First Tied-Arch Bridge in Chicago

Presented by:
Dr. Soliman Khudeira, P.E., S.E.

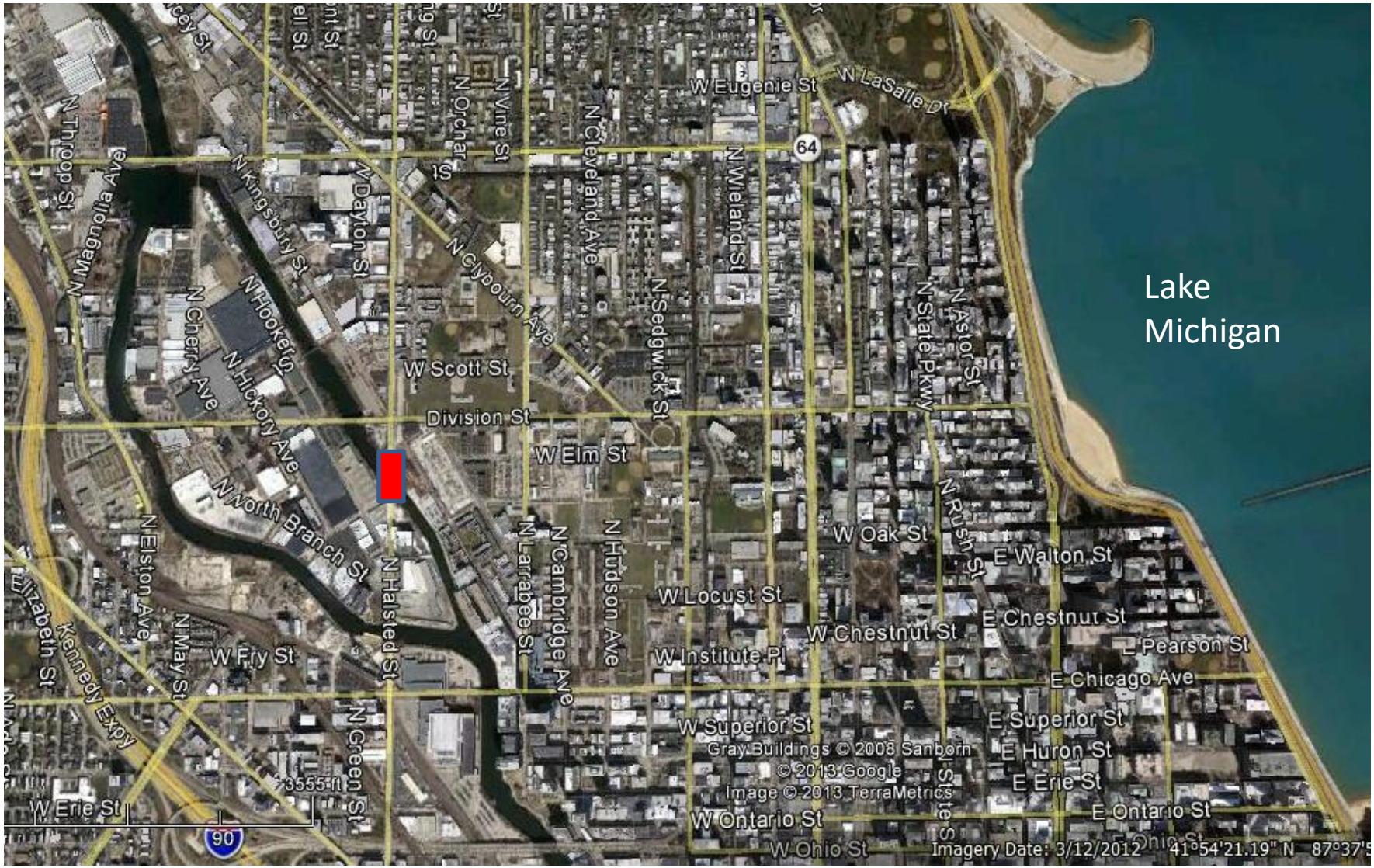
Chair of NAAAEA National Education Committee

Presentation Outline

- Project overview
- Substructure details
- Superstructure details
- Construction sequencing

Project Overview

Location Map



North Halsted Street Bridge

Location Map

Project Scope

- Remove the existing bascule bridge
- Install new fixed bridge

Existing and New Bridge

Existing Bridge

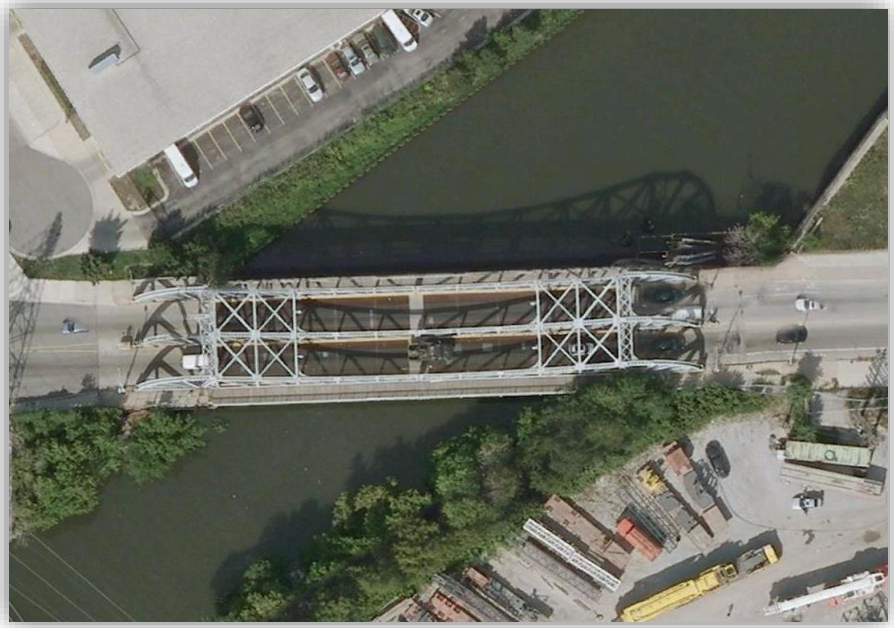
- Two travel lanes
- No bike lanes

New Bridge

- Four travel lanes
- Two-way bike lanes
- Can accommodate future river walk
- Improved aesthetics of the area

Existing Bascule Bridge

- **Structurally deficient**
- **Functionally obsolete**

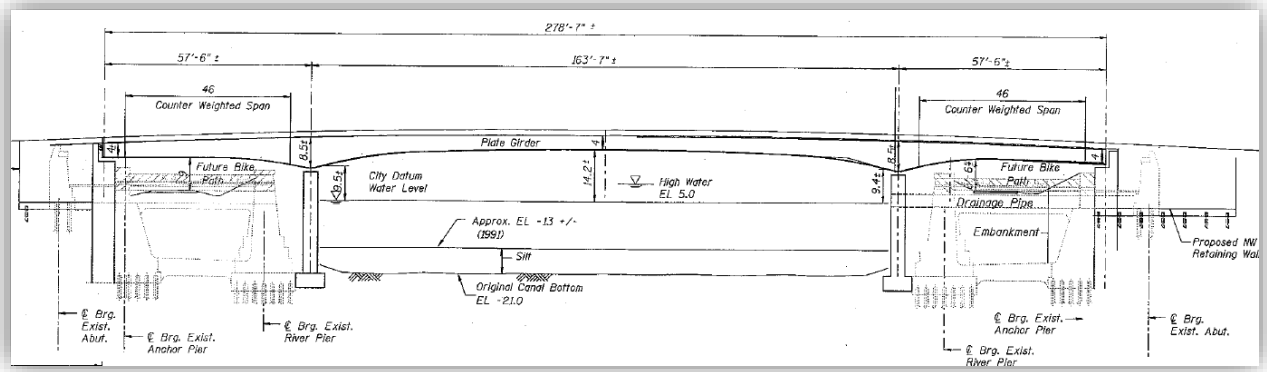


Factors Affecting the Selection of a Bridge Type

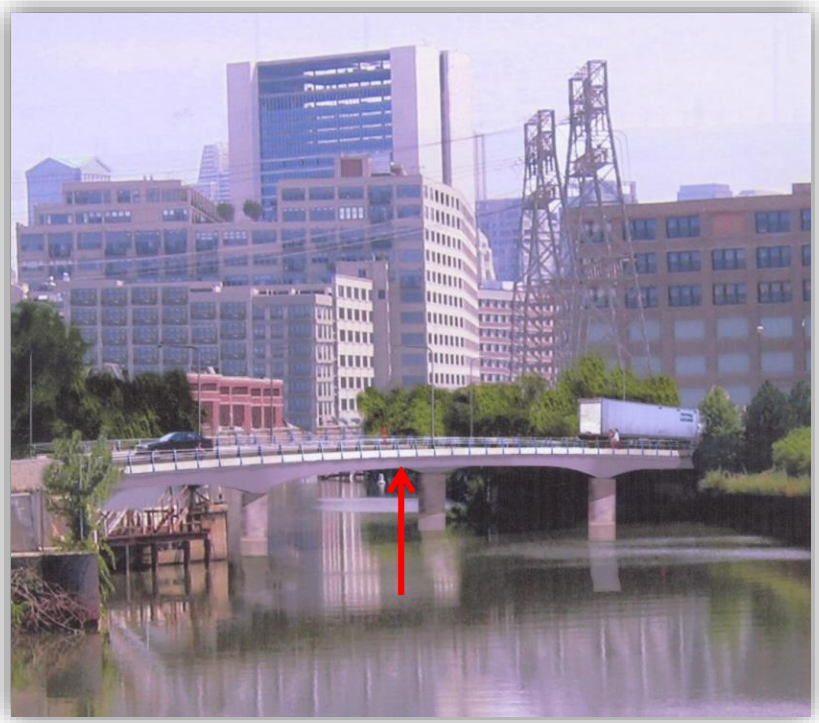
Factors Affecting the Selection of a Bridge Type

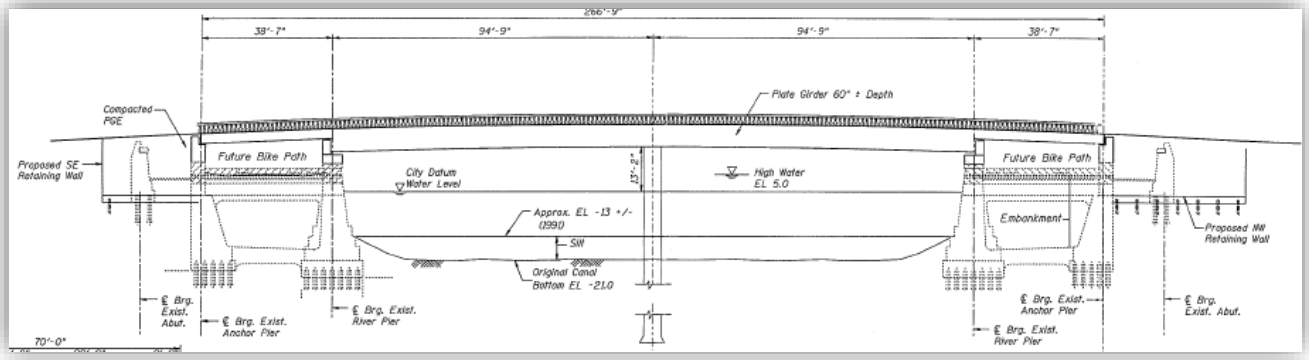
- Aesthetics
- Surrounding (Context Sensitive Design)
- The need for the infrastructure improvement to act as a focal point for revitalization of the area and to stimulate commerce
- Bridges provide opportunities to create landmarks/signature bridges can become enduring symbols for cities or neighborhoods.
- Structural constraints: span, redundancy, loading, soil conditions,
- Geometric constraints (hydraulics, horizontal and vertical required river clearance, adjacent buildings, under/above ground utilities, availability of adjacent land
- Budget
- Constructability

Bridge Type Study: Multi-Girder

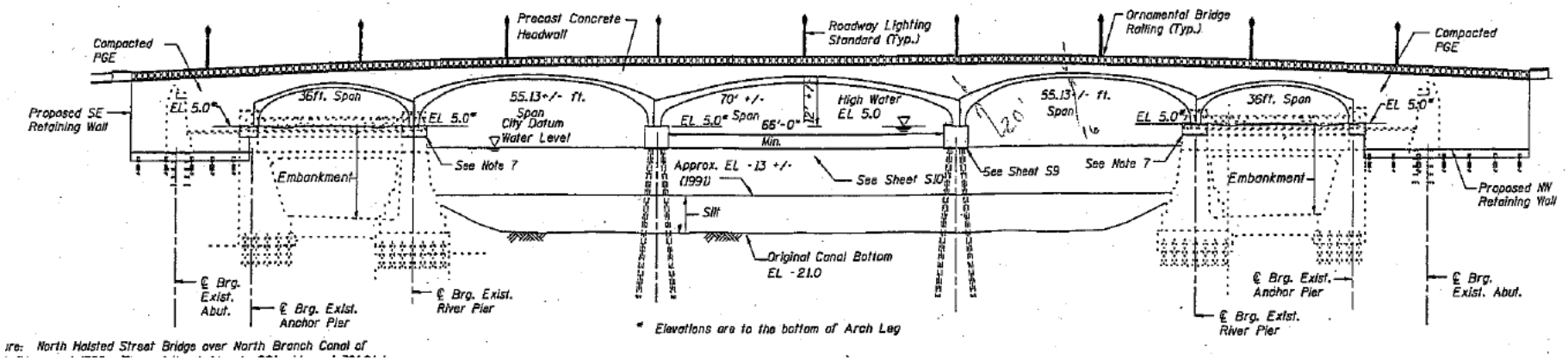


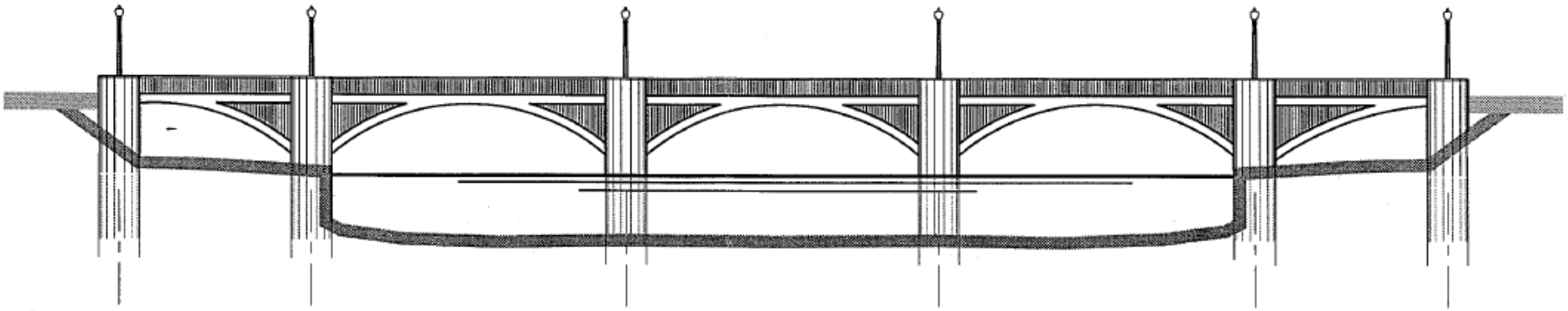
Bridge Type Study: Multi-Girder with Center Pier





