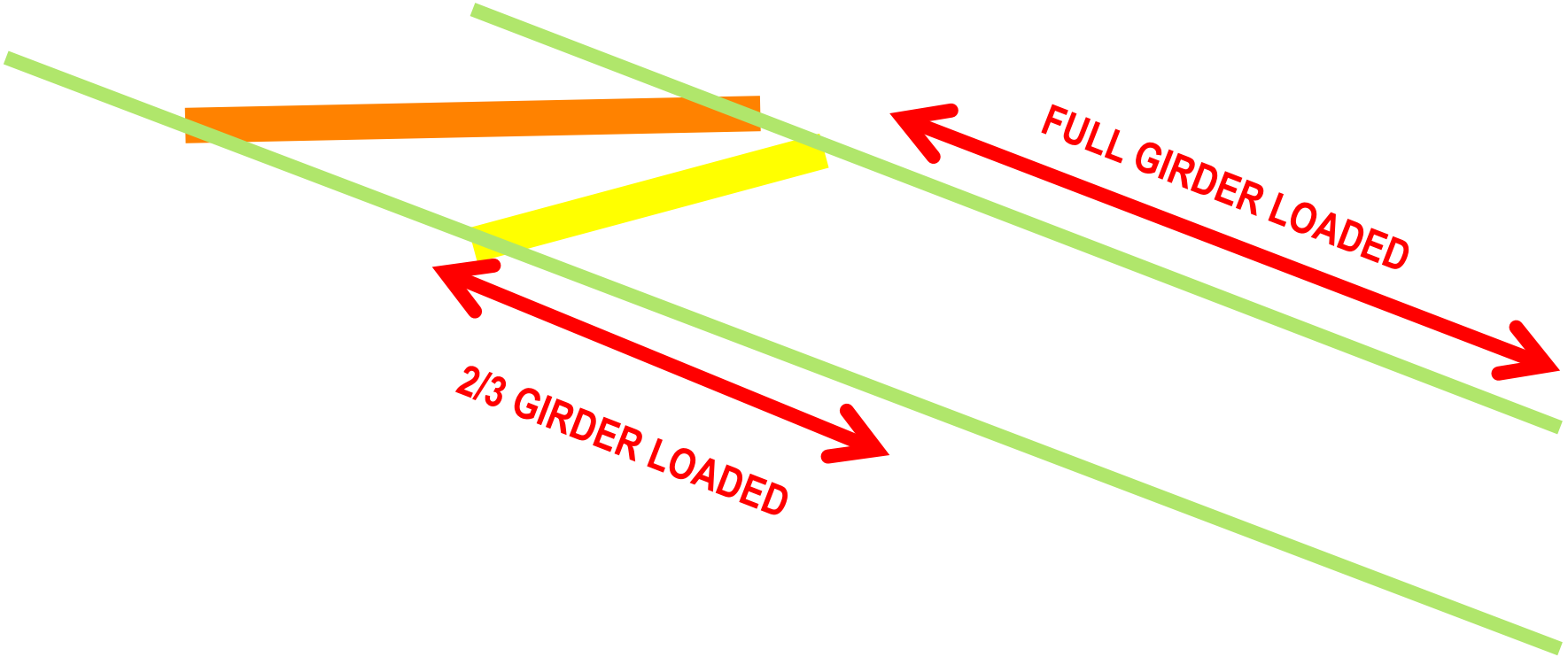



FULL GIRDER LOADED
2/3 GIRDER LOADED

Deck Placement

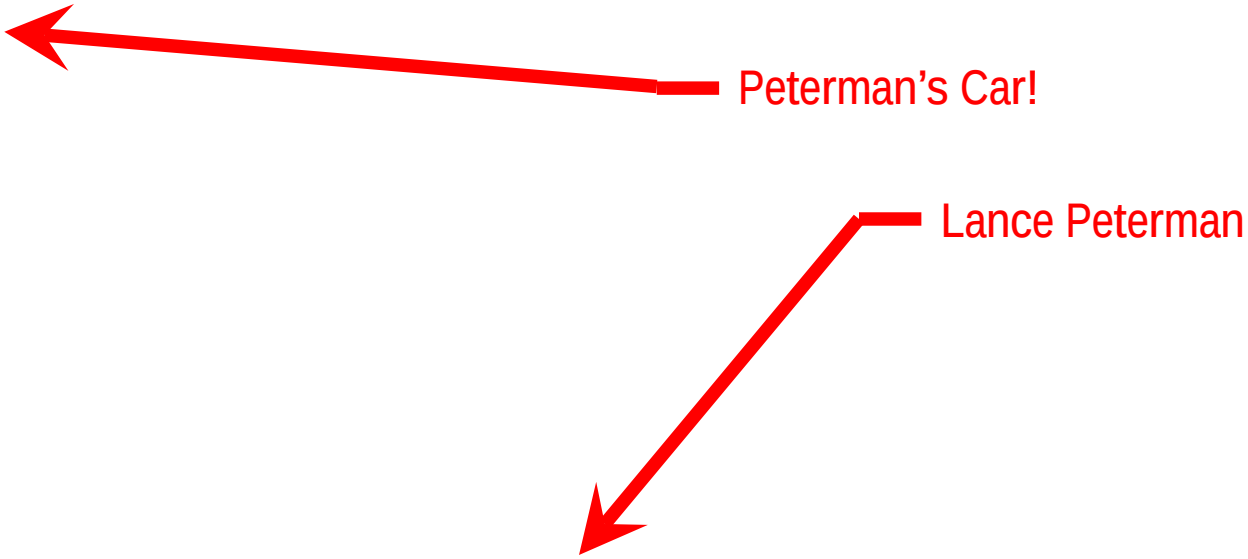
- Placement of concrete along skew to load girders equally




