Design of the

John James Audubon Bridge

Don Bergman, PE

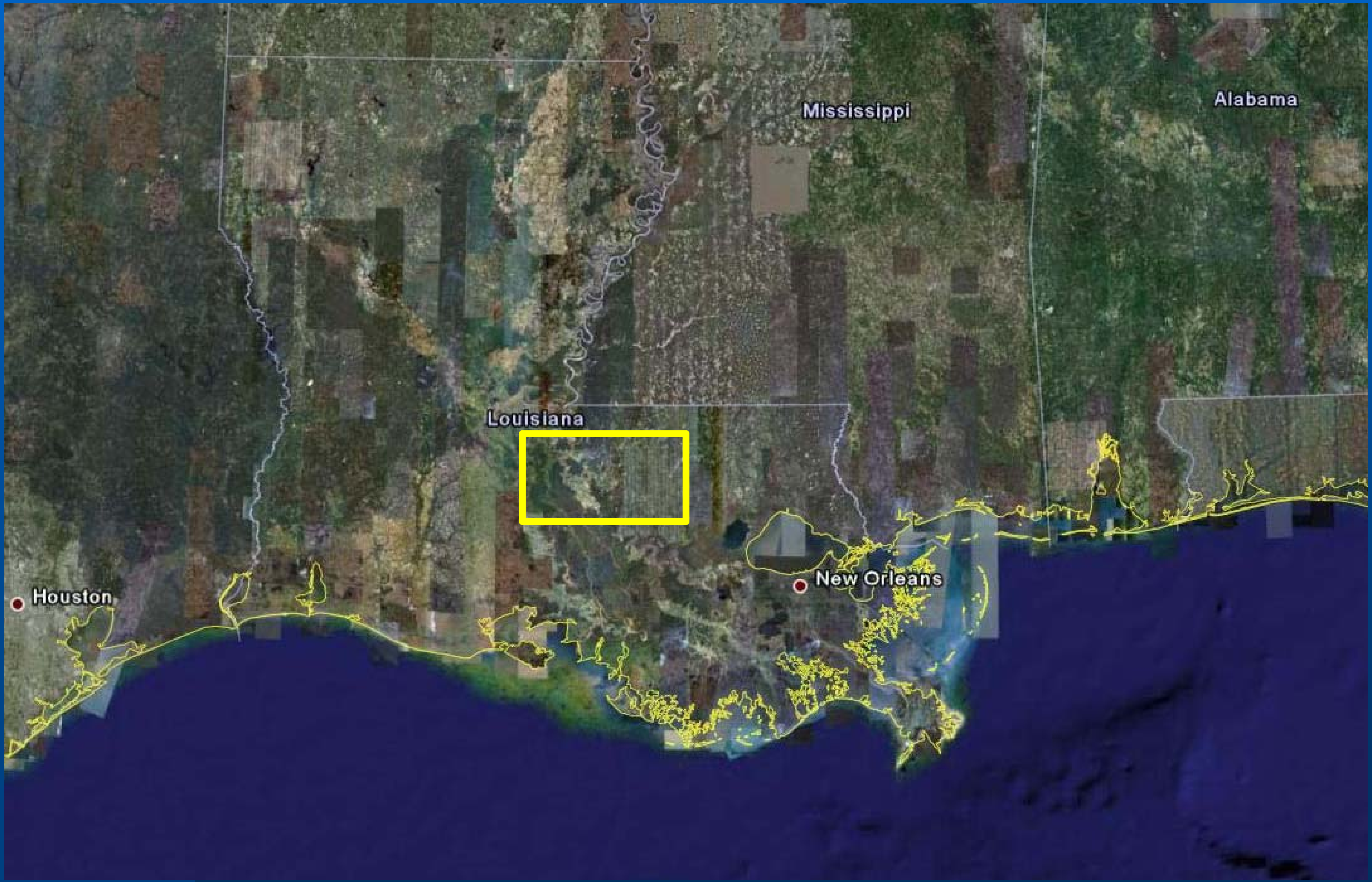
BUCKLAND & TAYLOR LTD.
Bridge Engineering

John J Audubon Bridge Project

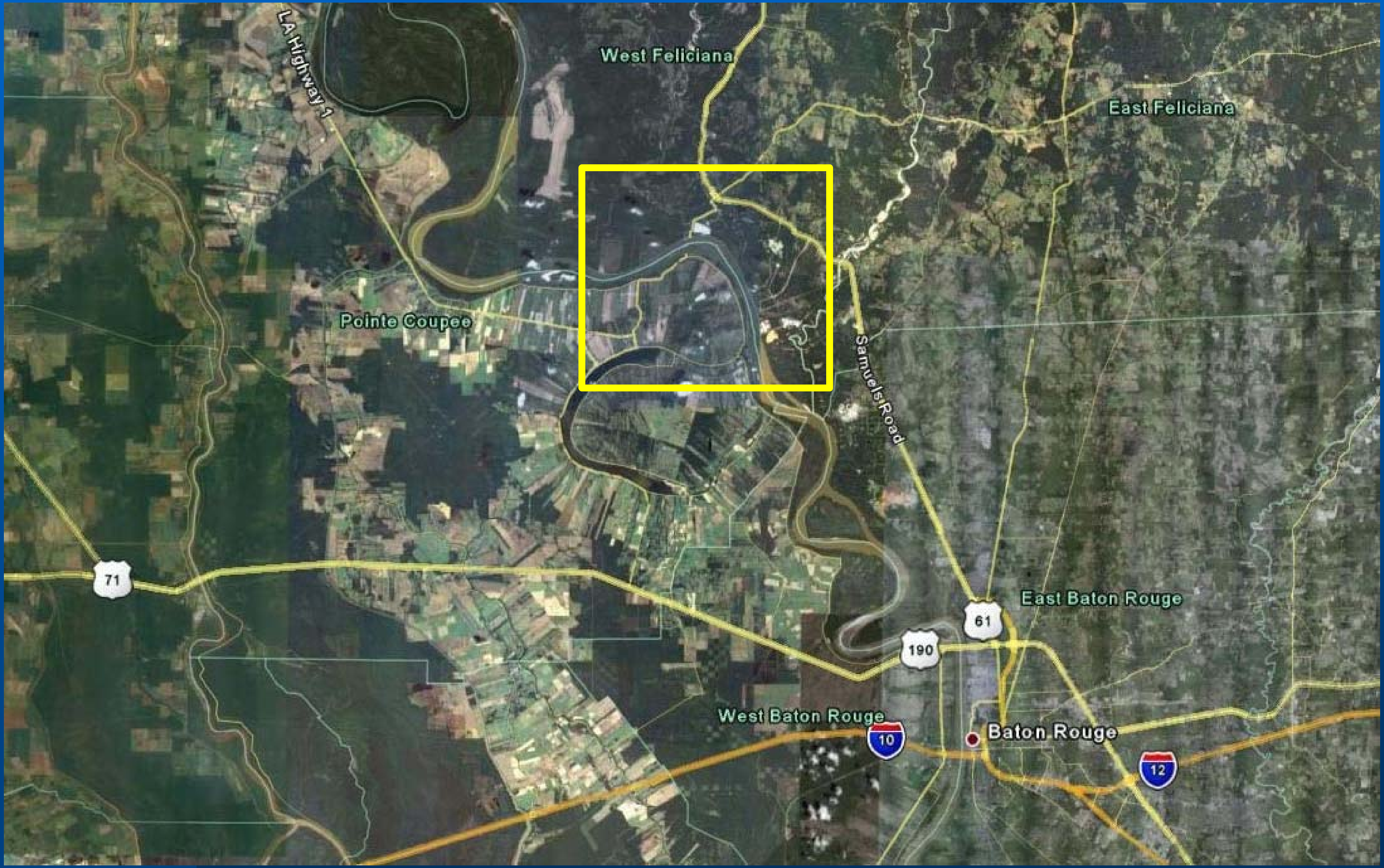
Project Background

- Bridge is centerpiece of new Mississippi River Crossing north of Baton Rouge
- Project included in LA Timed Management Program in 1989
- Selected as first design build project by LADOTD
- Awarded for $347M in 2006 to Audubon Bridge Constructors, a joint venture of:
  - Flatiron Constructors
  - Granite Construction
  - Parson Transportation
- Completion scheduled for 2010