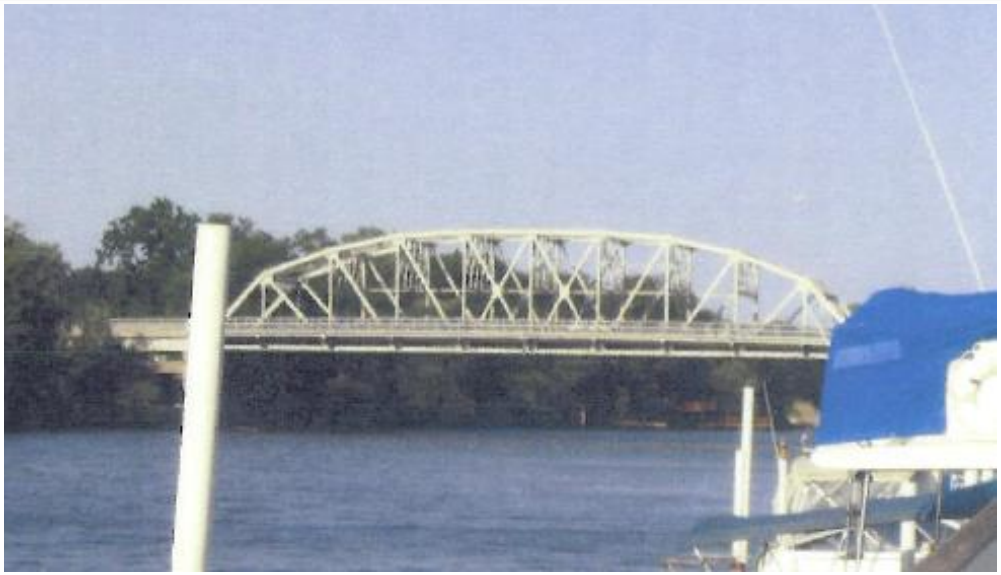
Bridge Type Study: Multi-Arch

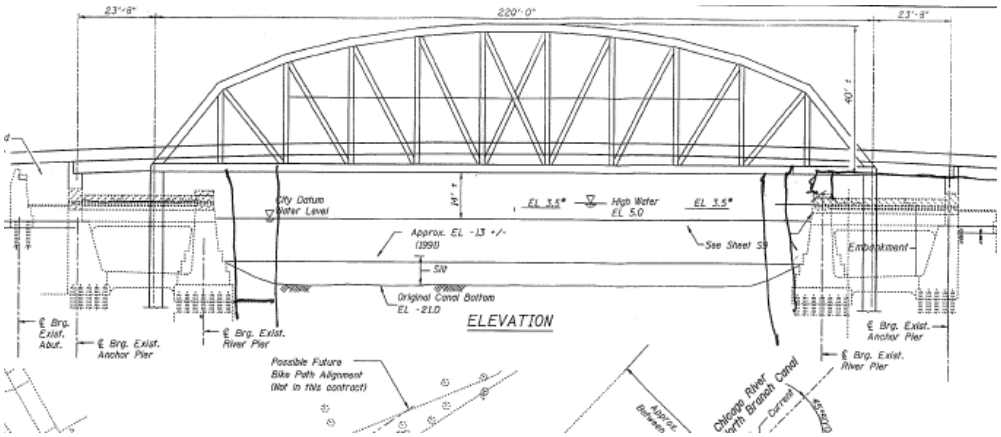




Aesthetic Bridge: Multi-Arch Bridge

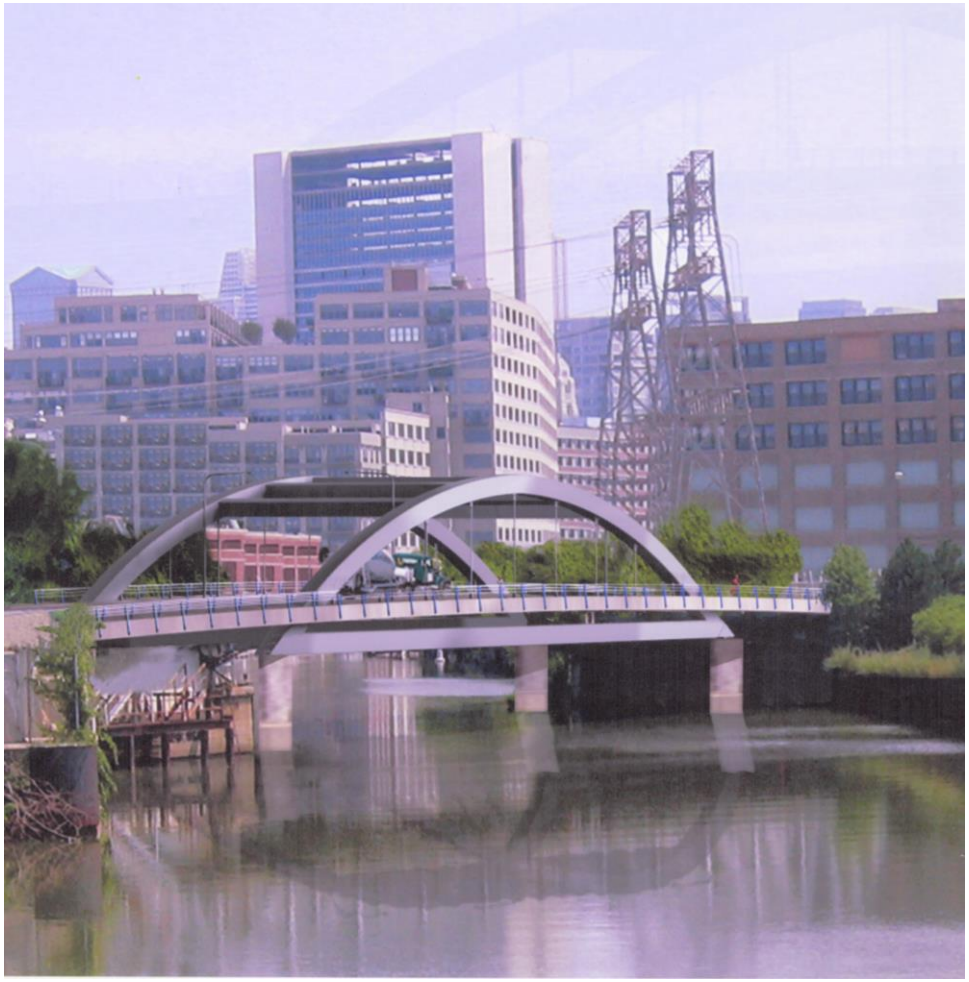
Bridge Type Study: Through Truss





Through Truss

Bridge Type Study: Tied-Arch

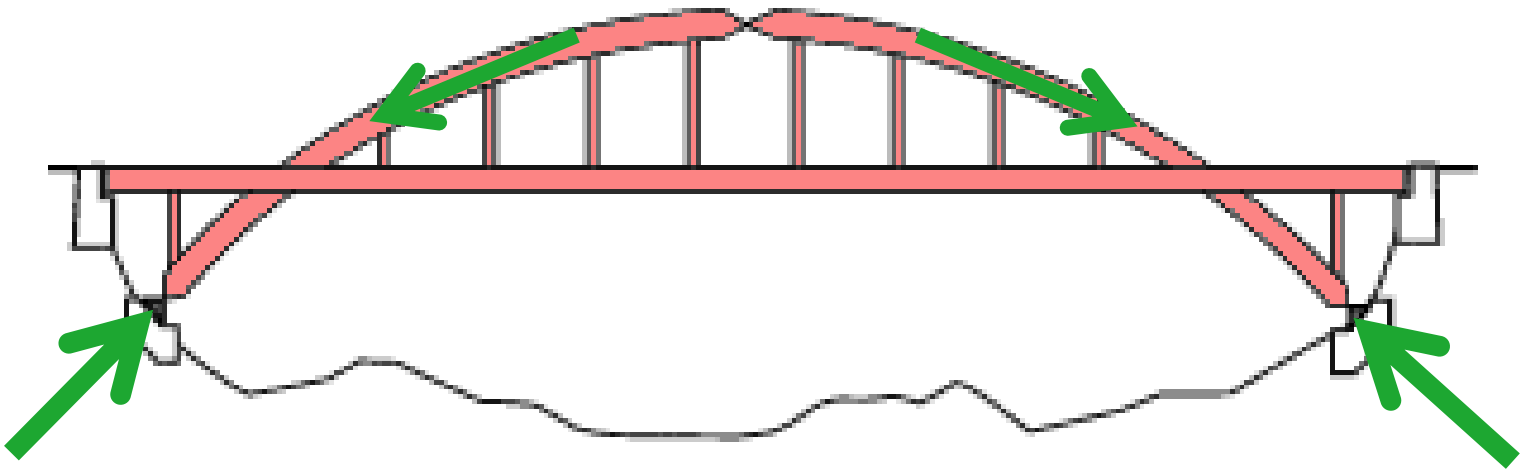


Aesthetic Bridge: Tied-Arch

North Halsted Street Bridge

Arch Bridges

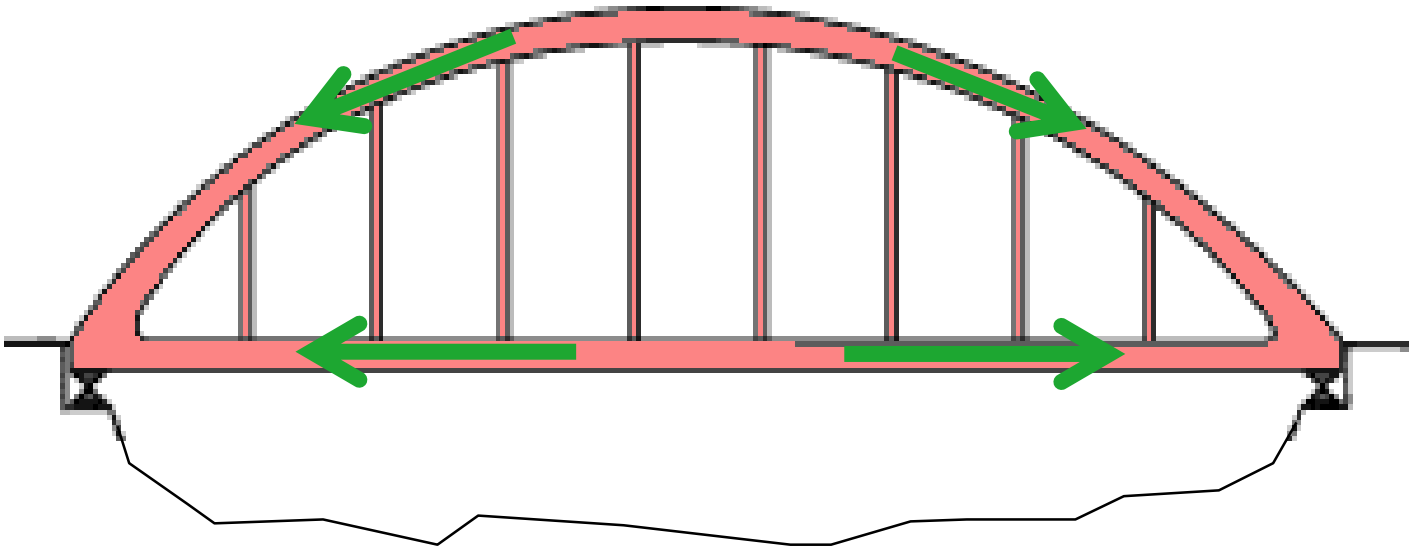
True Arch (or Thrust Arch) Bridges



- **The arch is in compression**
- **The horizontal thrust is resisted by the abutments**

True Arch Bridge (Thrust-arch Bridge)

Tied Arch Bridges

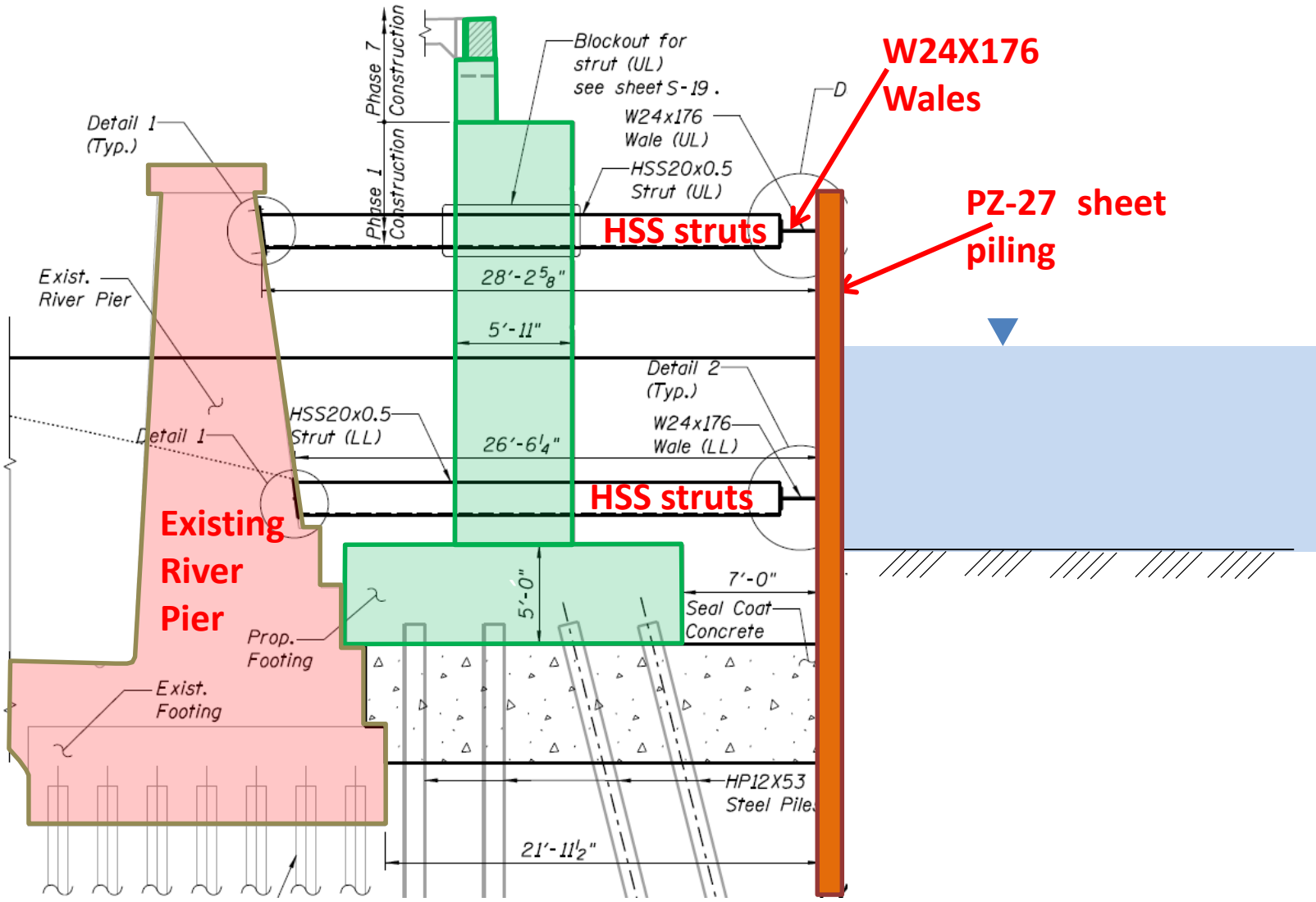


- The arch is in compression
- The horizontal thrust is resisted by the horizontal tie

Tied-arch Bridge

Substructure Details

Cofferdam / Abutment



Cofferdam / Abutment

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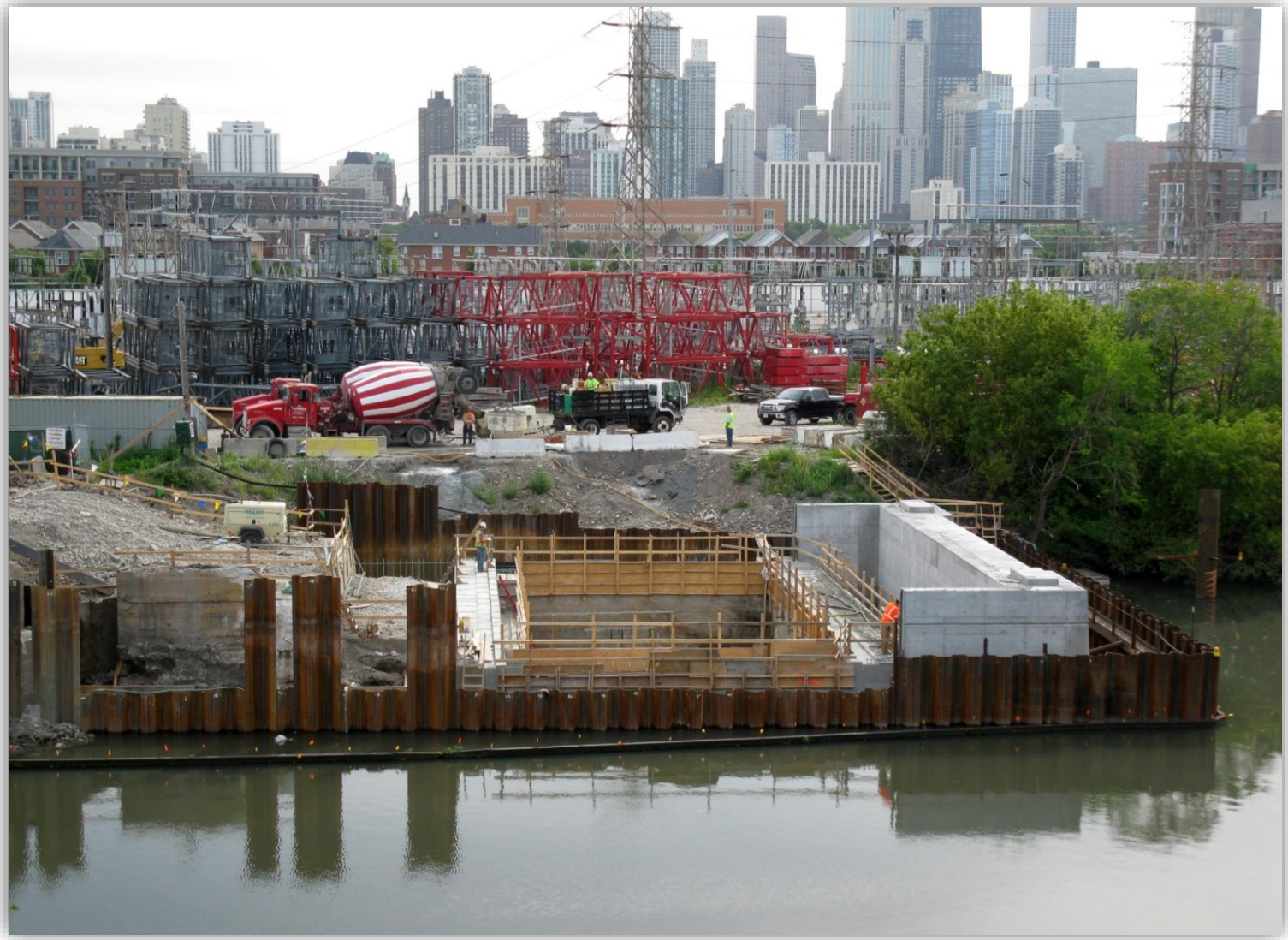
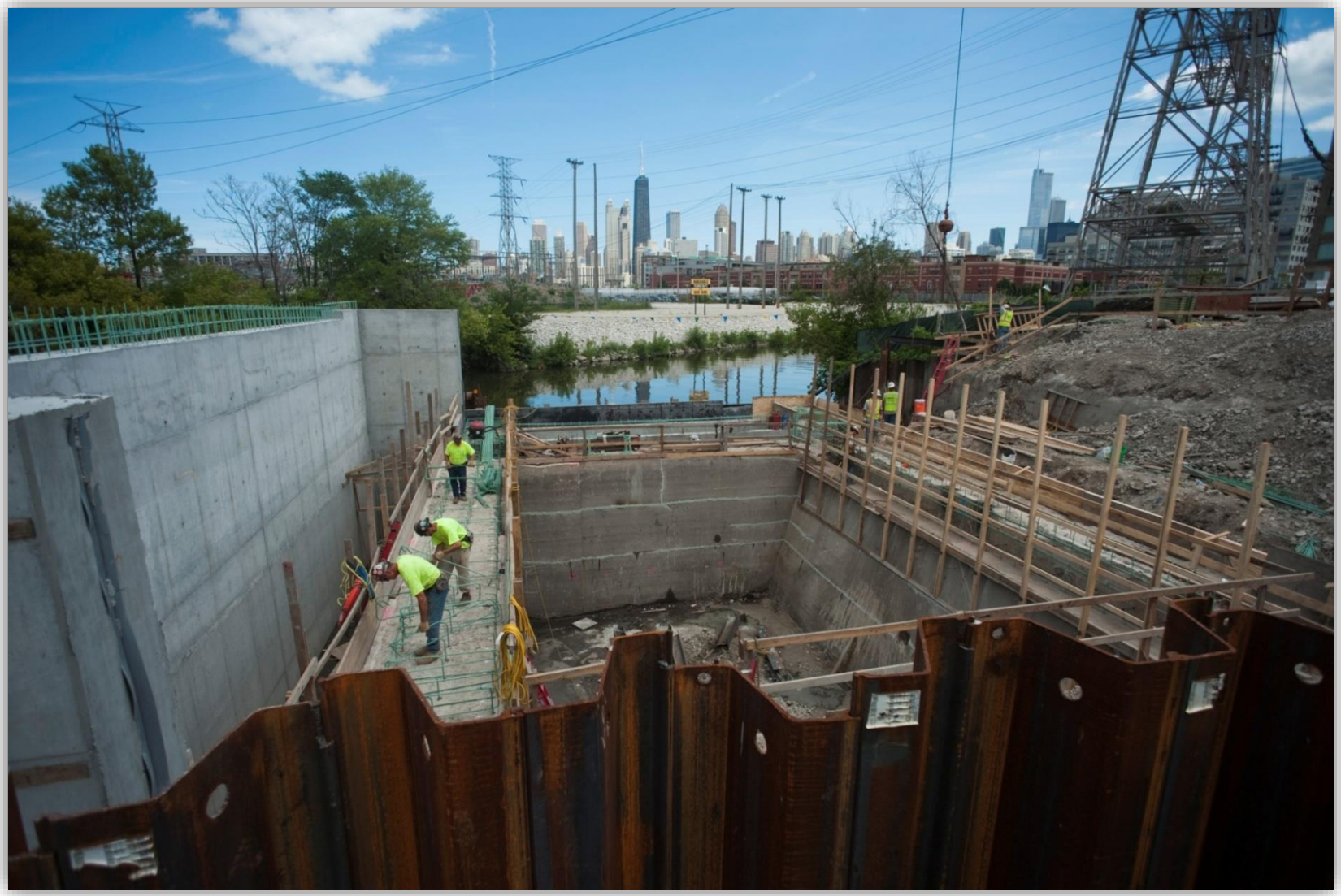
North Halsted Street Tied-Arch Bridge