FULL GIRDER LOADED
2/3 GIRDER LOADED

Deck Placement

- Bridge Paver rails extended to approach


Peterman’s Car!
Lance Peterman

Swivel Type Modular Expansion Joint

- Multi-directional movement capability
- Detail girders and end diaphragms to accommodate joint
- Special closure pour at joints
  - To minimize movement due to dead load effects (racking)
  - To reduce shrinkage effects

Sometimes it’s the little things…

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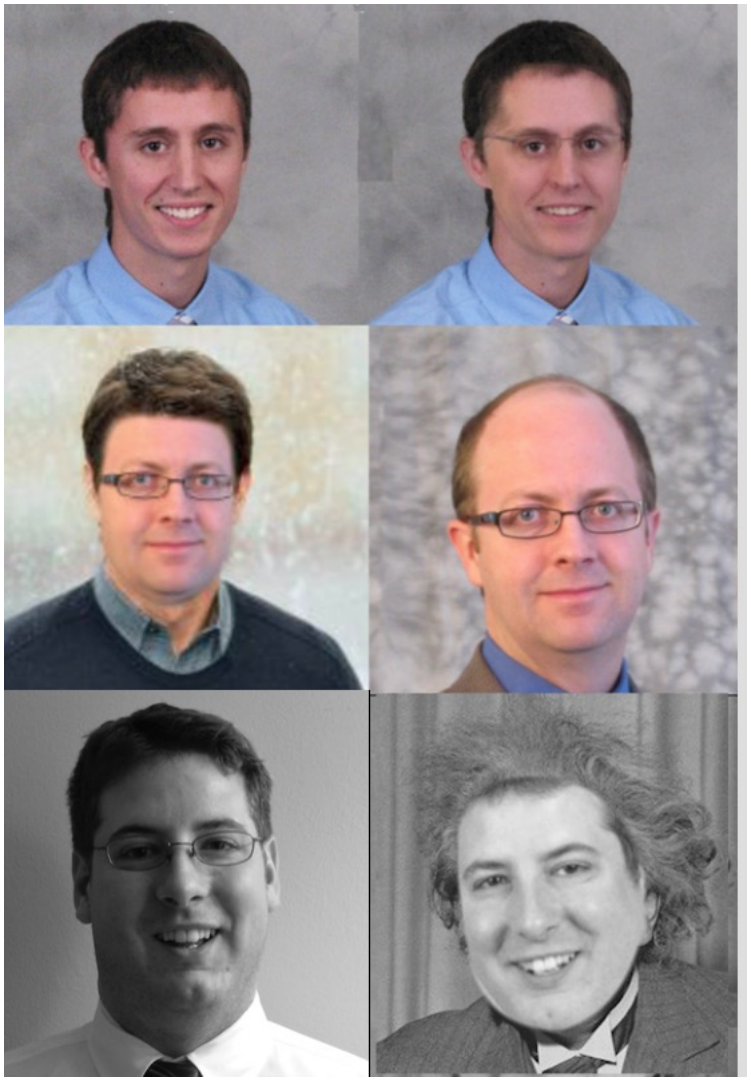
Summary

- Consider 3D FE analysis for severely skewed supports
- Recognize alternative load paths at severely skewed supports
- Be cognizant of high lateral forces at fixed bearings of a skewed support
- Specify fit condition for the girders and cross-frames
- Consider shop assembly to verify fit-up
- Place deck concrete along skew

Be aware of the effects of severe skew on staff!



Acknowledgments

- Client: Illinois Tollway
- Owner: IDOT
- General Contractor: Dunnet Bay Construction
- Steel Fabricator: Industrial Steel Construction
- Steel Erector: Danny’s Construction
- Resident Engineer: HR Green
- Erection Engineer: Benesch

QUESTIONS……

Illinois Tollway

HDR

Illinois Department of Transportation