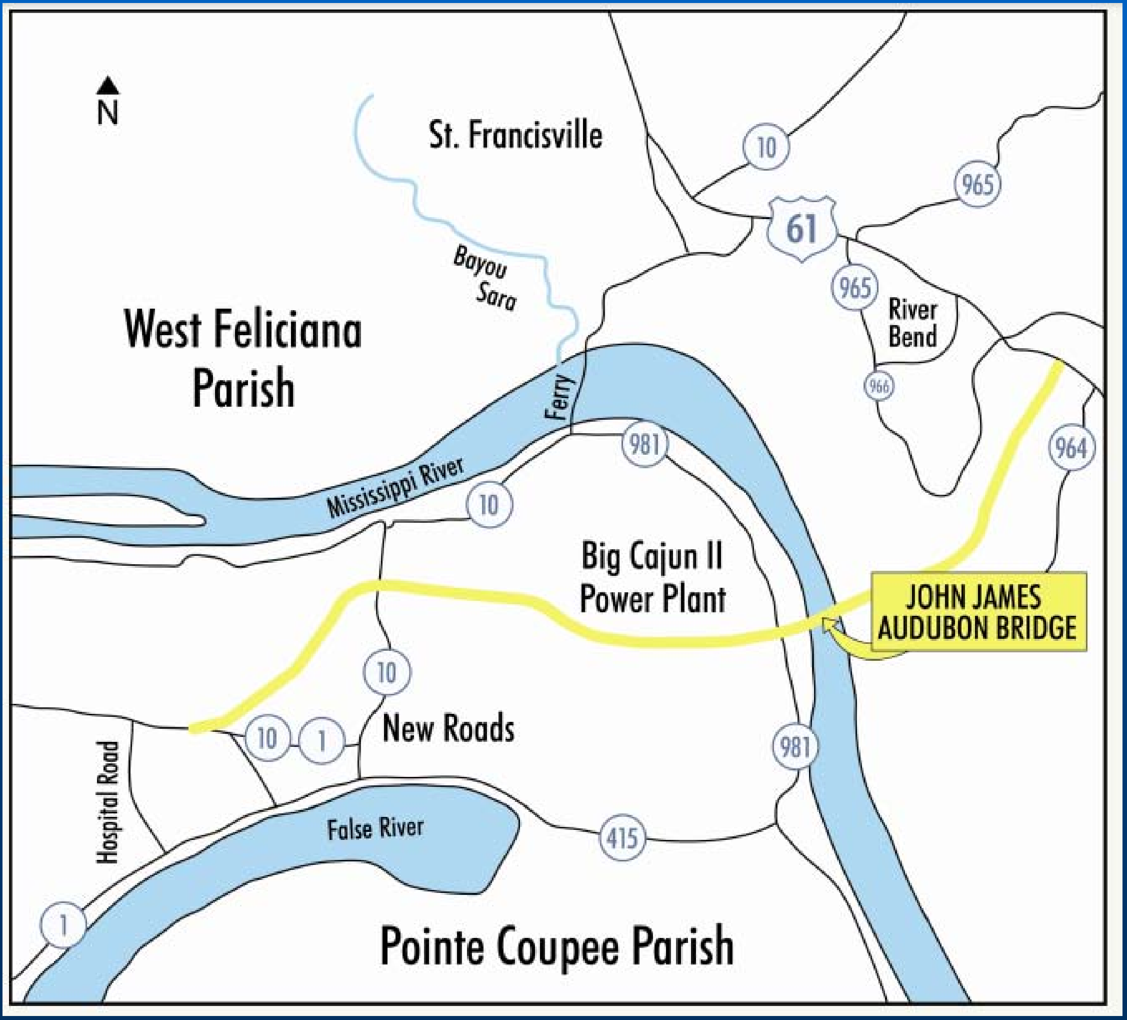
John J Audubon Bridge Project



John J Audubon Bridge Project



John J Audubon Bridge Project



Bridge Form

Composite Cable Stayed

Hooghly River

Alex Fraser

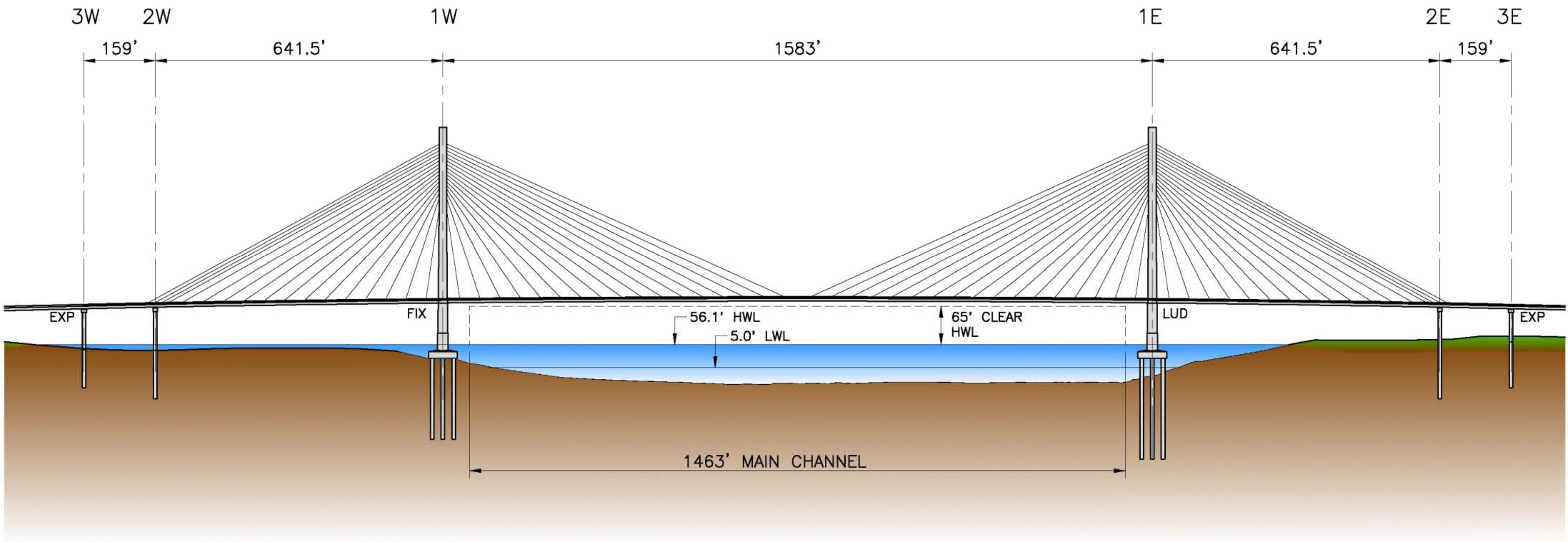
Bridge Form

Composite Cable Stayed