River Walk

Three-Sided Precast Concrete Underpasses



Three-Sided Precast Concrete Underpasses



Three-Sided Precast Concrete Underpasses

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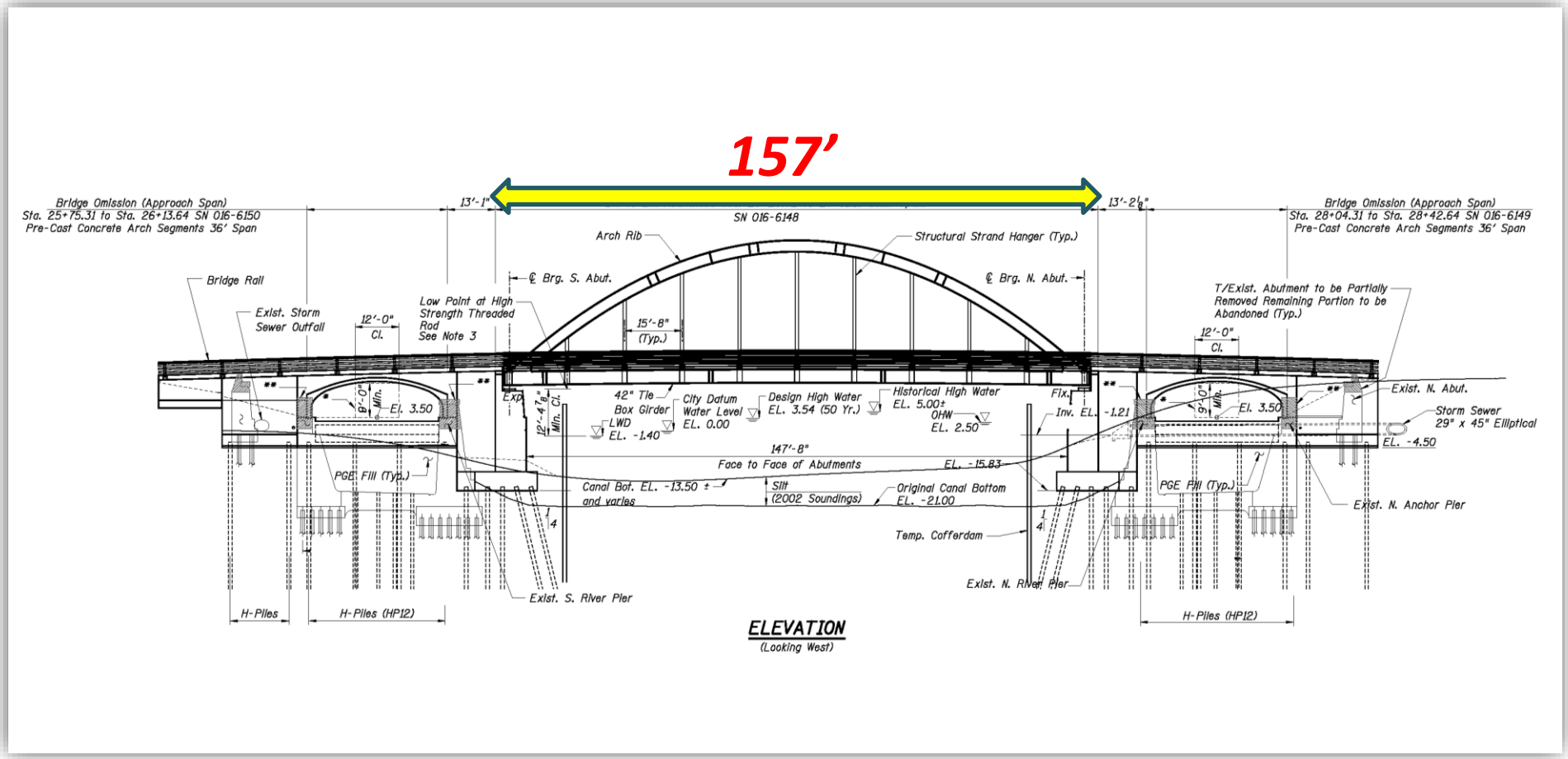
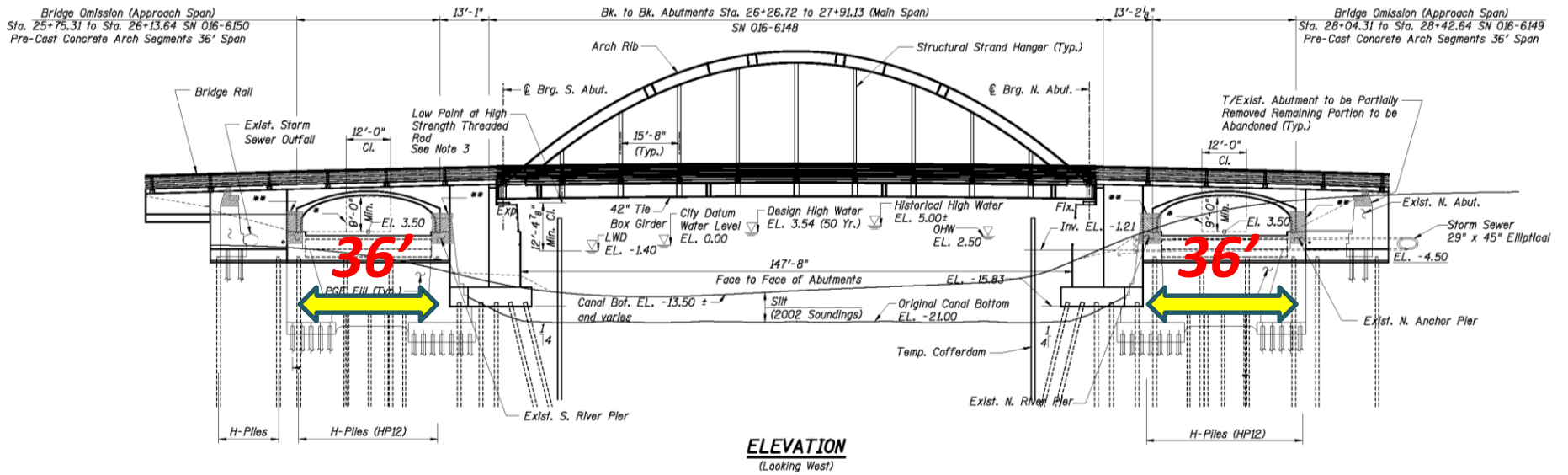
Three-Sided Precast Concrete Underpasses

Superstructure Details

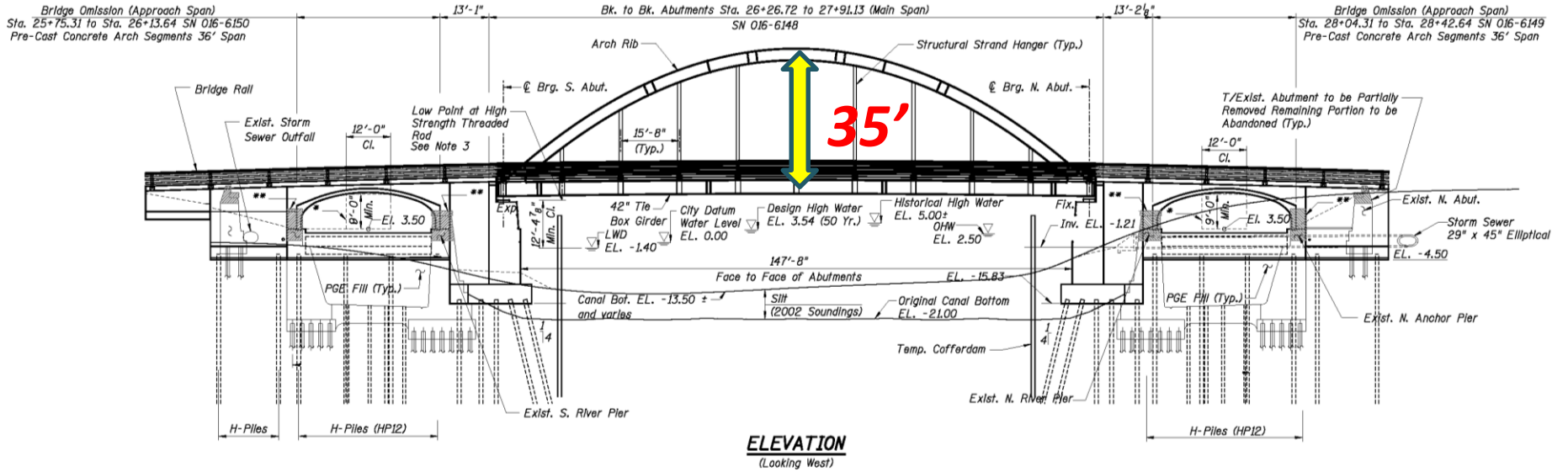
Superstructure Overview



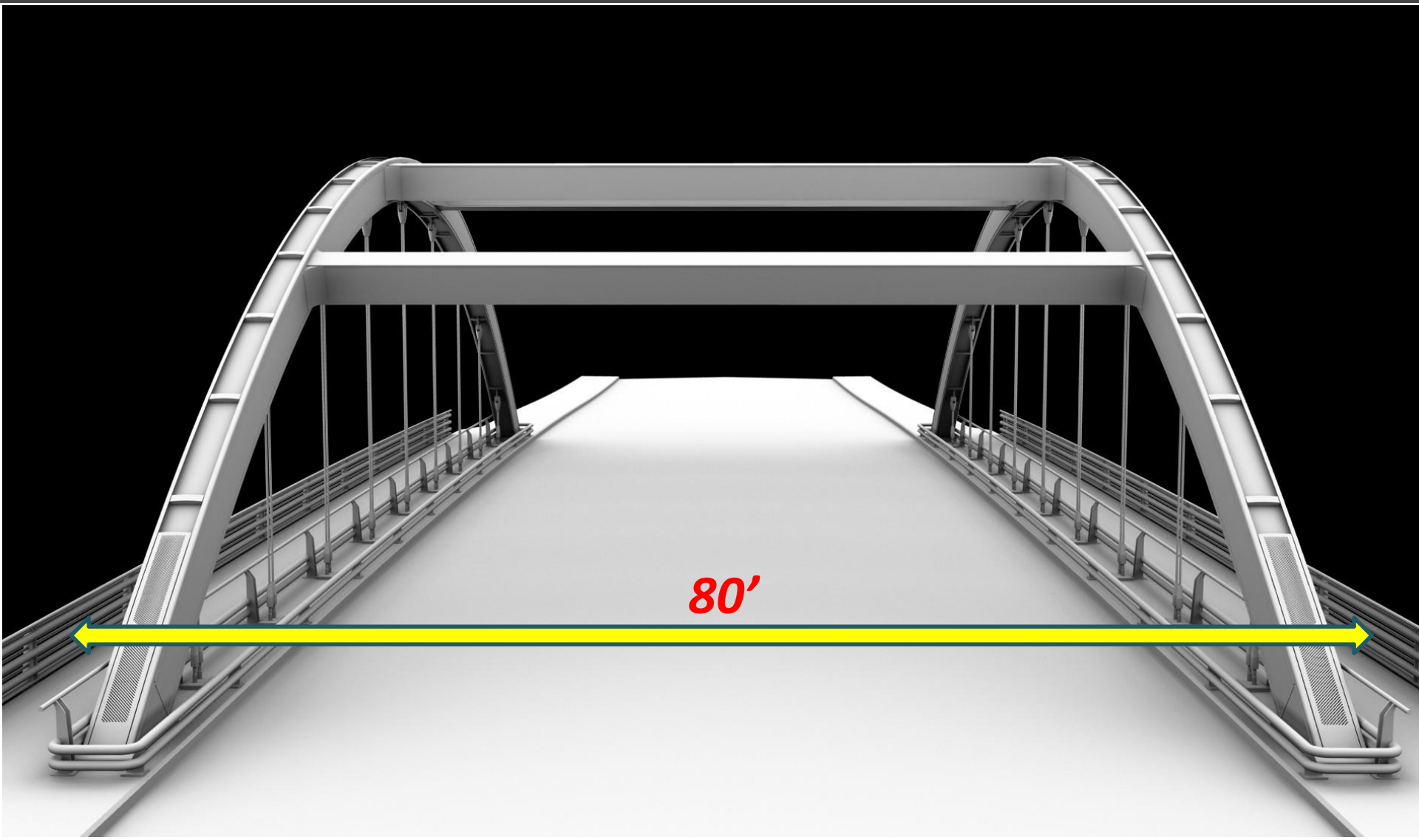
Superstructure Overview



Superstructure Overview



Superstructure Overview



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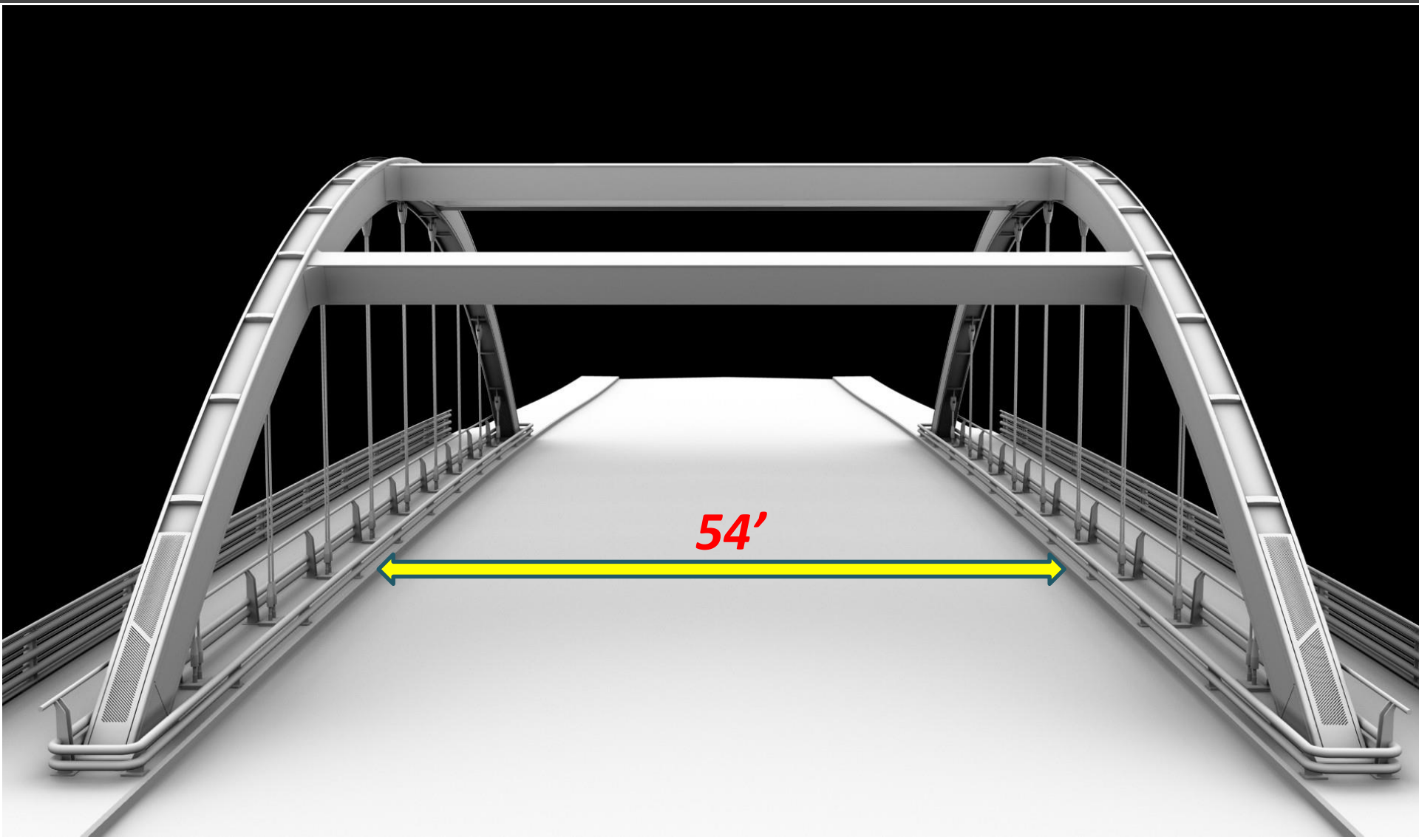

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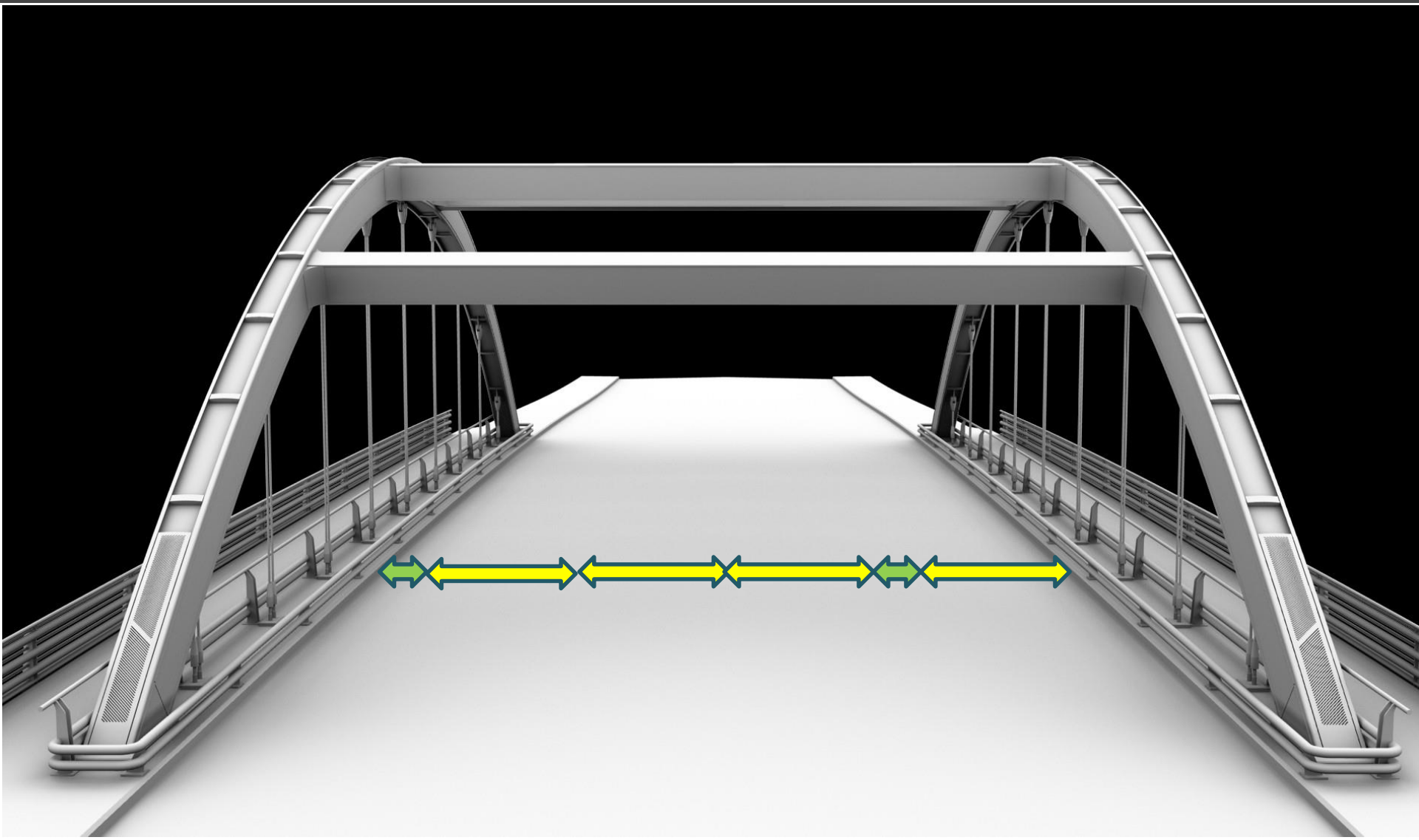

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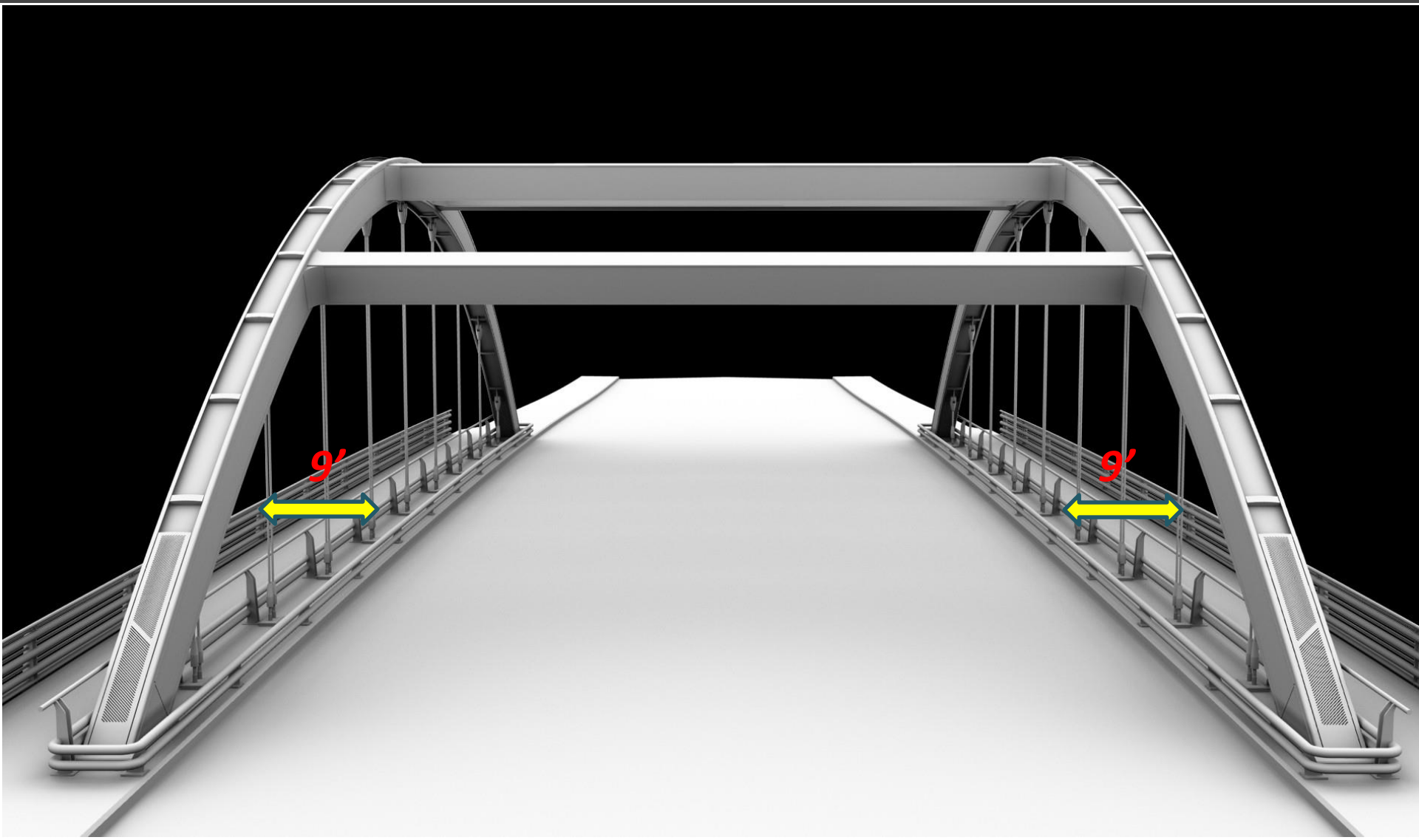

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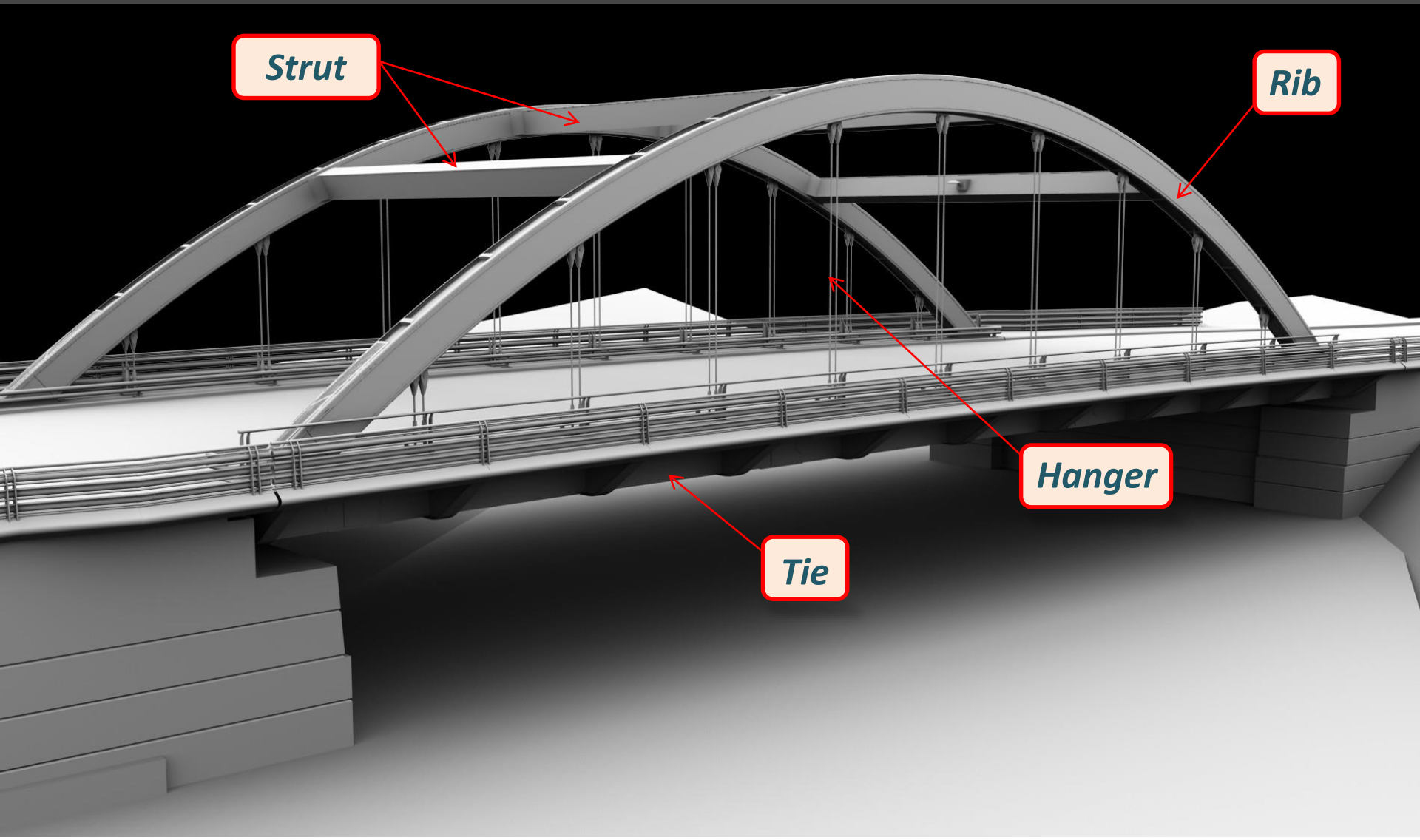

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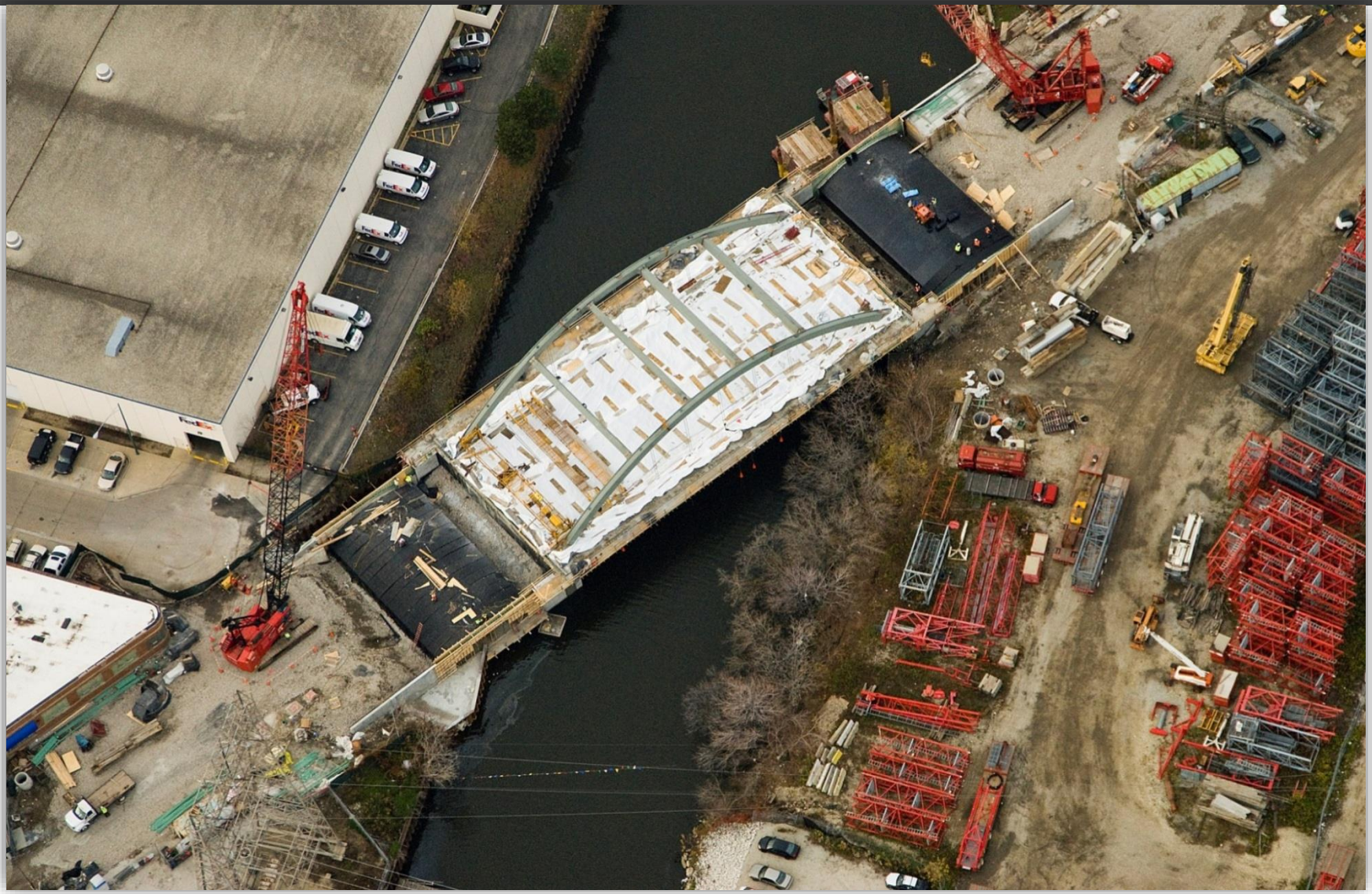
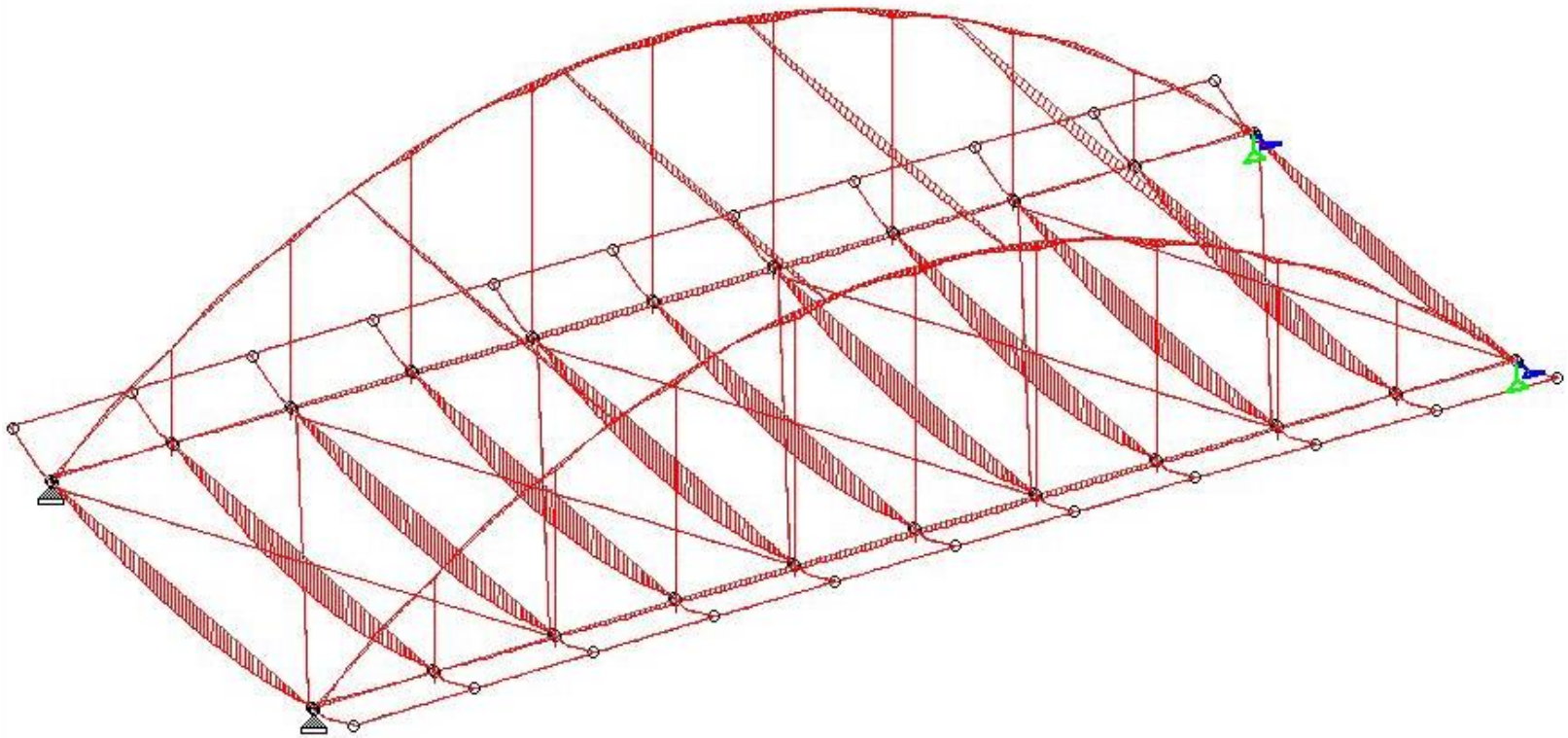