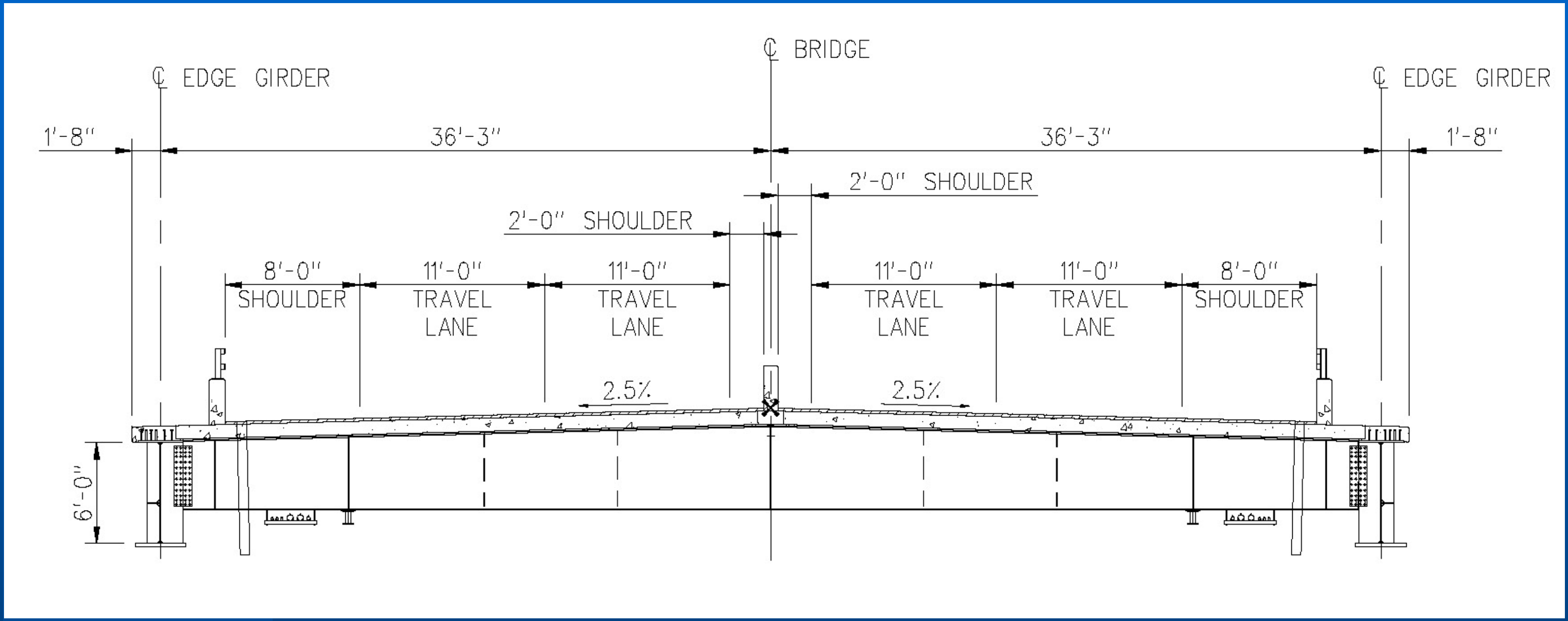
Cooper River

Ting Kau

General Arrangement

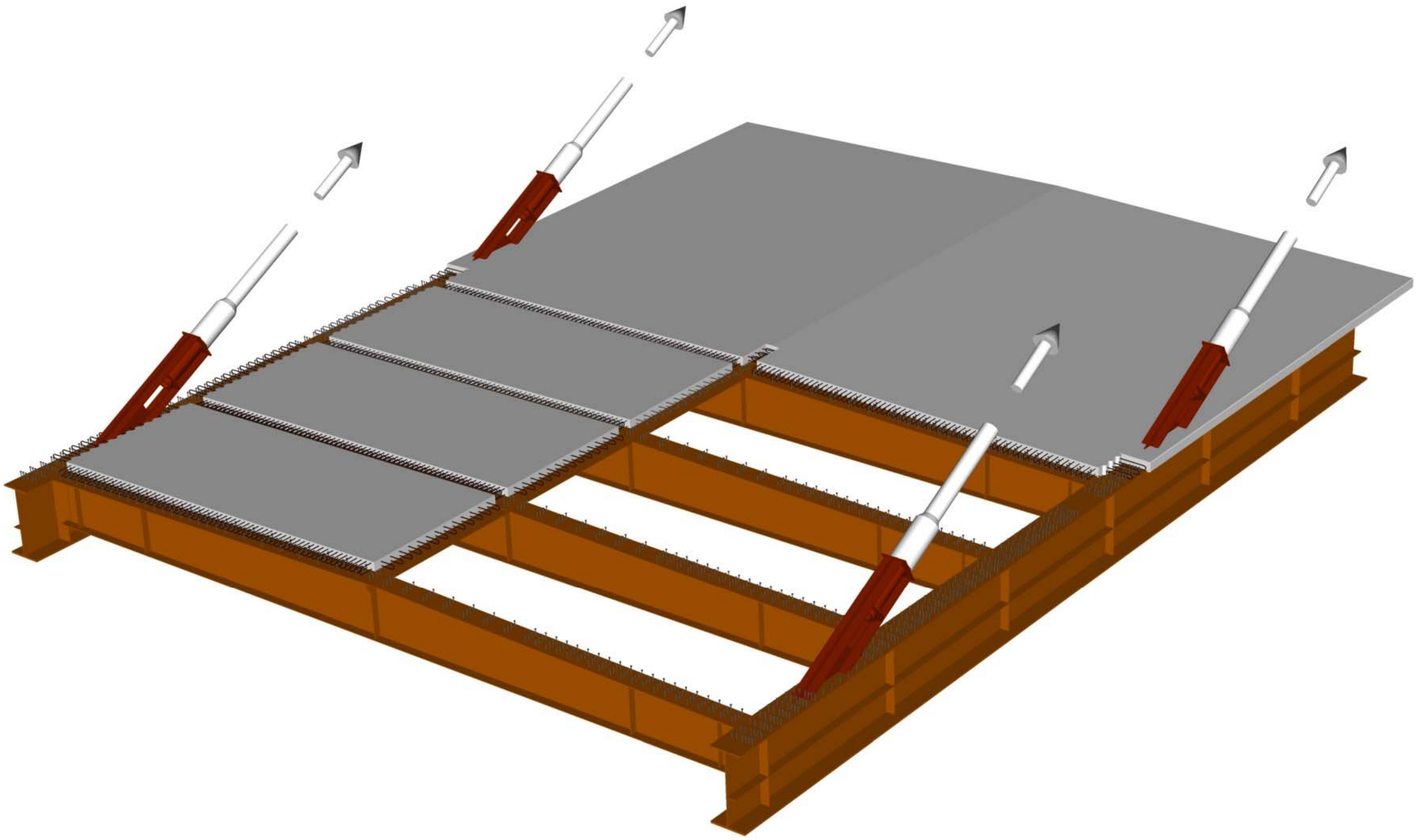


Deck Cross Section

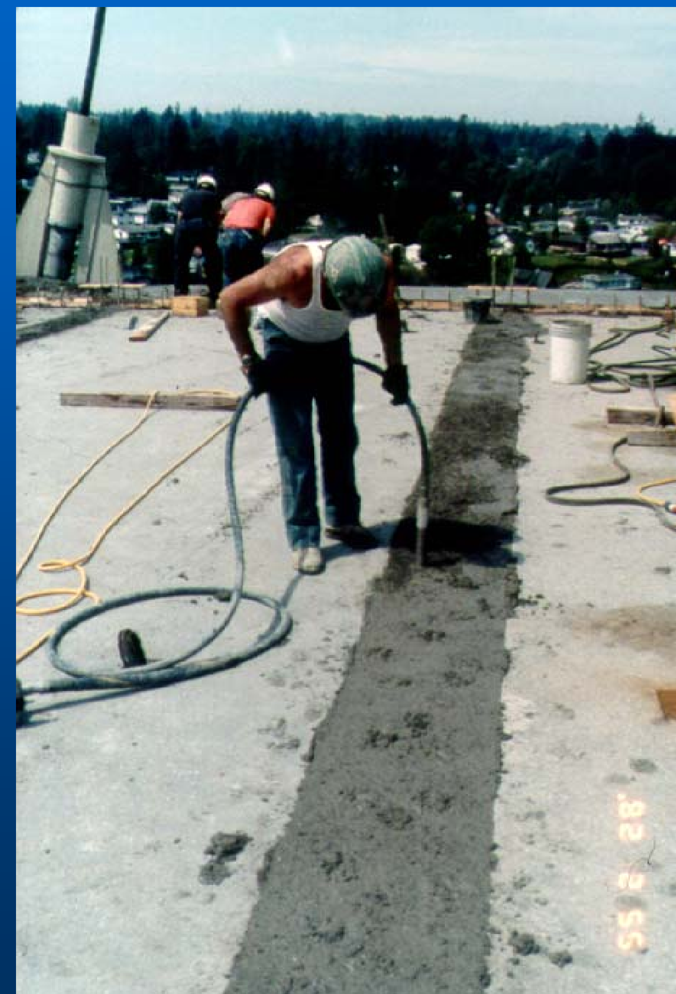


- Simple constructible open deck section
- Steel grid composed of simple longitudinal and transverse girders
- Composite deck slab

Composite Deck Arrangement

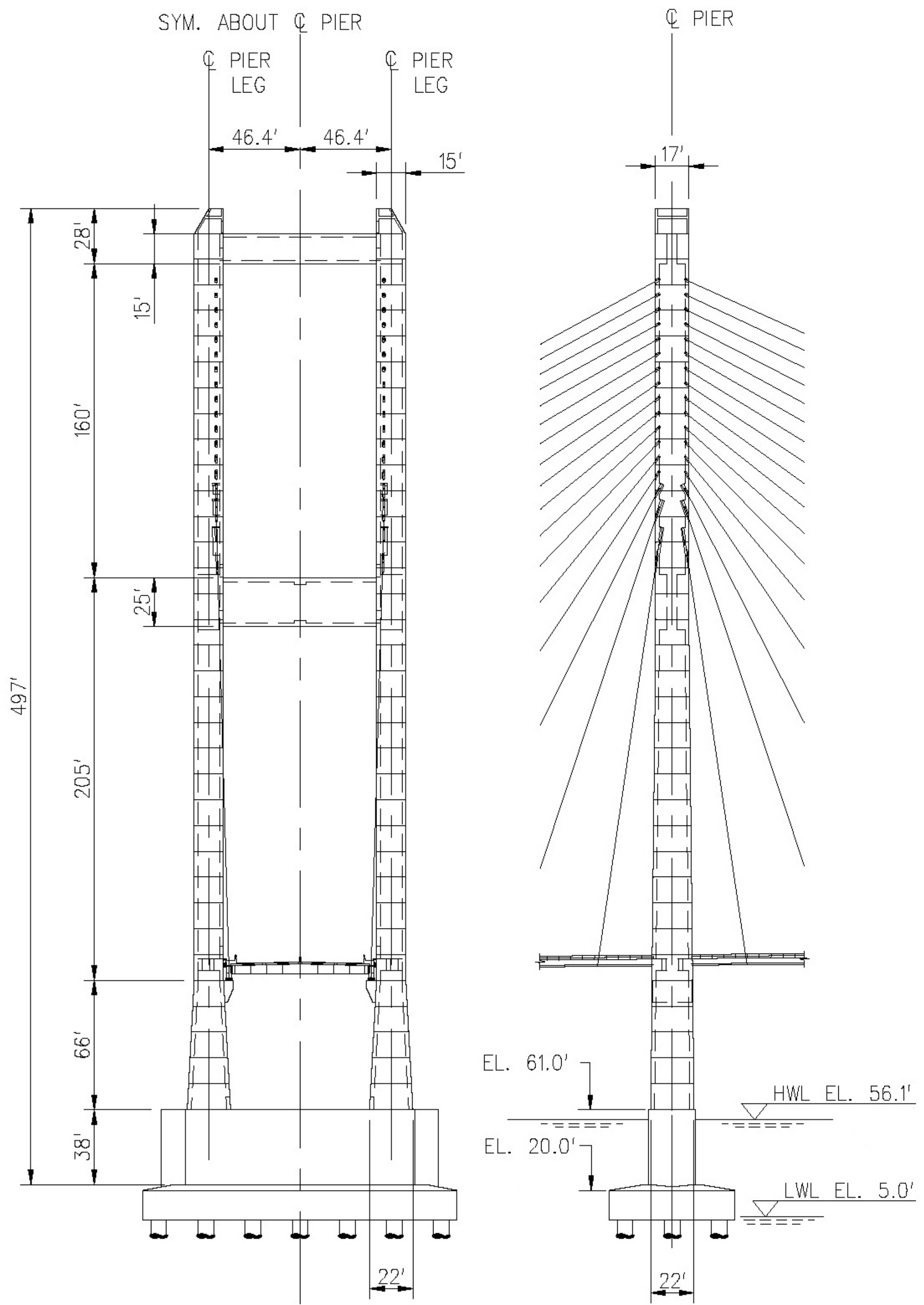


Composite Deck



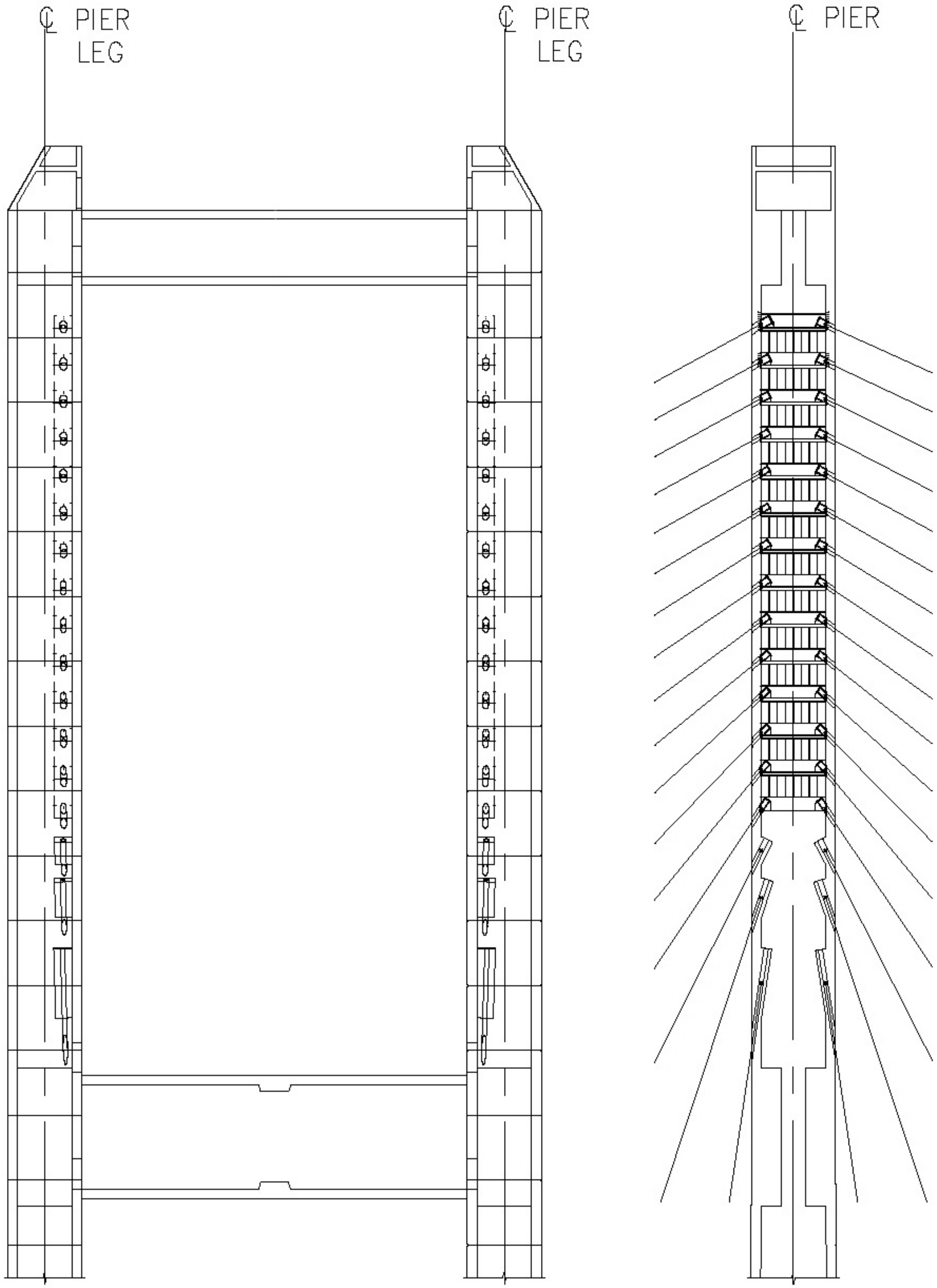
Towers

- Reinforced concrete H-tower
- Simple vertical legs efficient for jump forming
- Deck passes through tower with slight out-of-plane cable inclination
- No deck level crossbeam
- Deep pedestal
- 20 – 7.5' dia shafts

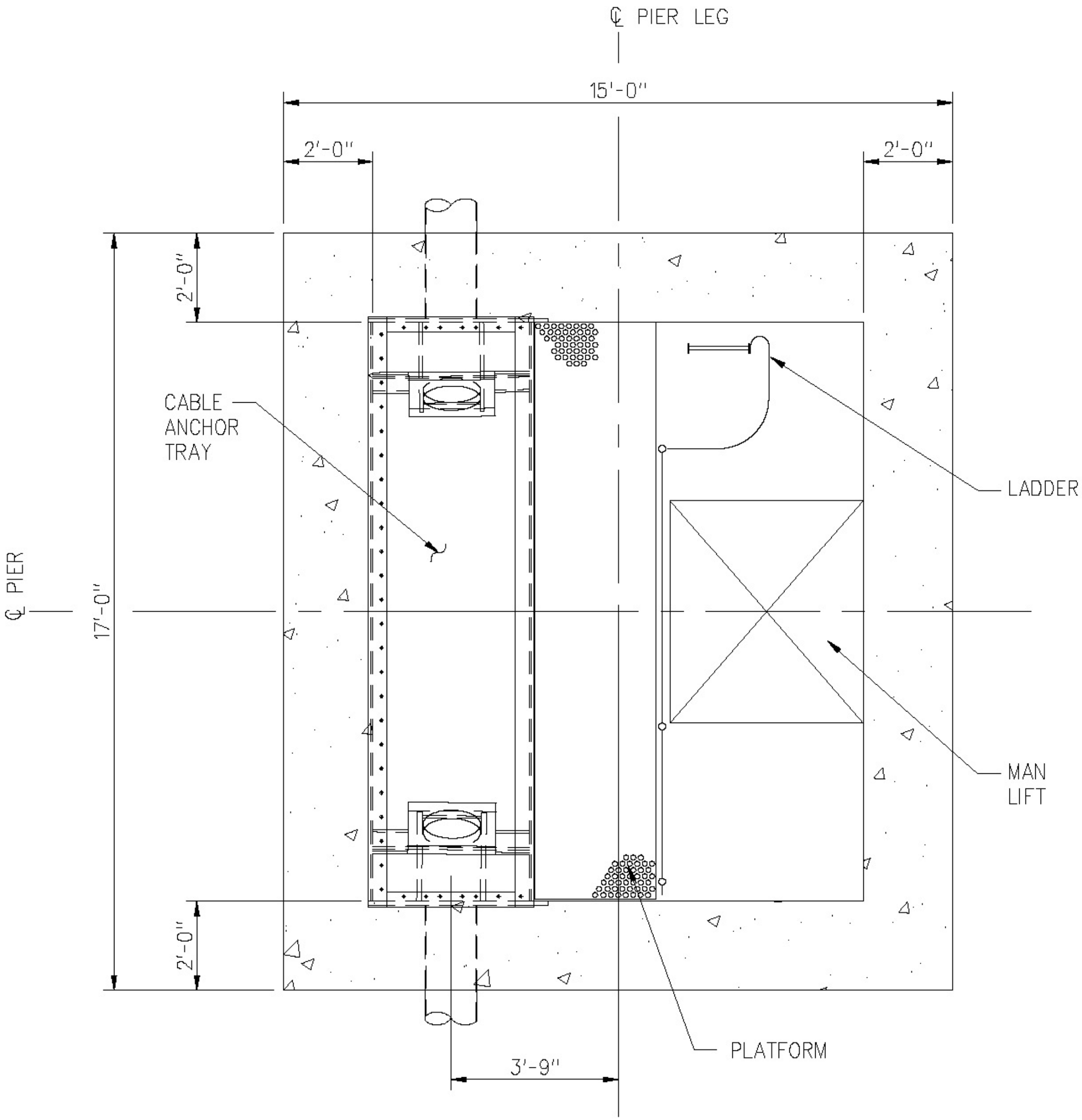


Tower

- Steel anchorage trays to anchor upper cables
- Concrete corbels for steep lower cables