North Halsted Street Bridge

3D STAAD ANALYSIS MODEL - Momments

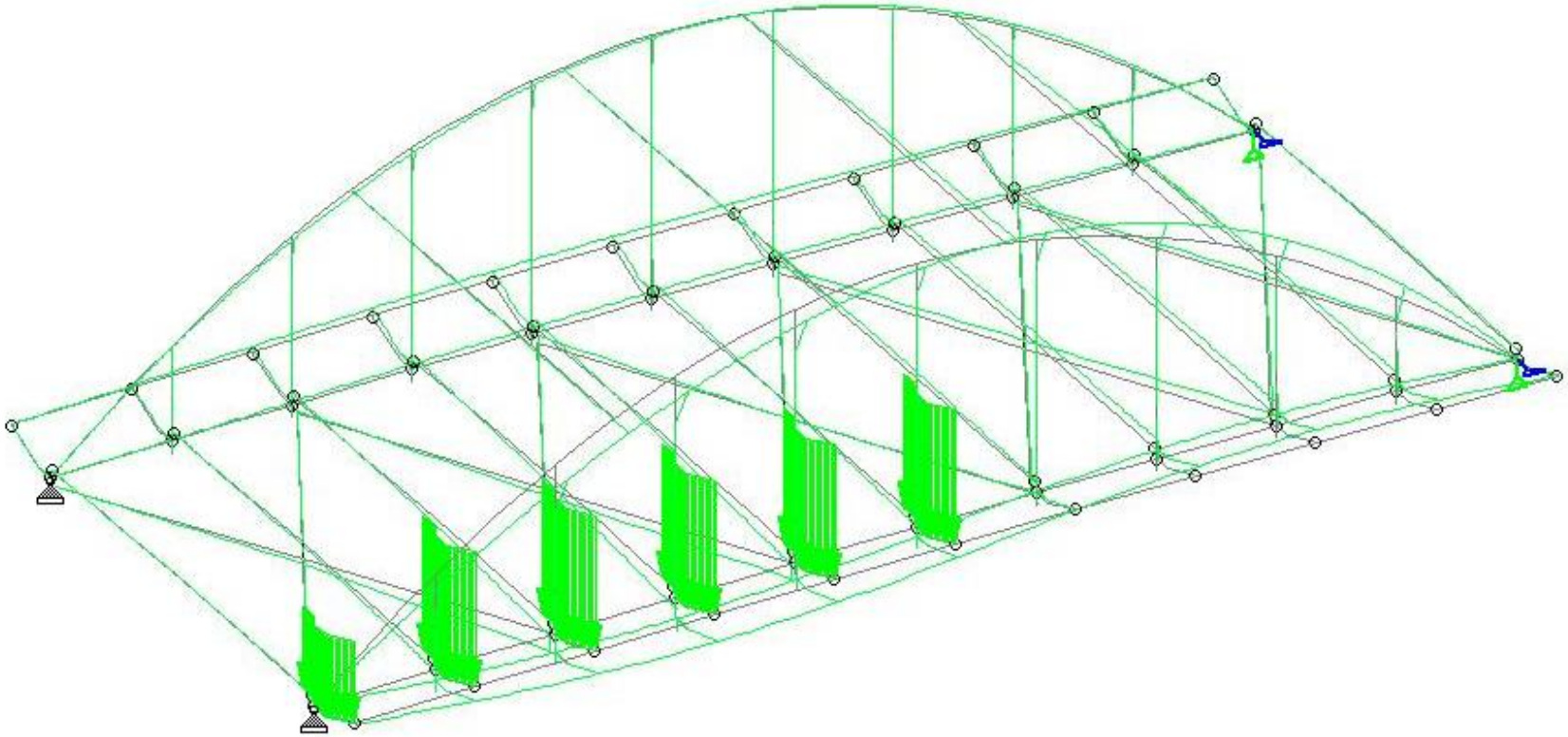


MOMENT DIAGRAM UNDER FULL DL

The rib was selected to be parabolic shape, which minimizes bending moment in the rib (Rib moment is only 25% of the moment in a floor beam)

North Halsted Street Bridge

3D STAAD ANALYSIS MODEL - Defelction



DEFLECTION DIAGRAM UNDER HALF SPAN LIVE LOAD

½ of the span is deflected down and the other ½ is deflected upward

North Halsted Street Bridge - **Redundancy**

Redundancy - Definition:

A redundant structure can redistribute the forces to other members (upon failure of a member) without causing collapse of the entire structure.

North Halsted Street Bridge - Redundancy

Three types of redundancy are provided:

- ***Internal Redundancy in the Tie***
  tie using bolts (rather than weld)

- ***Load Path Redundancy***
  Composite and continuous deck

- ***Structural Redundancy***
  Hangers provide continuity for the tie

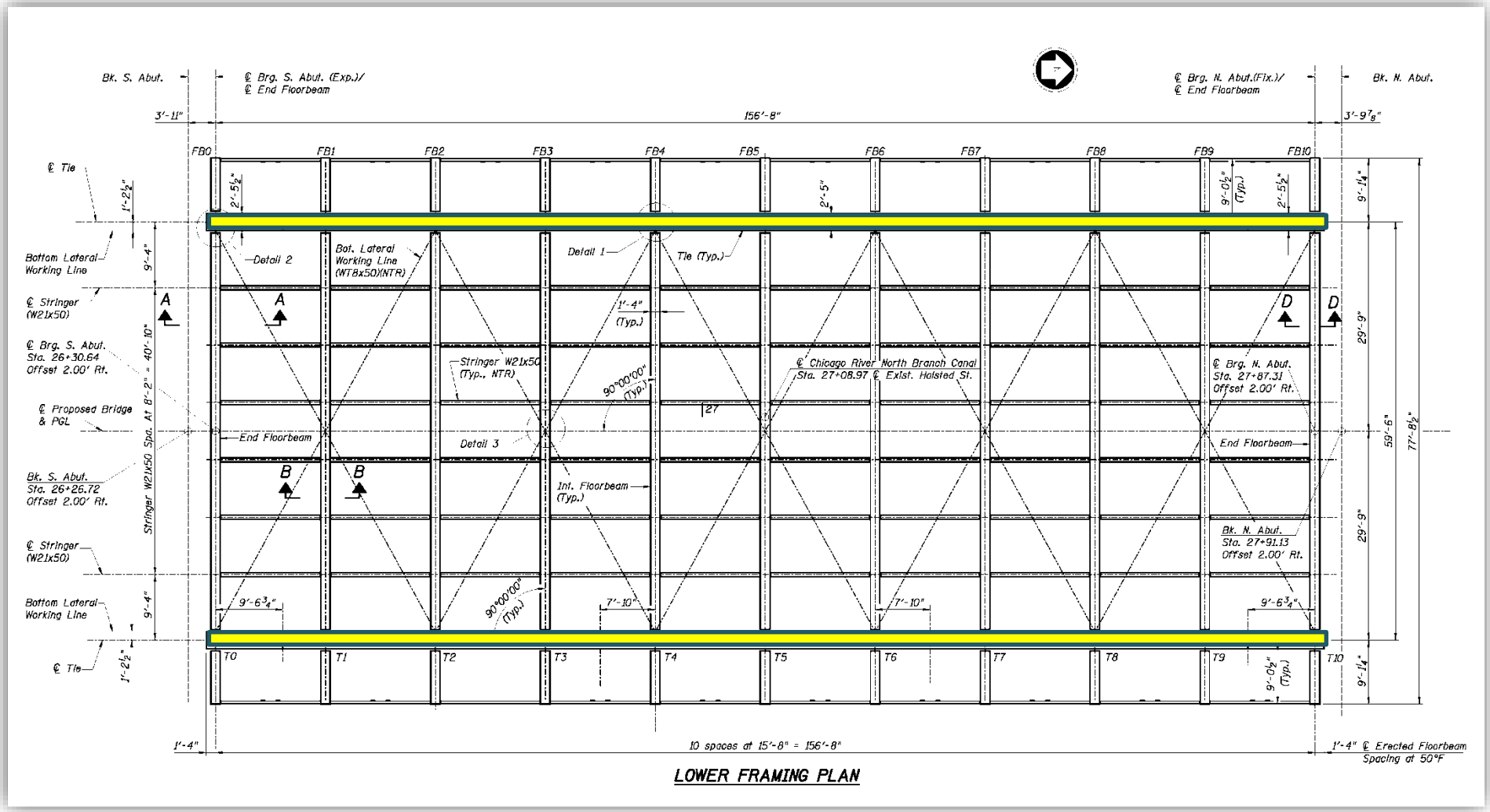
North Halsted Street Bridge - Composite

- ***Composite System:***
  - *Using shear studs: The tie, floor beams, and stringers are connected with the deck*
  - Allow the use of much shallower superstructure

North Halsted Street Bridge

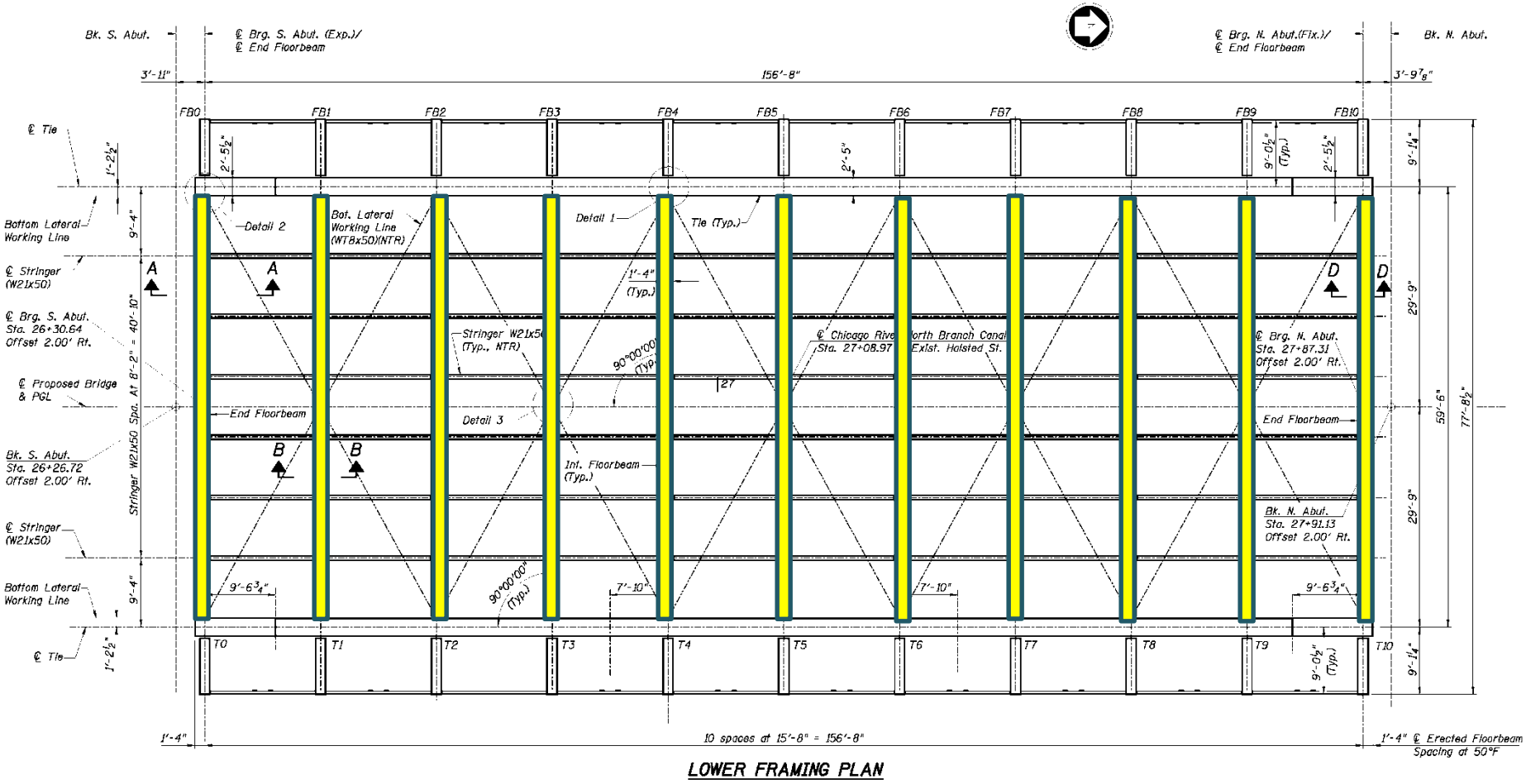
- ***Floor Framing***
- ***Steel Detailing***
- ***Member Cambering***

Lower Framing Plan



LOWER FRAMING PLAN

Lower Framing Plan



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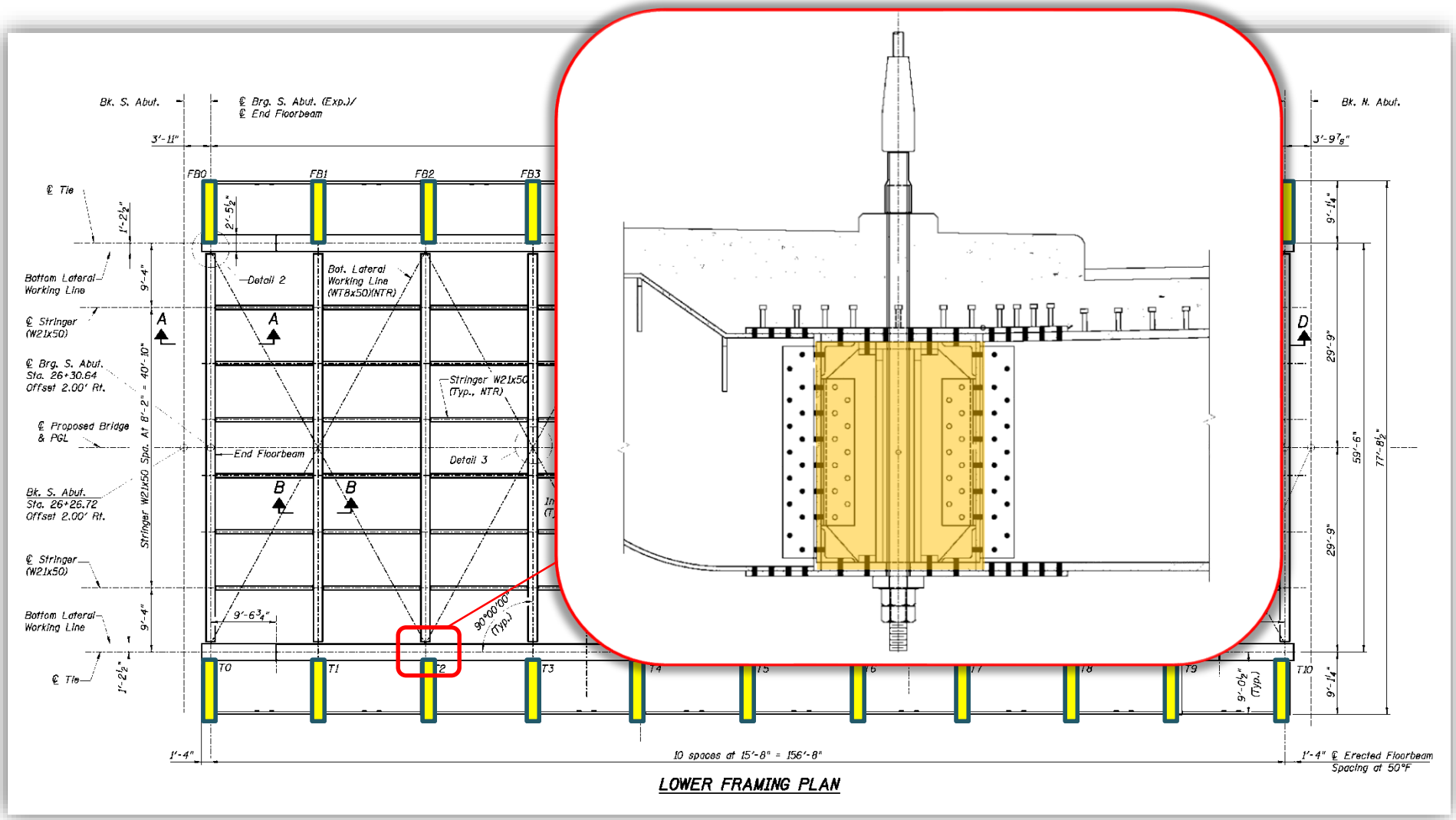