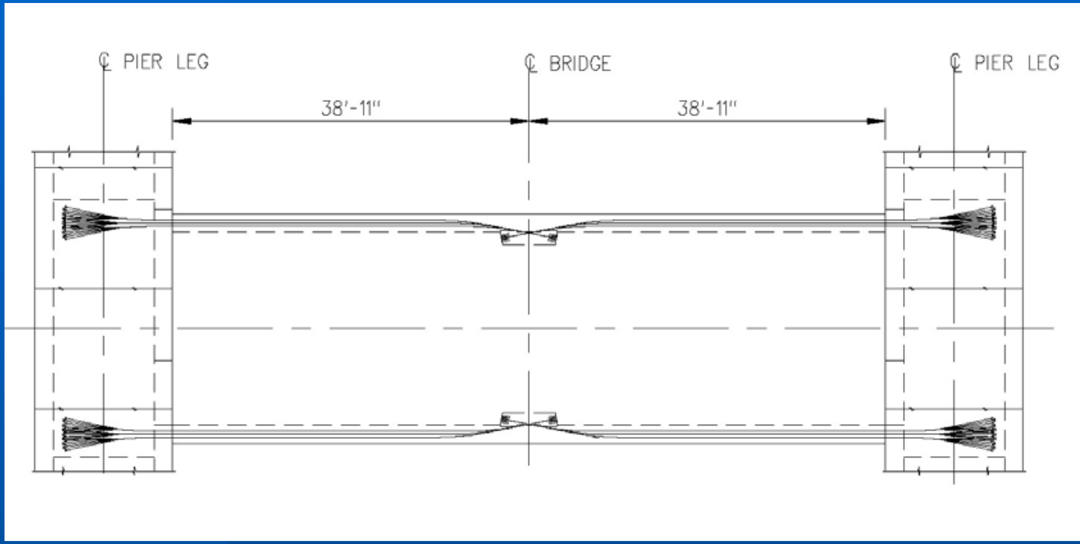


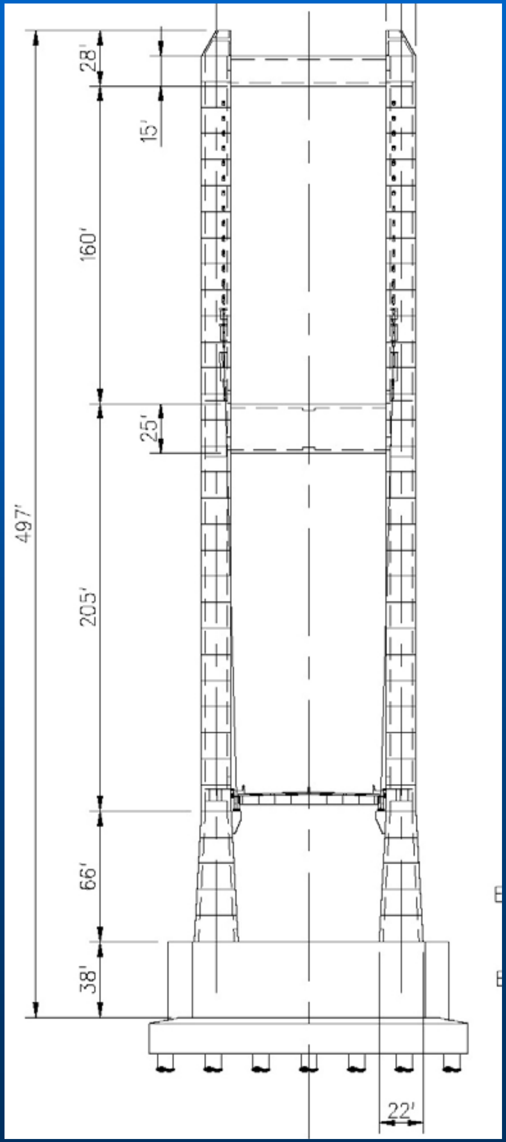
Tower Cross Section



- Cable anchorage on inside tower wall:
  - Minimizes cable plan angle
  - Capacity in event of cable loss
- Offset anchorage provides room fro access ladders and man lift

Tower Cross Beams





- Hollow concrete crossbeams
- Partially post-tensioned lower crossbeam
- Plain reinforced upper crossbeam

Stay System

Modern Parallel Strand Stay System (PSS)

- Bundled 7-wire strands
- State-of-the-Art Corrosion Protection
  - Galvanizing
  - Grease
  - Strand PE
  - Coextruded HDPE Pipe
- Friction dampers for vibration suppression
- Monostrand Jacking

Design for Wind

- Design of the bridge substantially governed by wind
- Three key wind issues to be addressed
  - Site specific wind characteristics for design
  - Aerodynamic stability
  - Wind loading

Wind Characteristics

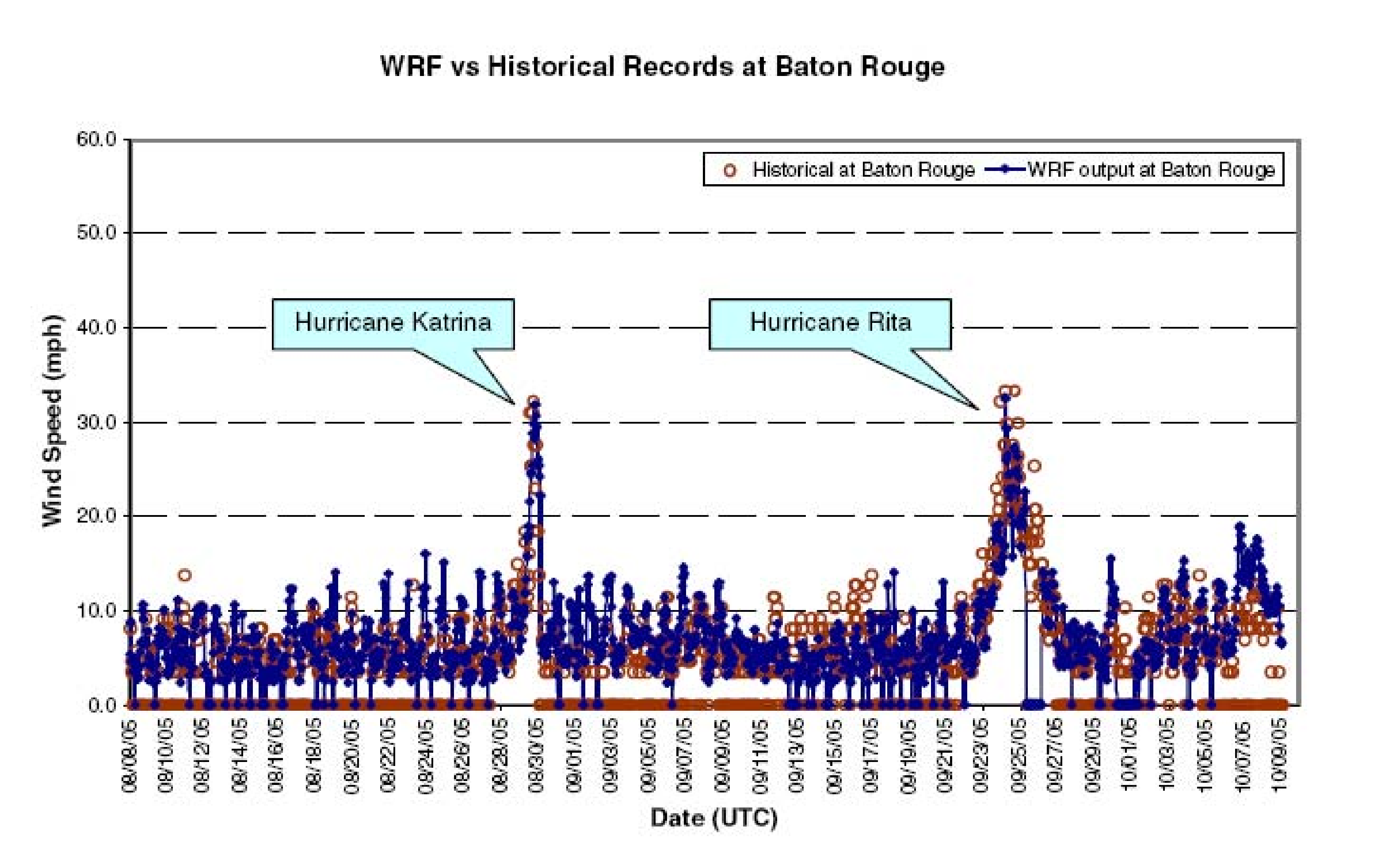
Design required definition of the following wind characteristics:

- Wind speed vs return period
- Wind vs directionality
- Turbulence intensity and turbulence scale

Wind Characteristics

- Wind speed and directionality determined using available near site data (Baton Rouge Airport)
- Site turbulence properties were determined using empirical methods based upon terrain at the site
- Project called for site wind monitoring to confirm site wind characteristics
- Instead wide scale climate modeling using the Weather Research and Forecasting (WRF) Model was used to confirm site specific wind characteristics

Wind Characteristics



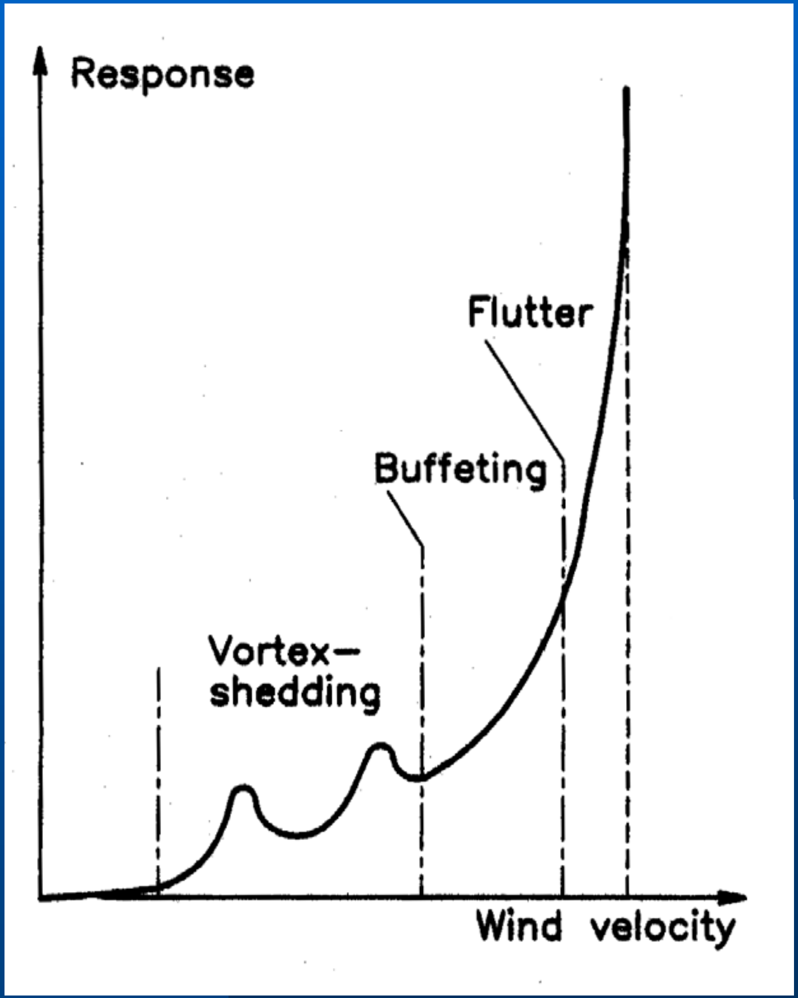
Wind Characteristics

Final Design Wind Speeds with Directionality

Application		Return Period (years)	Wind Speed (mph)	
			1 Hr Mean	10 Min Mean
Structural Design	Construction Stage	20	65	-
Structural Design	Completed Bridge	100*	80	-
Flutter	Construction Stage	1000	-	89
Flutter	Competed Bridge	10,000	-	101

*** Approximate – ASCE7-02 scaled up**

Aerodynamic Response of Bridge



How does a bridge deck respond aerodynamically to real wind?

Stability

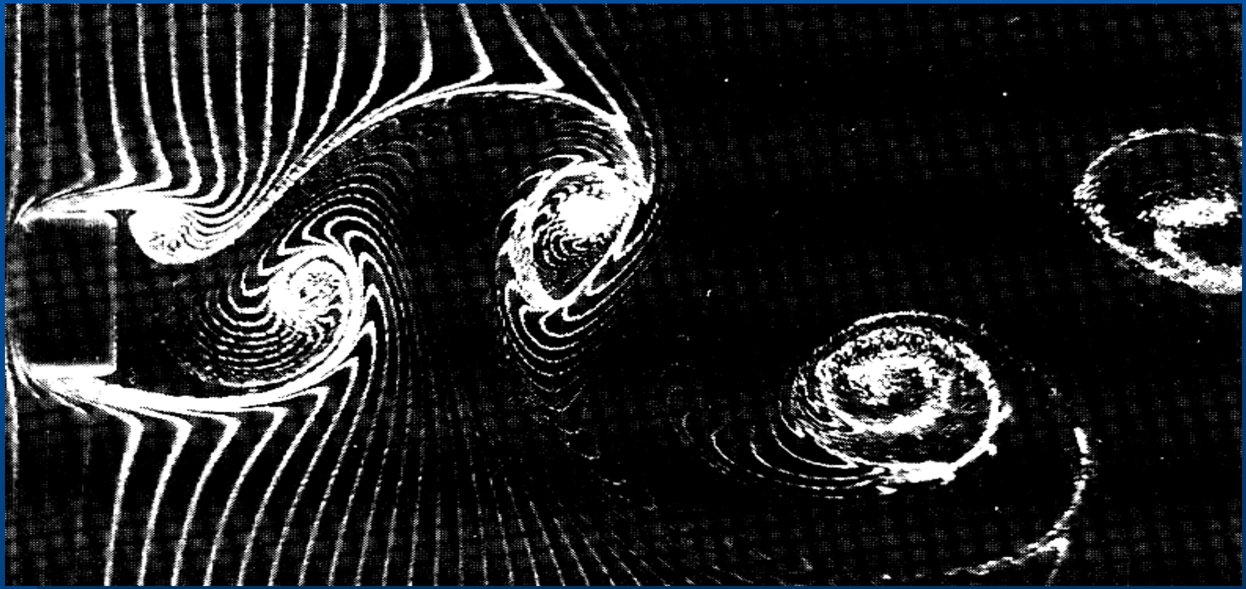
- **Vortex Shedding**
- **Flutter**

Wind Loading

- **Buffeting**

Vortex Shedding

- Fluctuating force due to formation of vortices from upper and lower surfaces of body
- Low wind speed phenomenon
- Assess response in sectional wind tunnel tests

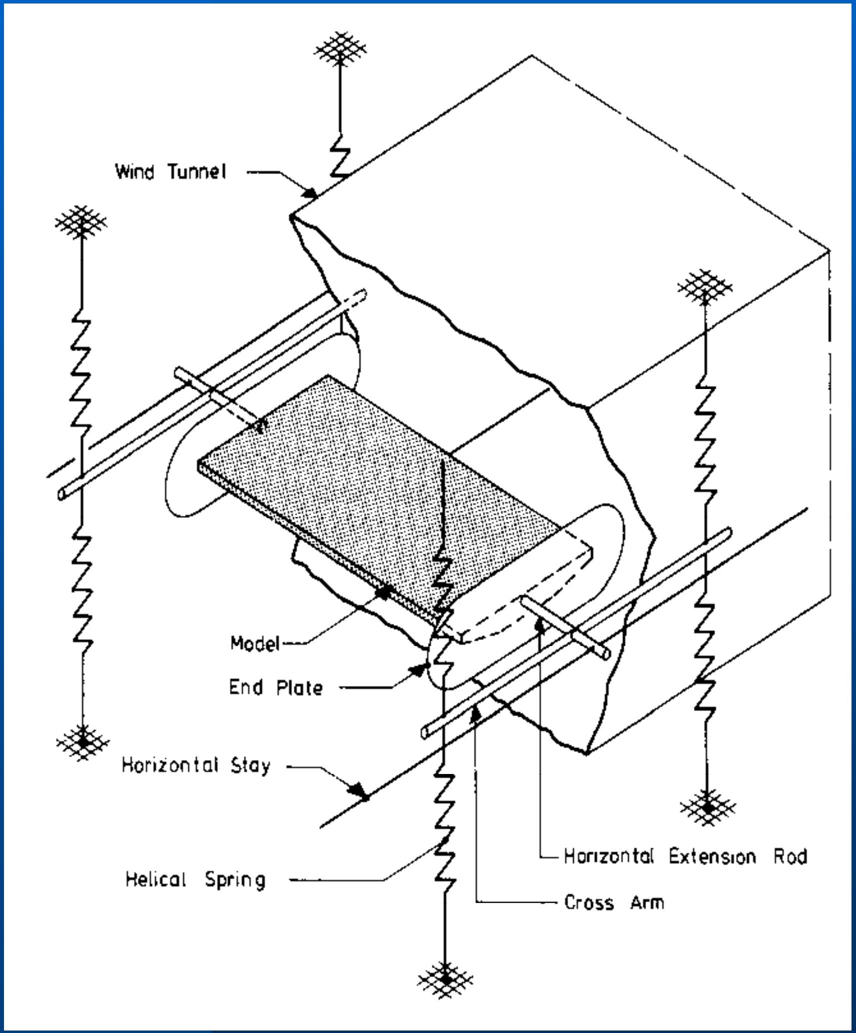


Flutter

- Self-excited aerodynamic instability

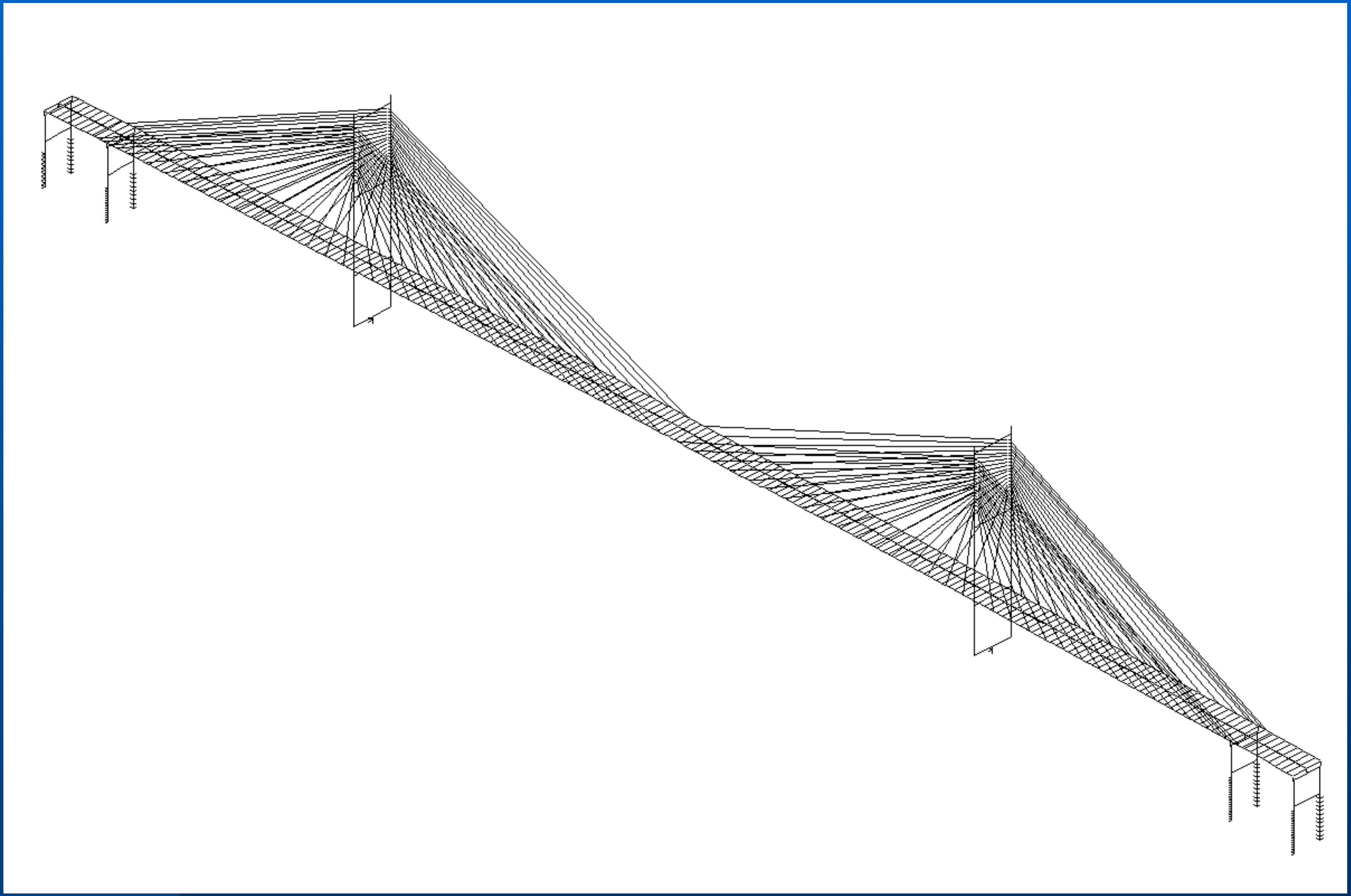
- Result of torsion or coupled torsion and vertical motion
- Total torsional damping becomes negative causing oscillations to diverge to levels causing failure
- Assess critical wind speed in a sectional wind tunnel test