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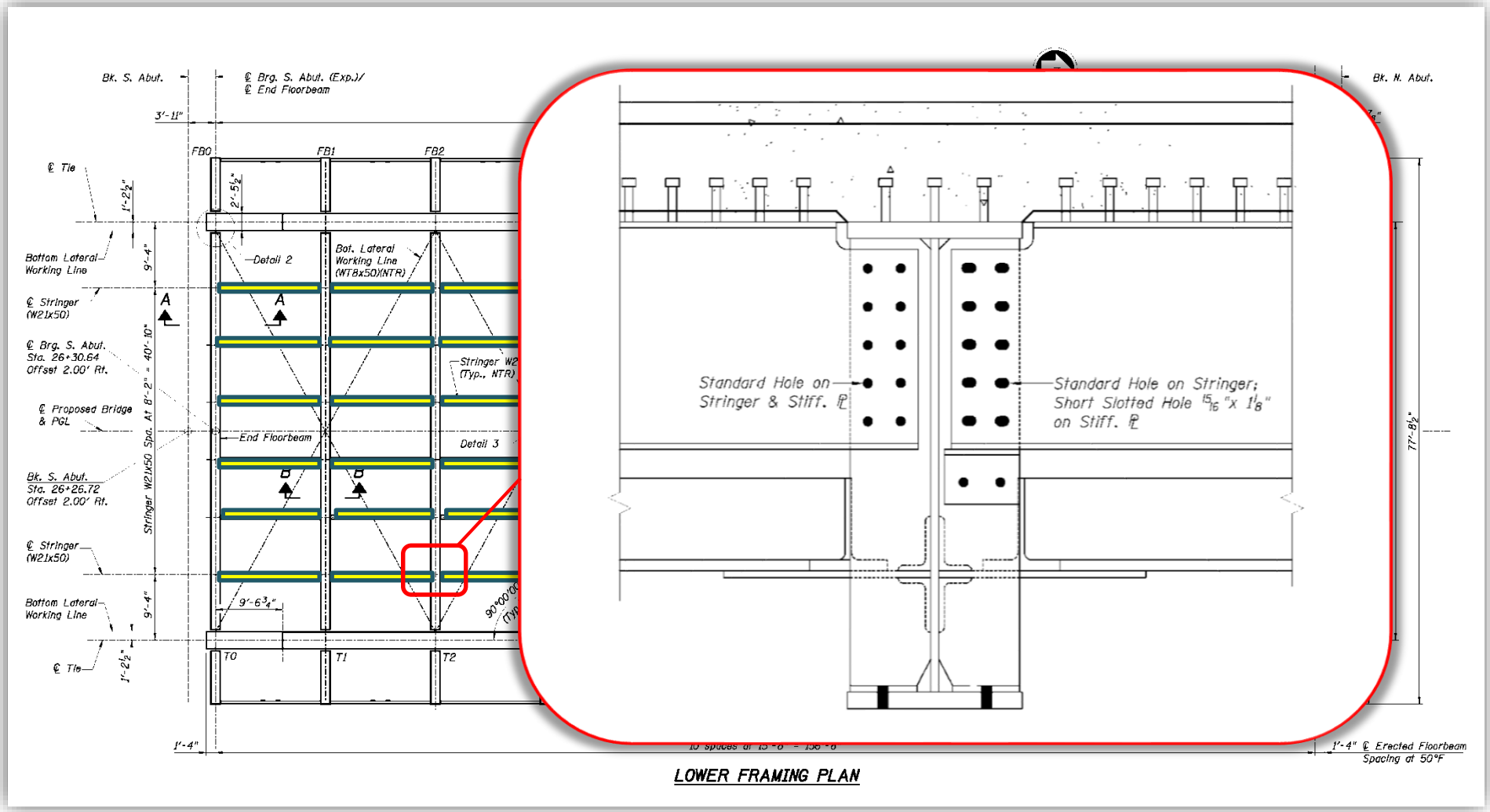


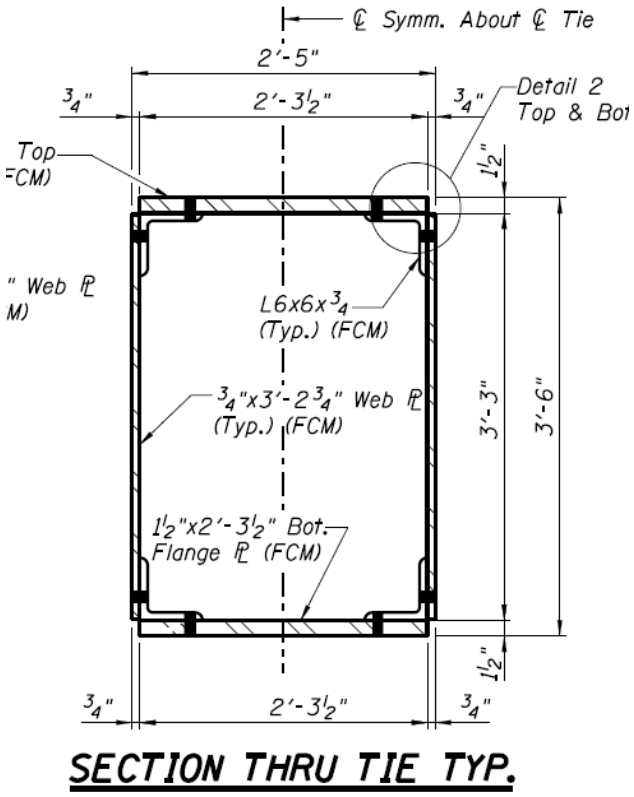
LOWER FRAMING PLAN

Construction of Lower Framing

North Halsted Street Bridge

- *Floor Framing*
- ***Steel Detailing***
- ***Member Cambering***

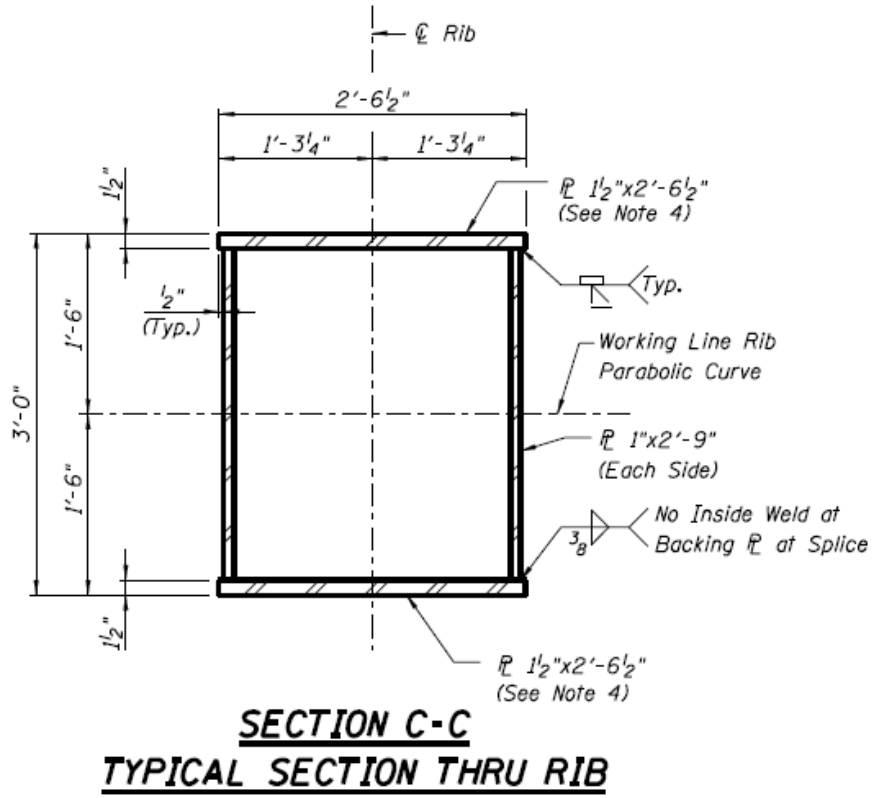
North Halsted Street Bridge - Tie



SECTION THRU TIE TYP.

TIE

North Halsted Street Bridge – Arch (Rib)

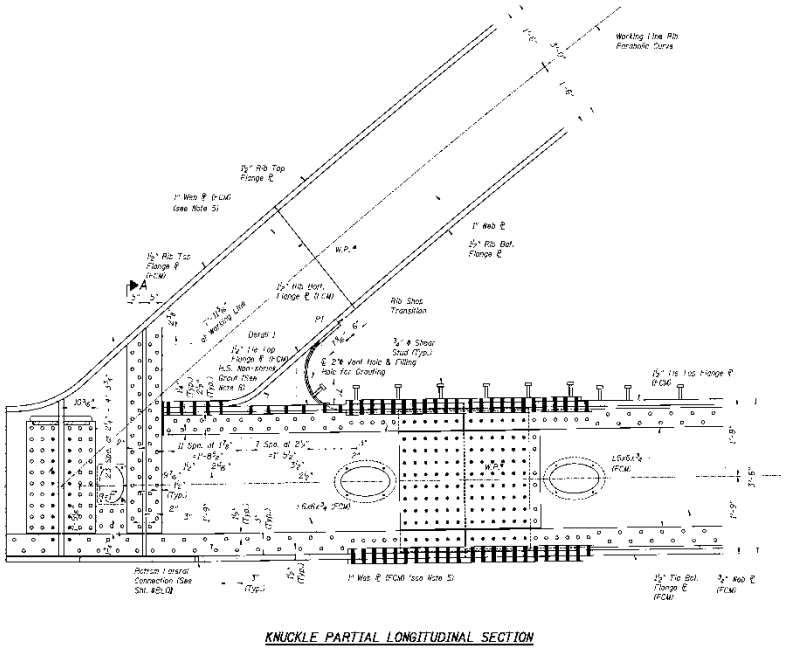


SECTION C-C

TYPICAL SECTION THRU RIB

Arch

North Halsted Street Bridge - Knuckle

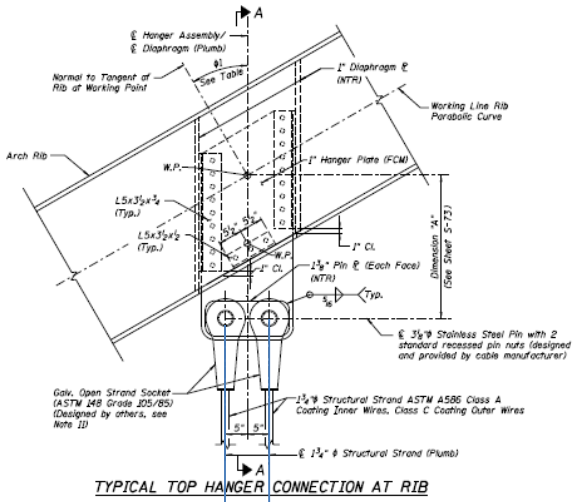


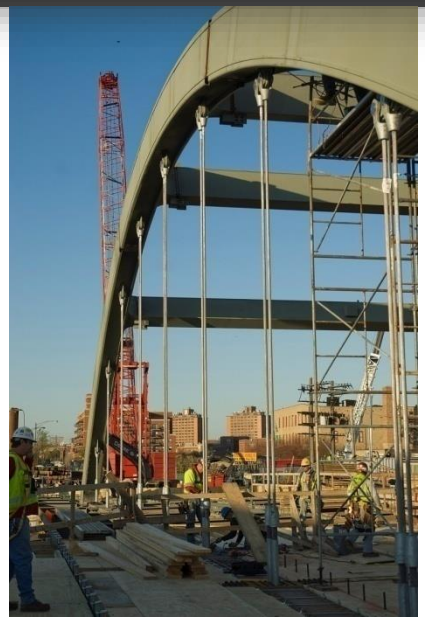
KNUCKLE PARTIAL LONGITUDINAL SECTION

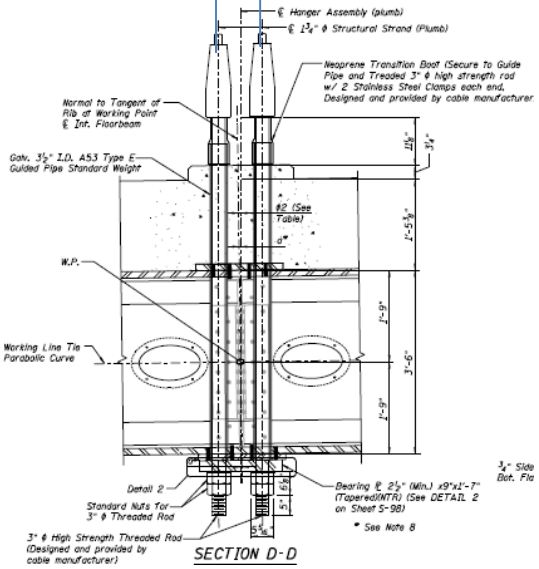
KNUCKLE

Due to the complicated stress distribution at this location, finite element analysis was performed

North Halsted Street Bridge - Hangers







Two 1 ¾" Φ HANGERS

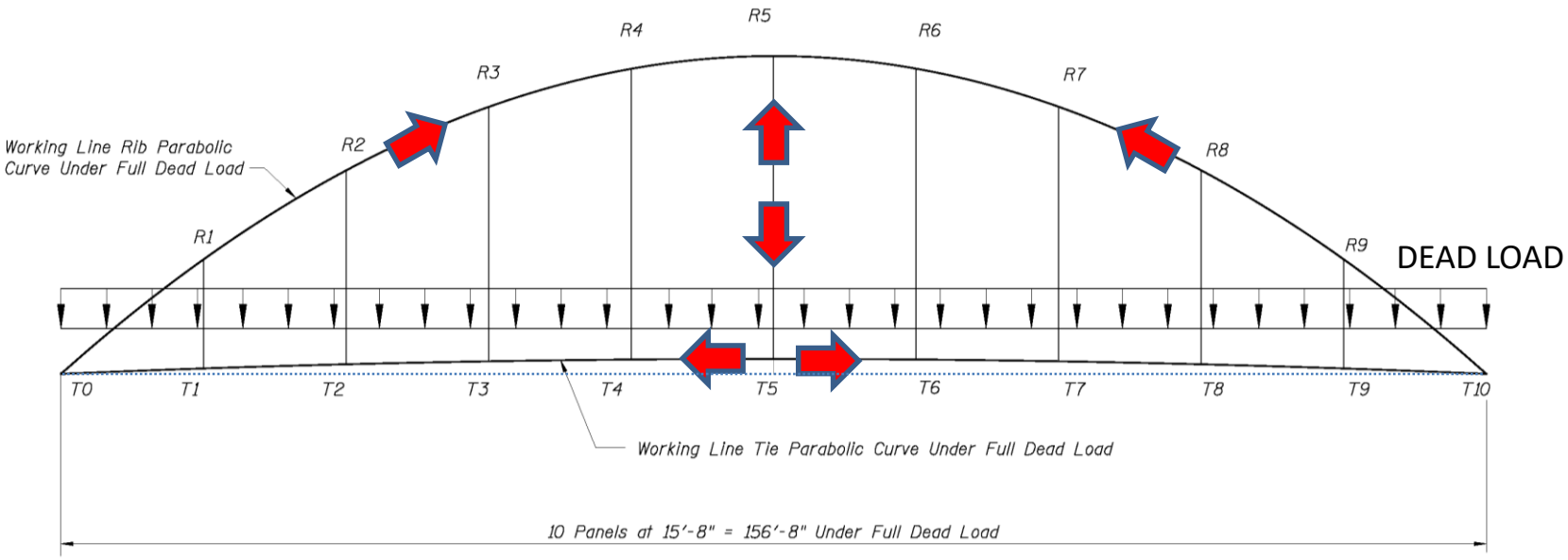
Each of the two cables are designed to support the entire force temporarily

North Halsted Street Bridge

- *Floor Framing*
- *Steel Detailing*
- ***Member Cambering***

North Halsted Street Bridge - Cambering

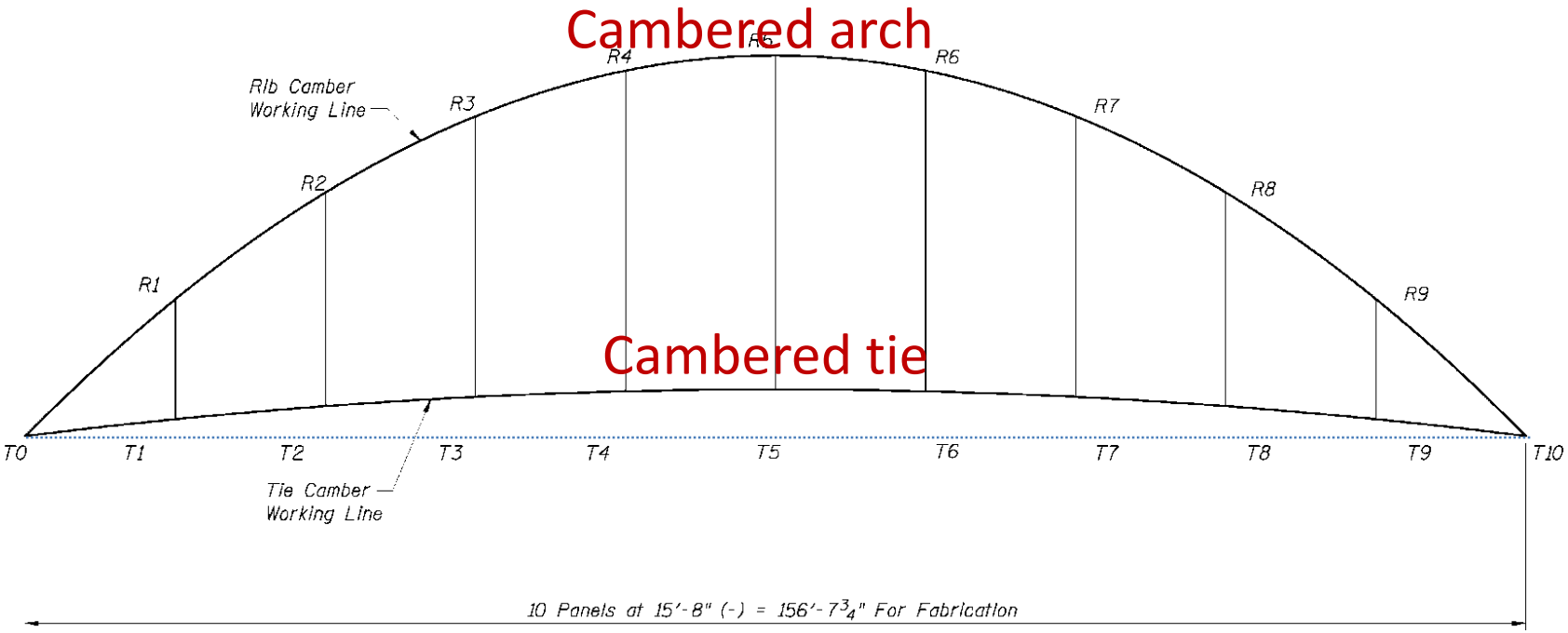
ARCH FINAL PARABOLIC SHAPE
UNDER FULL DEAD LOAD (DC+DW)