Sectional Wind Tunnel Tests

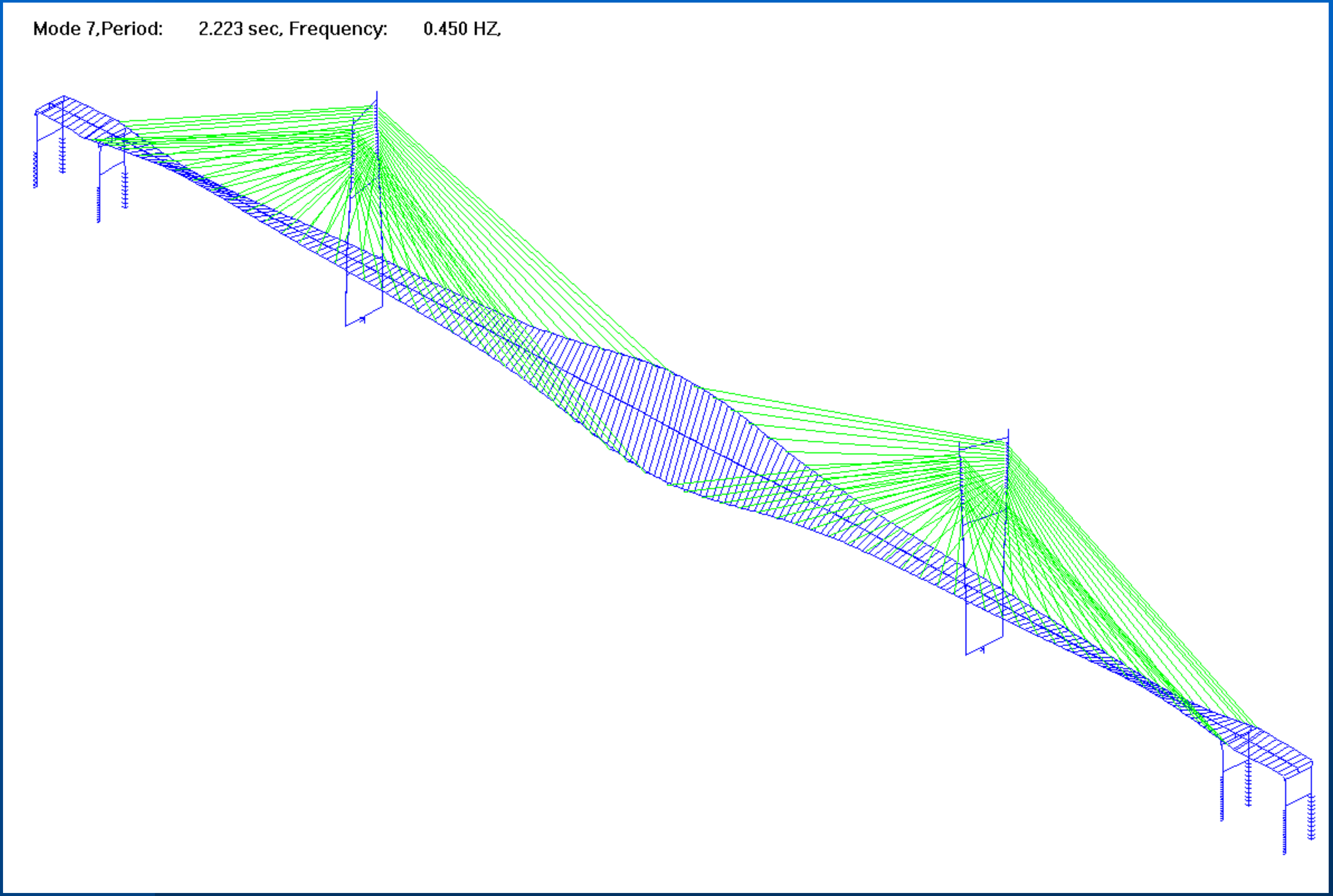


- Fundamental form of testing
- Models two modes: vertical and torsional
- Dependent on modeling by the Designer

Finite Element Model



Sectional Wind Tunnel Tests



Stability Acceptance Criteria

Flutter Criteria (Collapse)

- Torsional deck response of 1.5º
- Vertical deck response of span/200

Vortex Shedding Criteria (Comfort)