ARCH GEOMETRIES UNDER FULL DEAD LOAD

In order to achieve the theoretical design shape, all major force-carrying-members are cambered

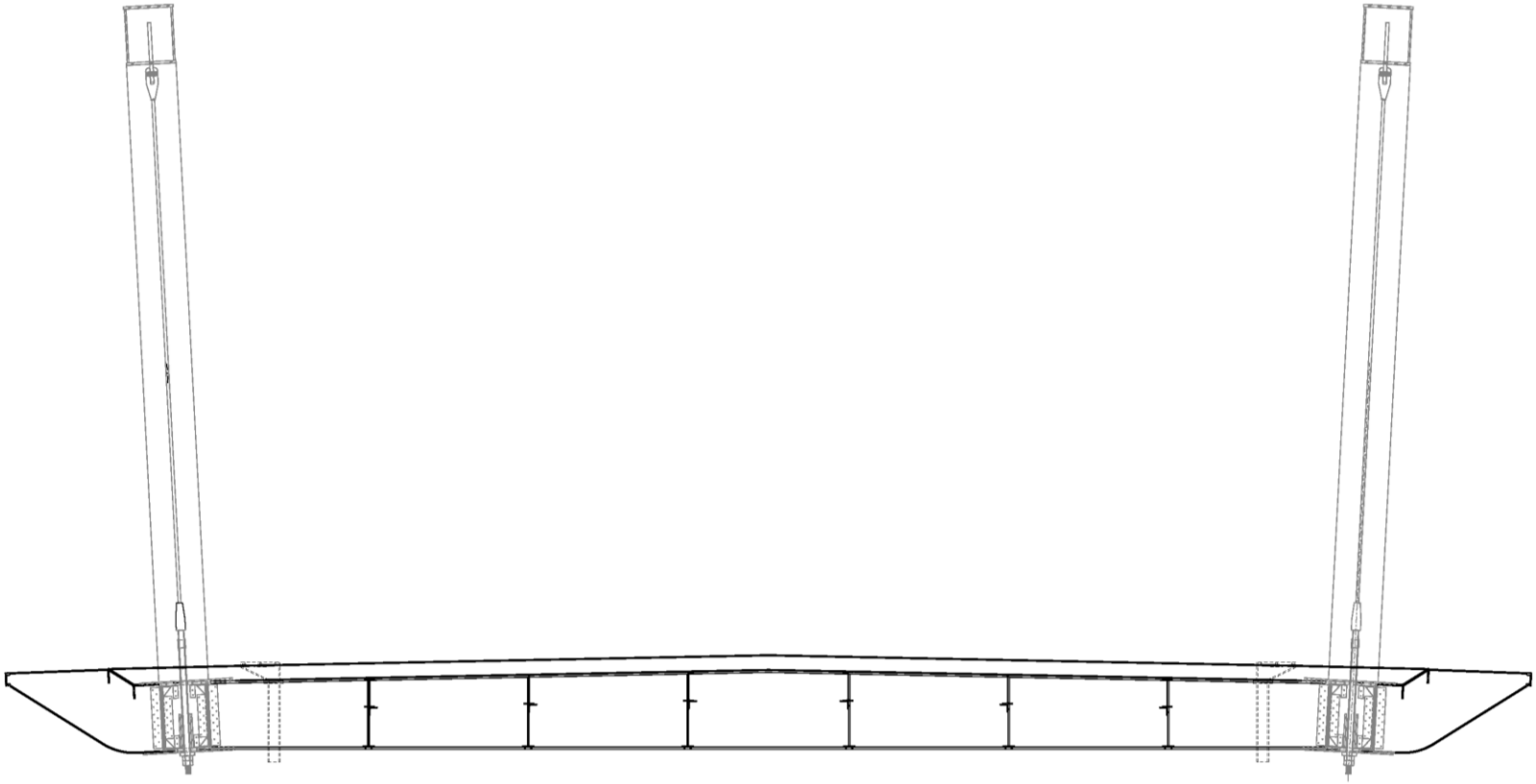
North Halsted Street Bridge - Cambering



ARCH CAMBER DIAGRAM FOR FABRICATION

Tie and hangers are made shorter. The arch is made higher

North Halsted Street Bridge - Cambering

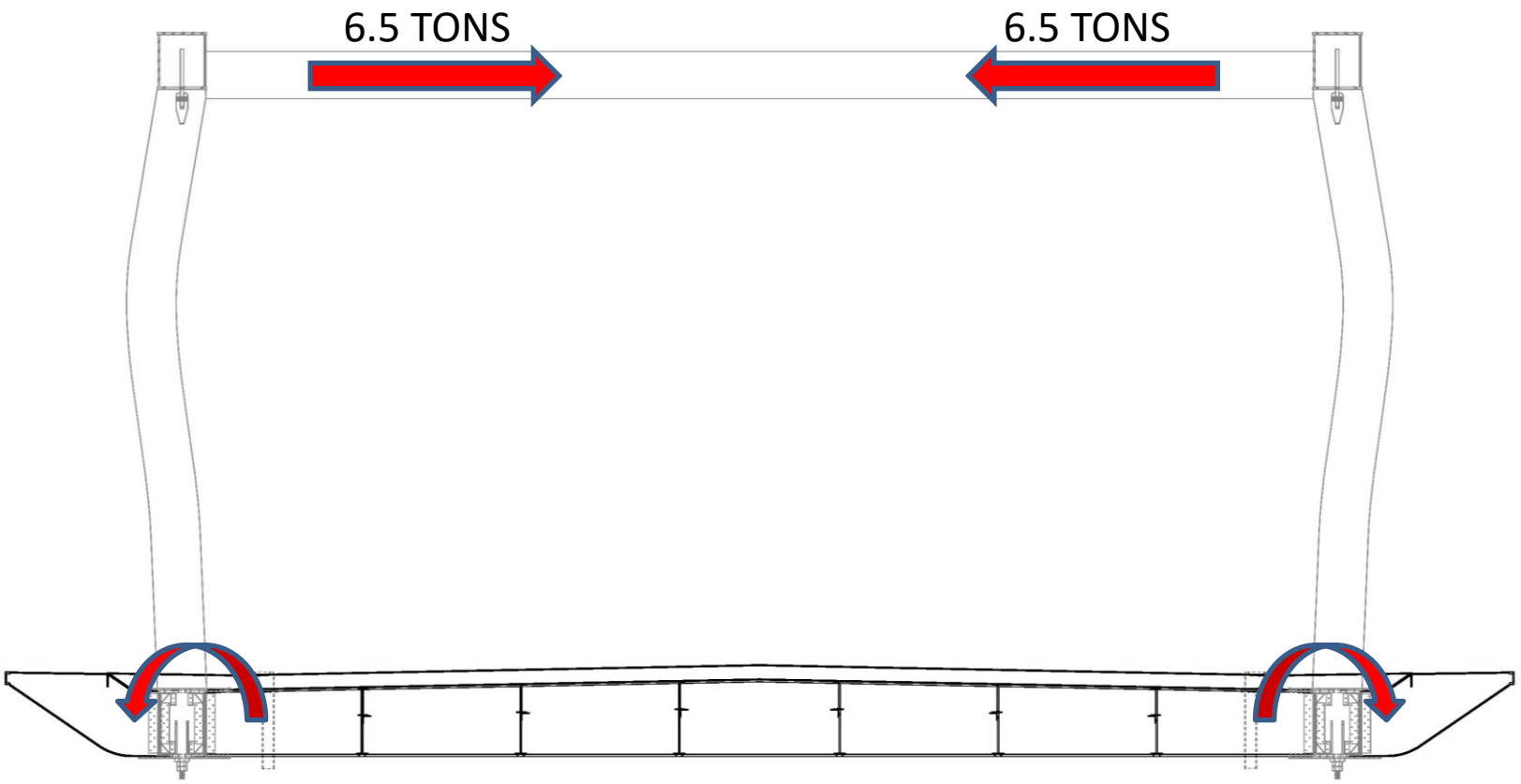


SLANT-CUT FLOORBEAMS CONNECTED WITH ARCH FRAMES

Floorbeams are also cambered:

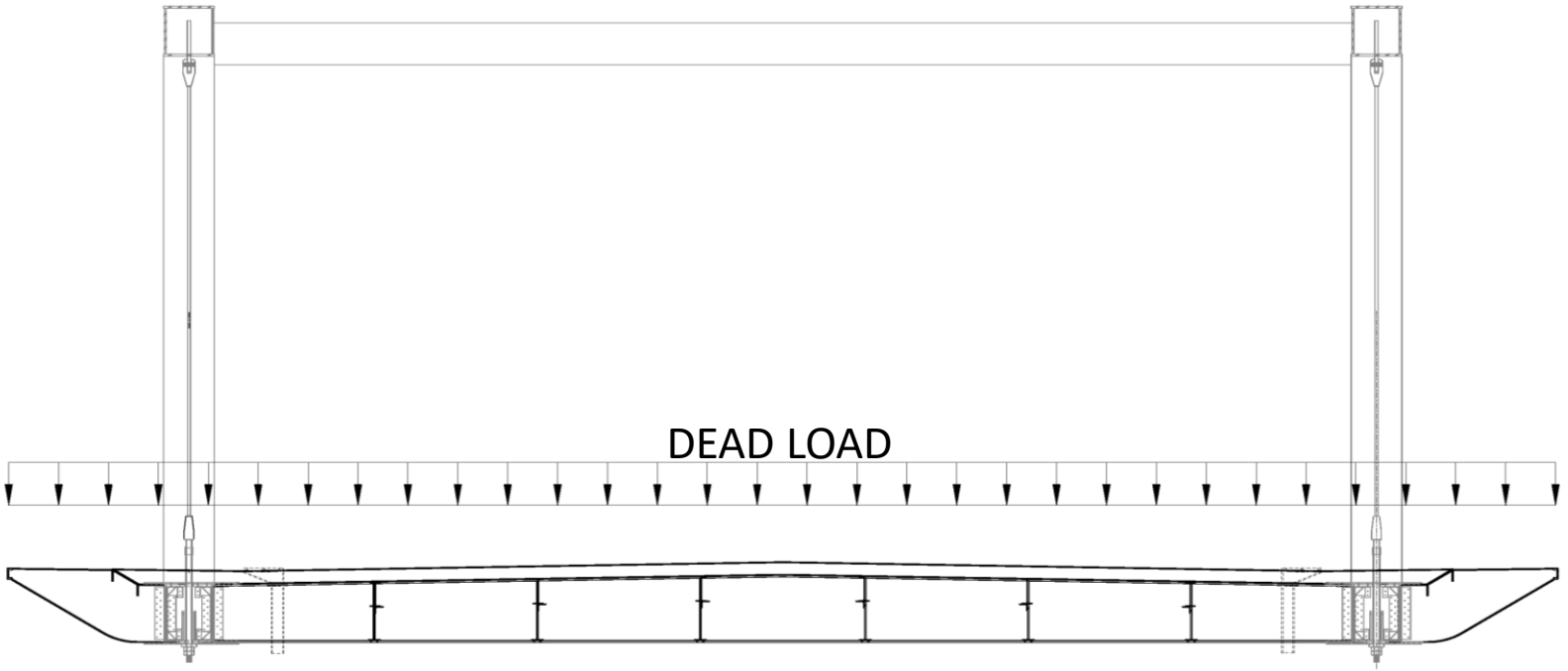
1) Conventional flexure upward camber
2) The two ends are cut in slant angle to anticipate the end rotation

North Halsted Street Bridge



ARCH FRAMES ARE FORCED TO BE CONNECTED WITH TOP STRUTS

North Halsted Street Bridge



FINAL GEOMETRY UNDER FULL DEAD LOAD

Construction Sequencing

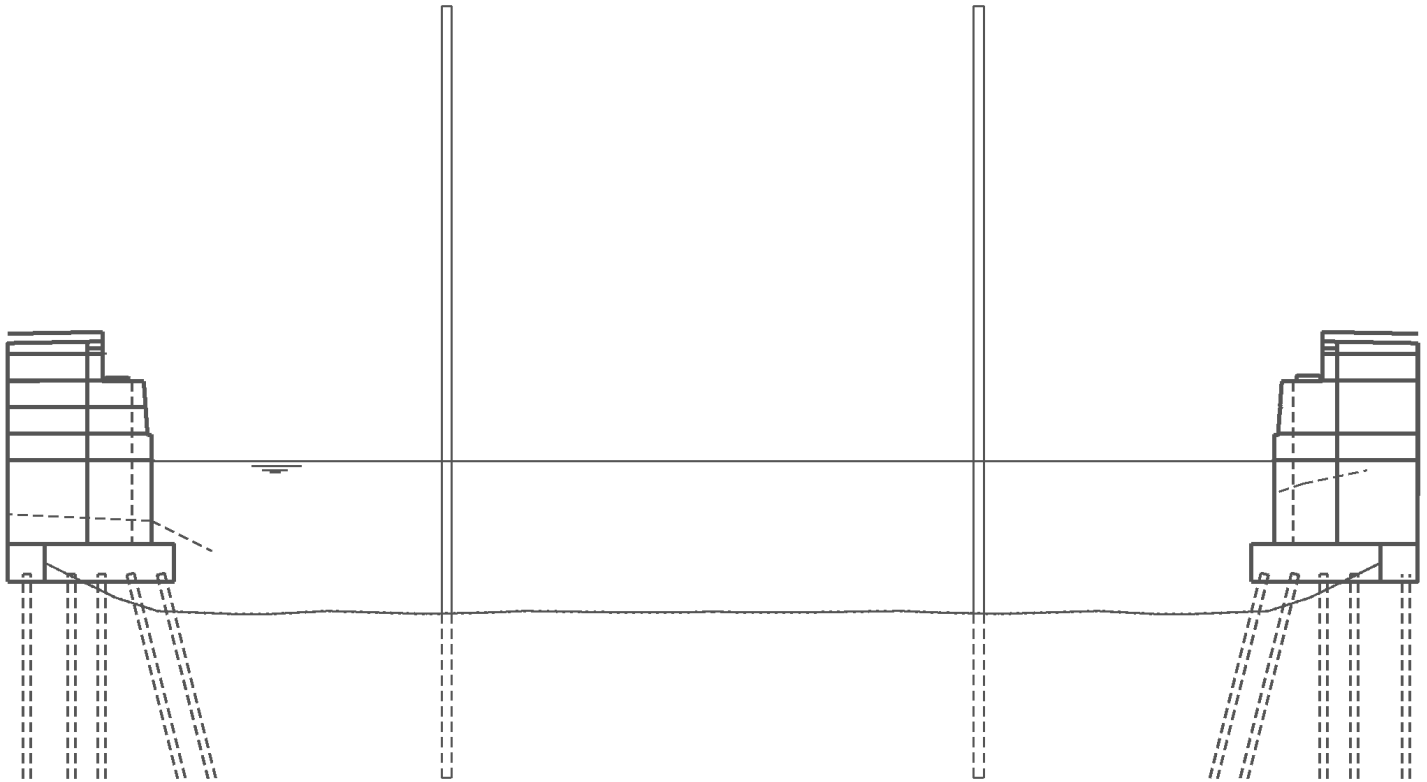
Tied-Arch - Construction Methods

Tied-Arch Bridges - Two Construction methods:

1. ABC (Accelerated Bridge Construction)
2. Build-in-place

North Halsted Street Bridge

Erection Stages - Stage 1



North Halsted Street Bridge

Erection Stages - Stage 2

North Halsted Street Bridge

Erection Stages - Stage 2

North Halsted Street Bridge

Erection Stages - Stage 3

North Halsted Street Bridge

Erection Stages - Stage 3

North Halsted Street Bridge

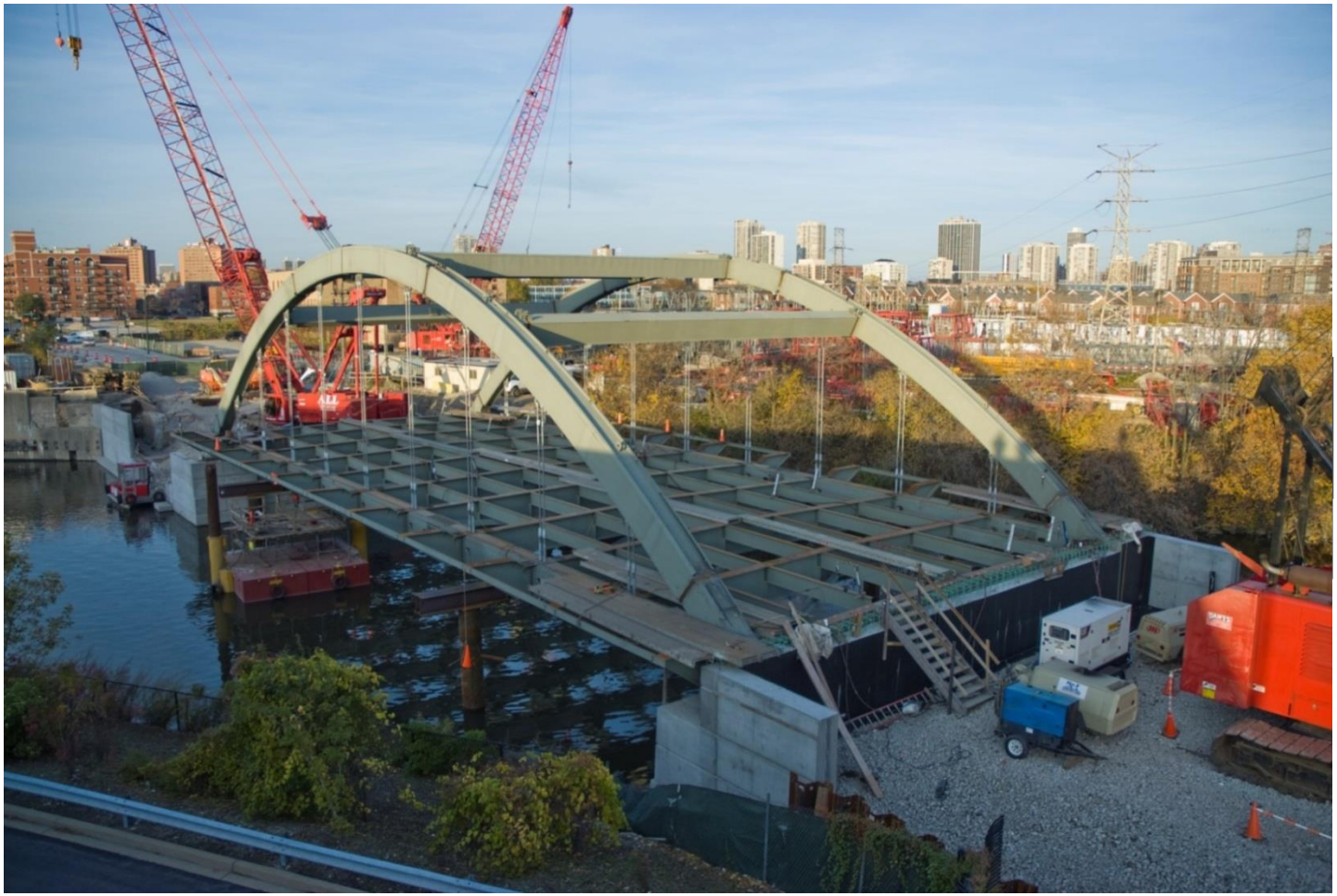
Erection Stages - Stage 4

North Halsted Street Bridge

Erection Stages - Stage 4

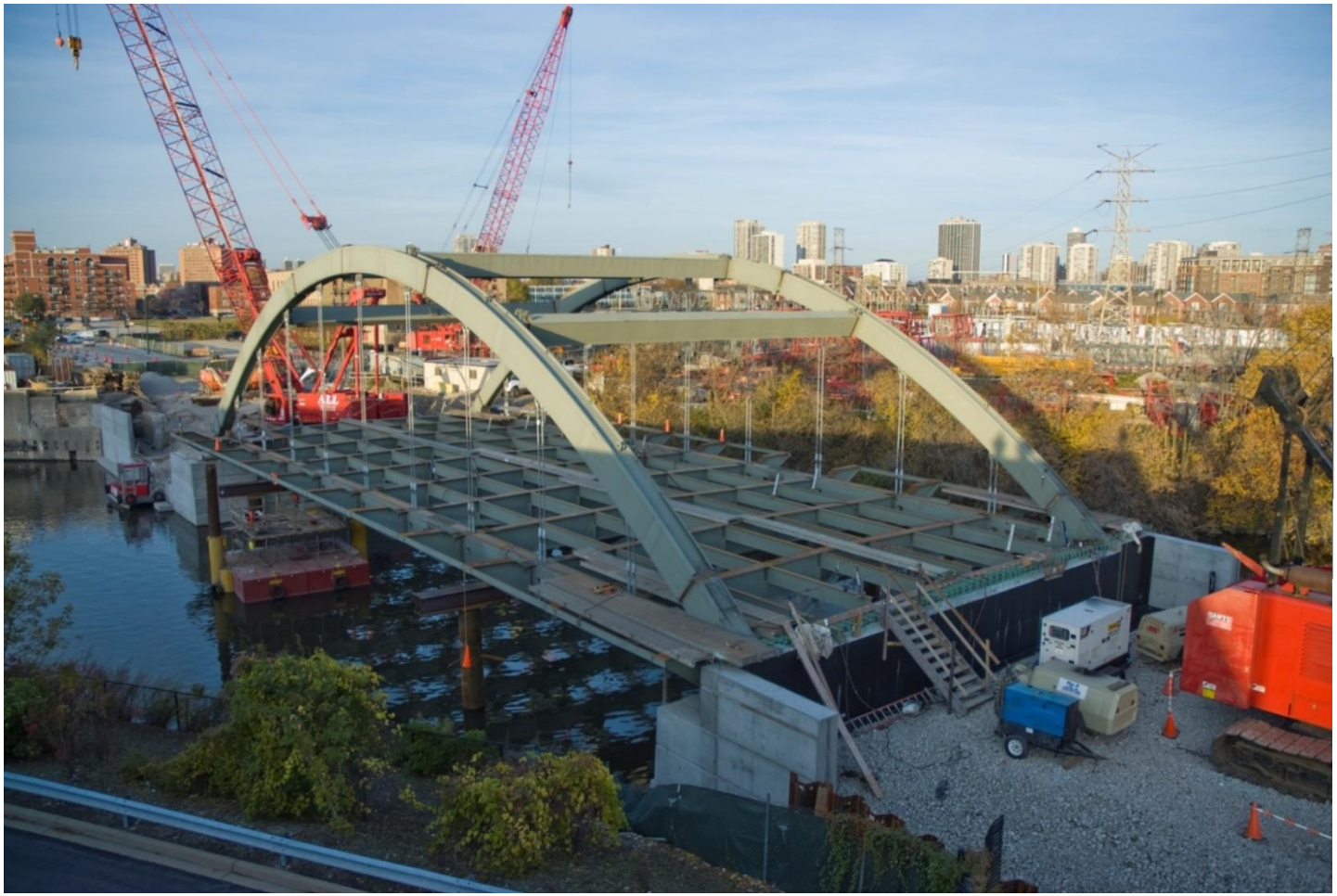
North Halsted Street Bridge

Erection Stages - Stage 5



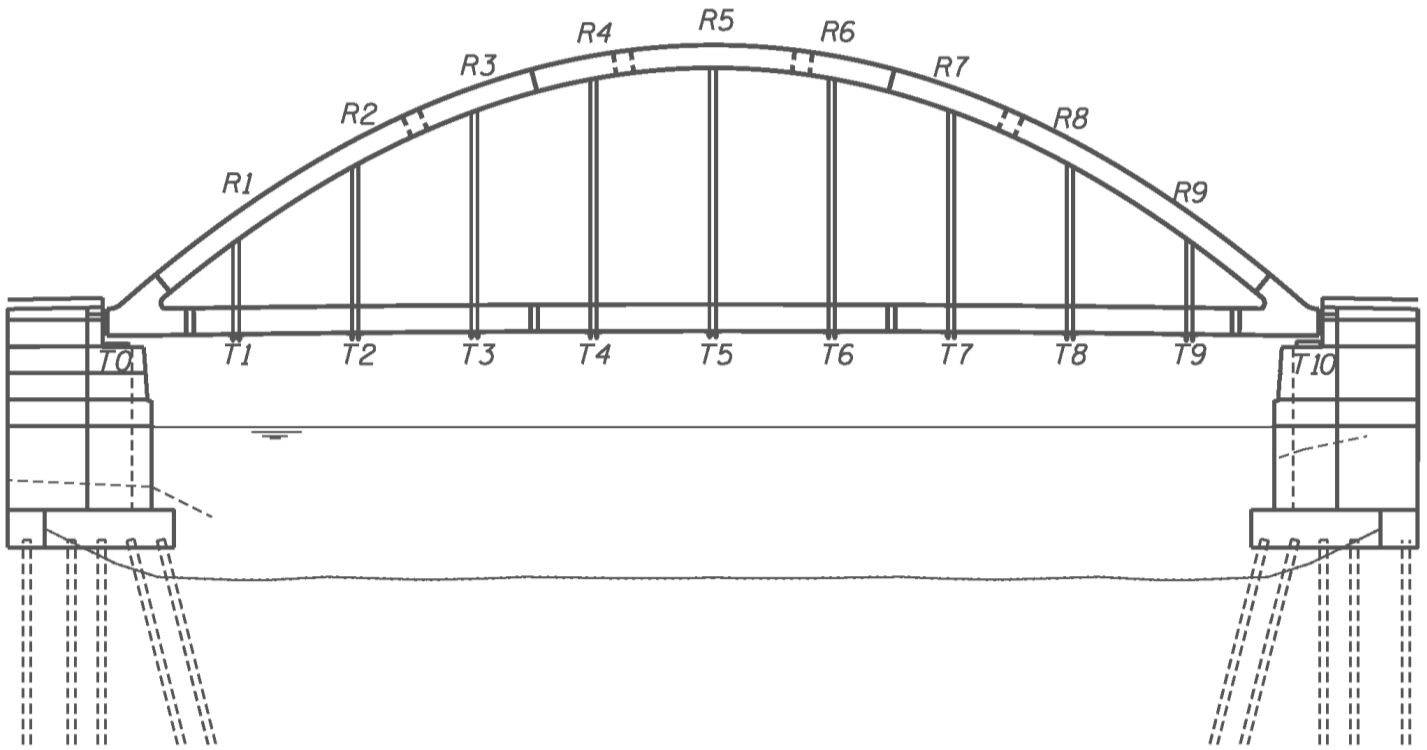
North Halsted Street Bridge

Erection Stages - Stage 5



North Halsted Street Bridge

Erection Stages - Stage 6



North Halsted Street Bridge

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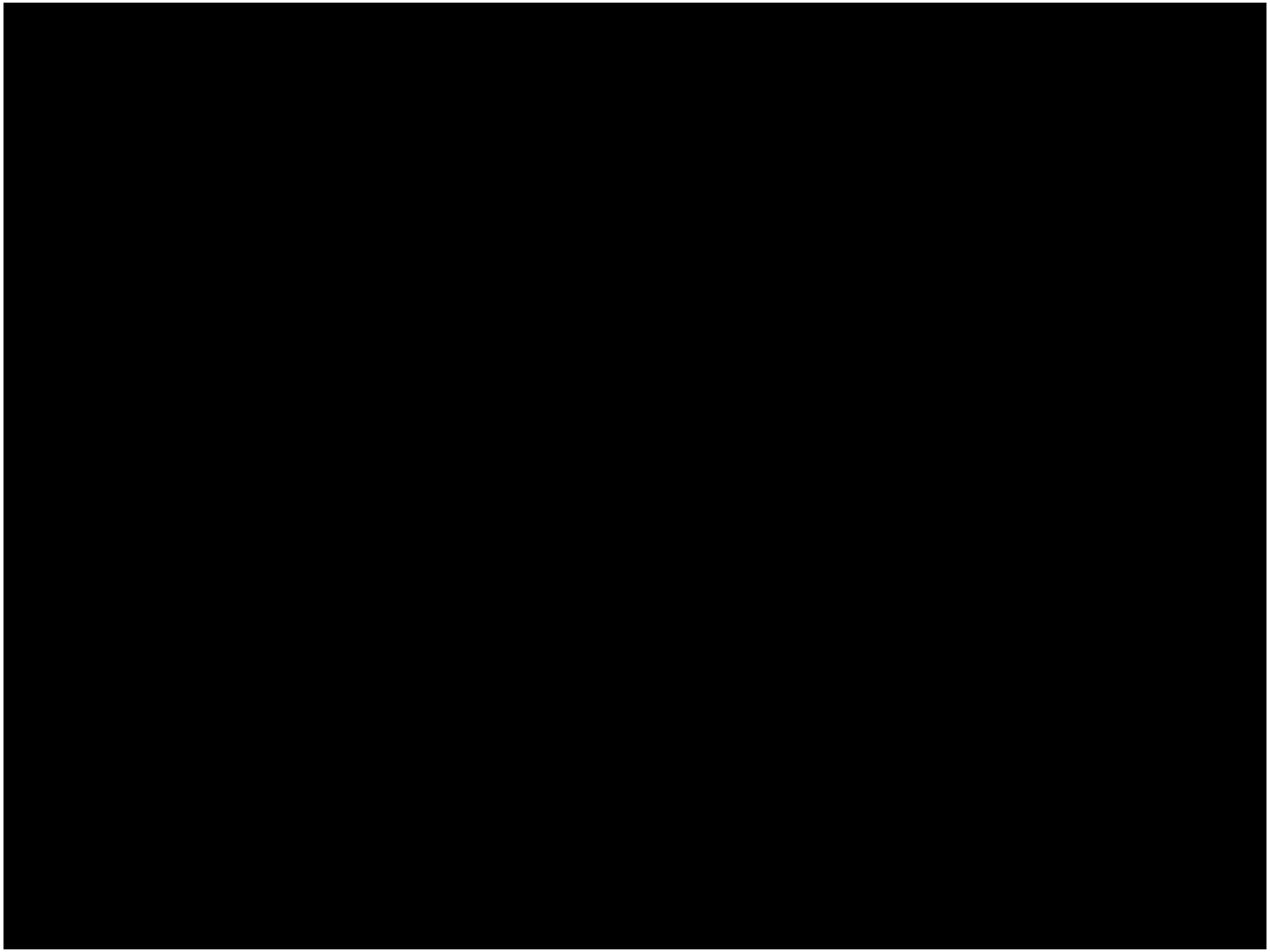
North Halsted Street Bridge

CABLE HANGER: FORCE TESTING

Construction Sequencing



Completed Bridge Photos

North Halsted Street Bridge

North Halsted Street Bridge

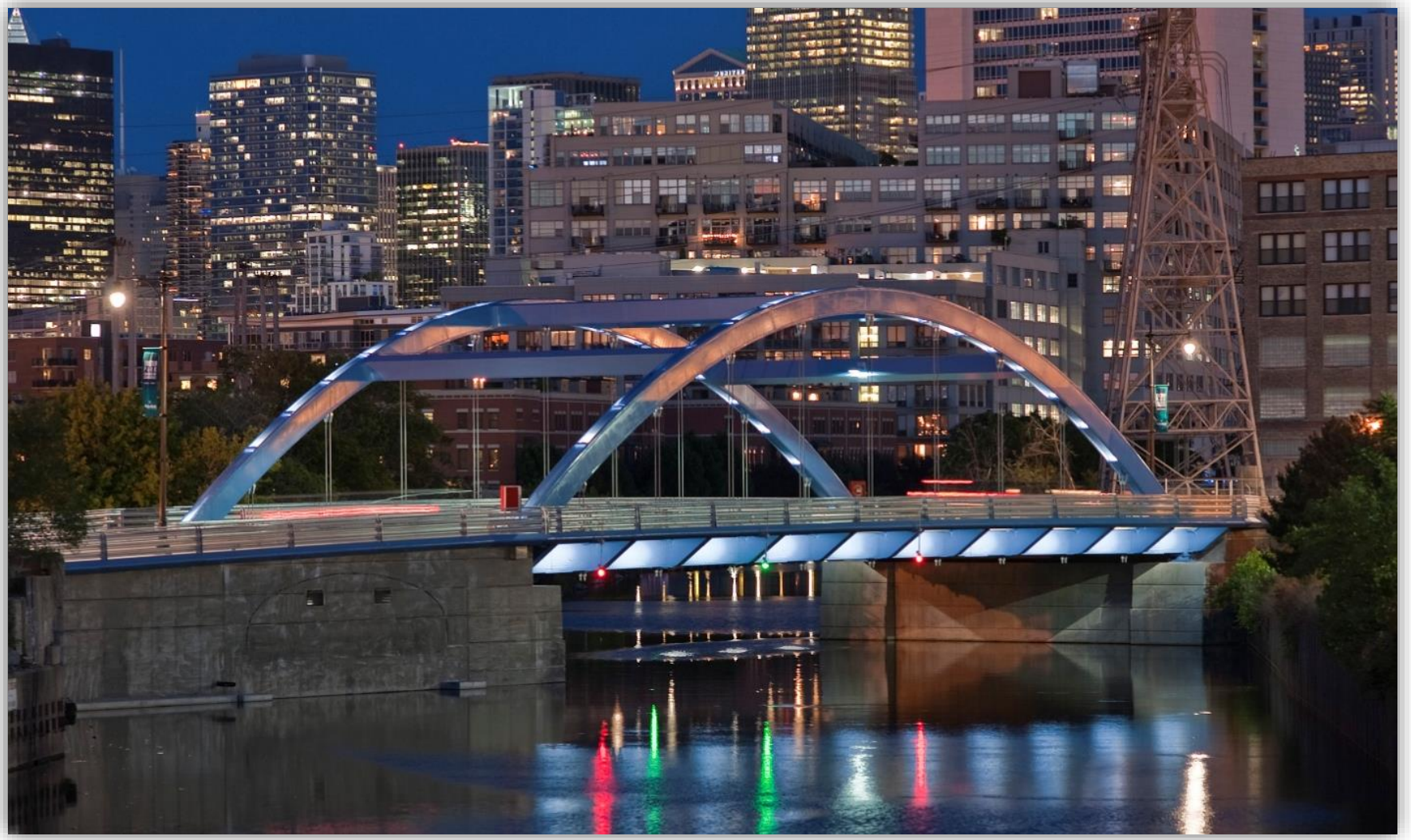
North Halsted Street Bridge

North Halsted Street Bridge

North Halsted Street Tied-Arch Bridge

North Halsted Street Tied-Arch Bridge

North Halsted Street Bridge



North Halsted Street Bridge

Owner:

Chicago Department of Transportation

Engineering Team:

Prime Consultant – ***H.W. Lochner***
Main Sub-consultant – ***HBM Engineering***
Peer Reviewer – ***Parson Brinckerhoff***

Architectural Team:

Architect – ***Muller & Muller***
Lighting Architect – ***Schuler Shook***
Historic Documentation – ***Johnson Lasky***

Construction Management:

Benesch

Contractor:

Walsh Construction

North Halsted Street Bridge

Thank you