- 5% g for winds to 30 mph
- 10% g for winds to 45 mph
- No limit above 50 mph

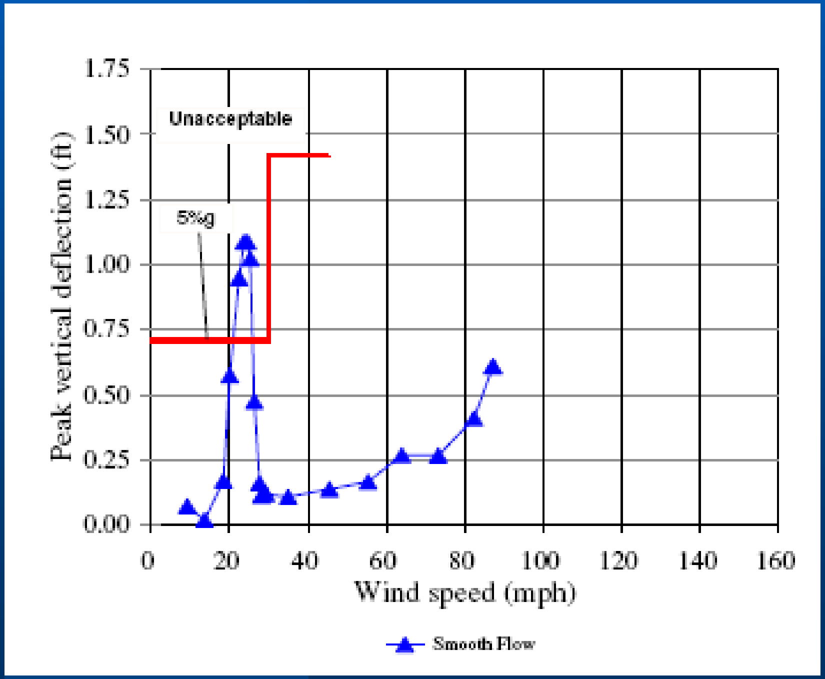
Sectional Wind Tunnel Tests

Basic Deck Section – No Edge Modifications

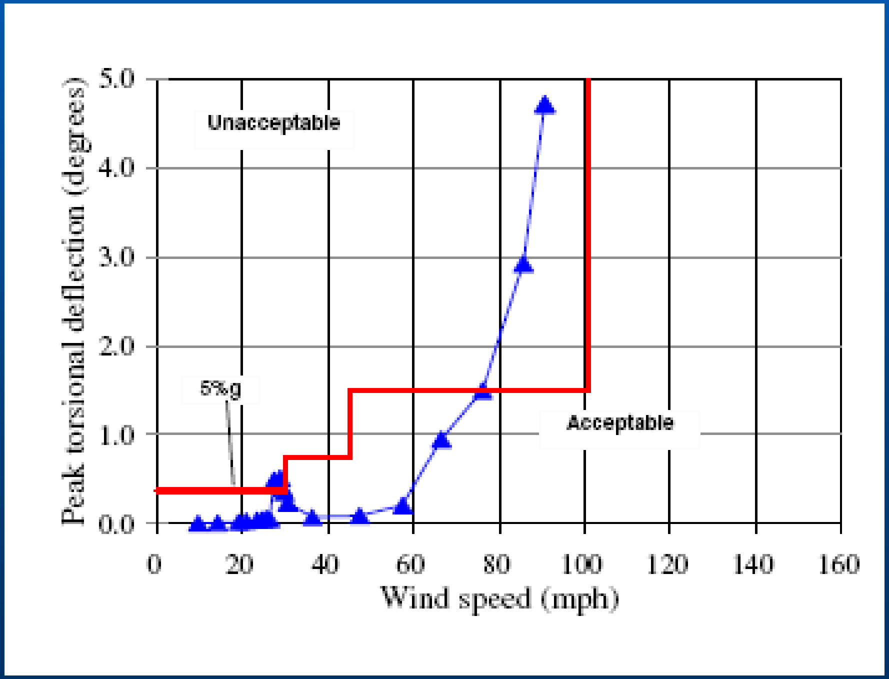
Sectional Wind Tunnel Tests

Basic Deck Section – No Edge Modifications

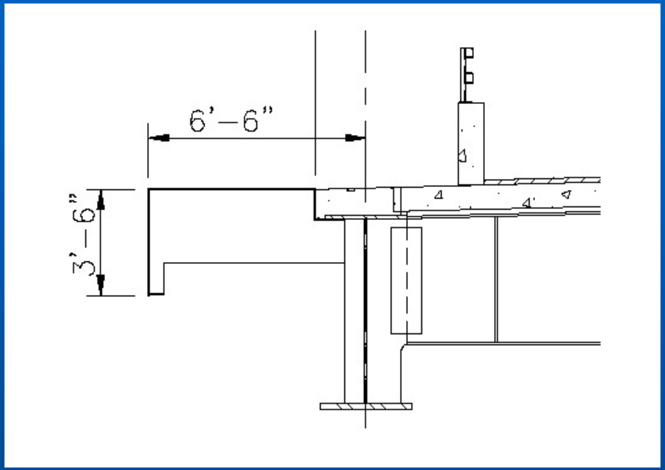
Vertical response



Torsional response



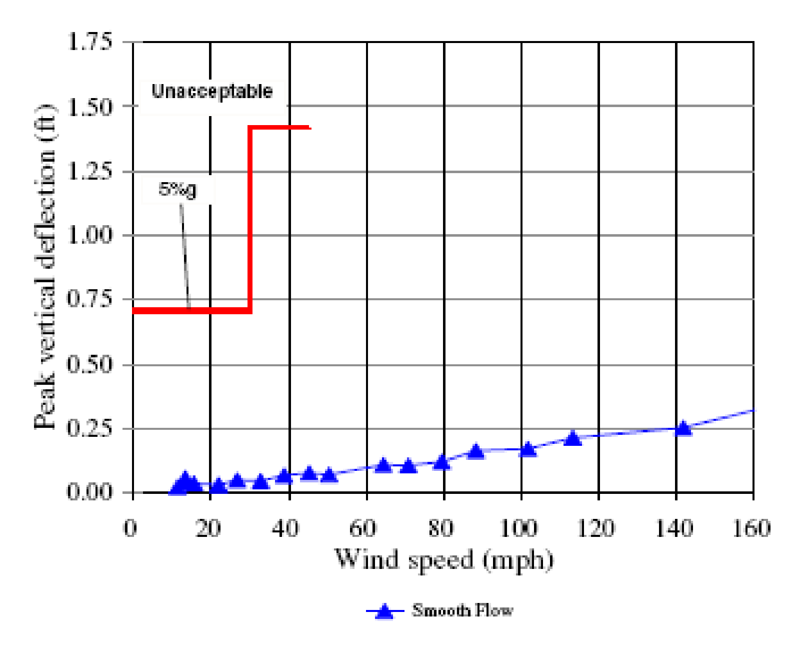
Sectional Wind Tunnel Tests



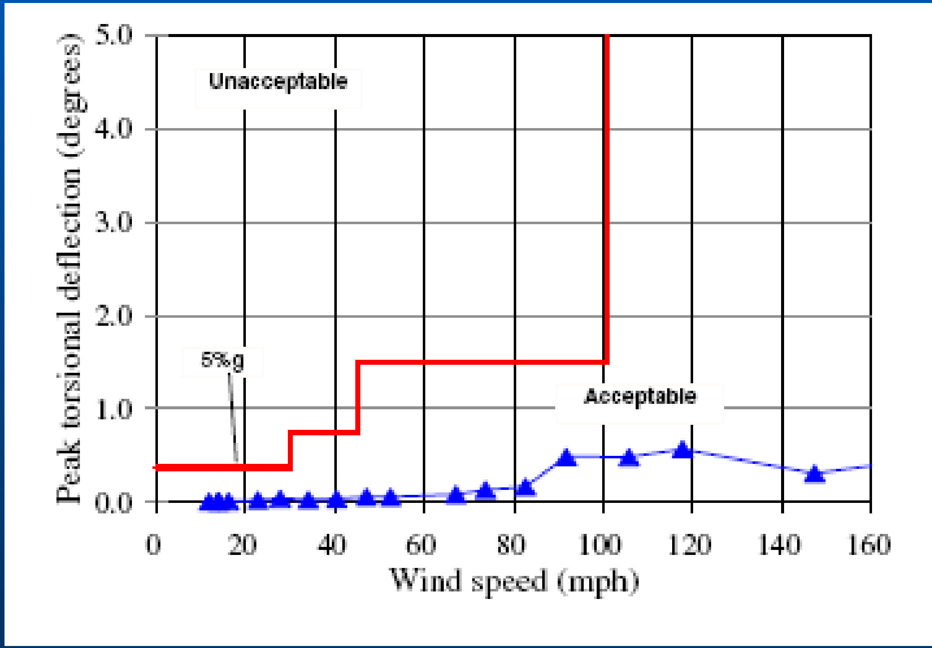
Sectional Wind Tunnel Tests

Modified Deck Section – With Edge Modifications

Vertical response



Torsional response



Wind Loads

For short to medium span bridge which are relatively stiff

- Simple uniform wind pressure was applied to the exposed area of bridge
- AASHTO still uses this approach for short to medium spans
- With the advent of wind tunnel testing measured drag forces could be applied instead of simple wind pressures

Wind Loads

There remains a problem with this approach for long span flexible bridges:

- Simple application of static forces does not acknowledge the full dynamic response of a long span flexible bridge in naturally turbulent wind
- This added dynamic response of the structure is generally referred to as buffeting and it must be addressed

Wind Loads - Buffeting

What is buffeting?

- **Dynamic response of structure from uneven loading due to turbulence in natural wind**
- **Buffeting induces vibration in the bridge's natural modes of vibration**
- **For long span flexible structures the resulting forces which include dynamic inertial forces typically exceed those calculated using simple static wind pressures**

Buffeting

How are the wind loads on the bridge determined in order account for Buffeting?

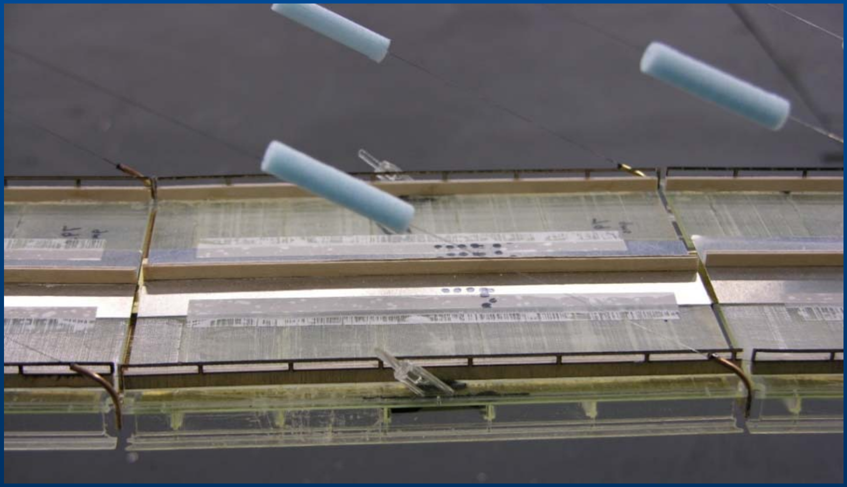
Buffeting Analysis:

- **Analysis techniques permit calculation of approximate buffeting response of the structure**

3D Aeroelastic Wind Tunnel Testing:

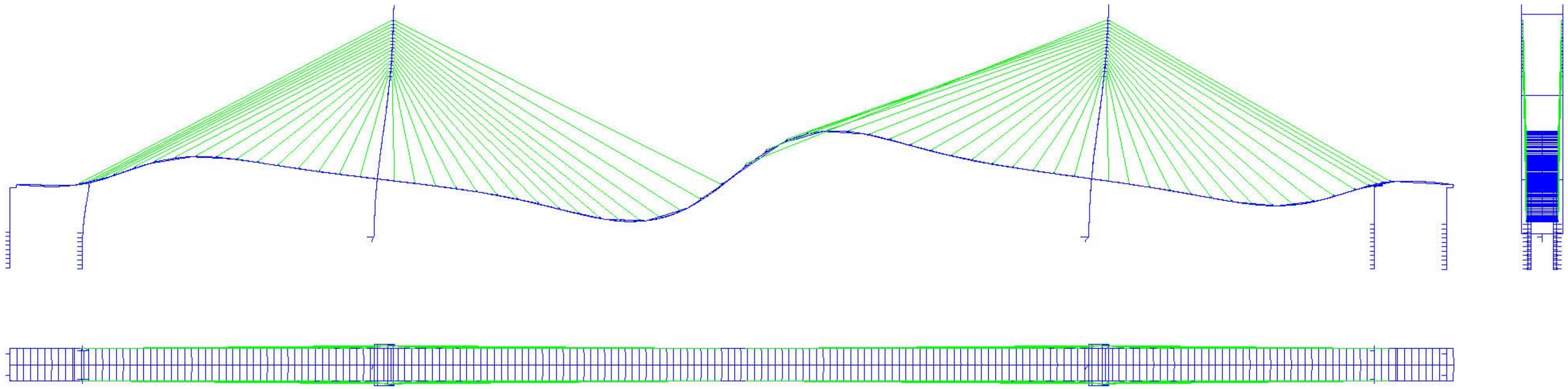
- **Buffeting response can be directly measured from wind tunnel tests**
- **Greater confidence than analytical methods**

Buffeting



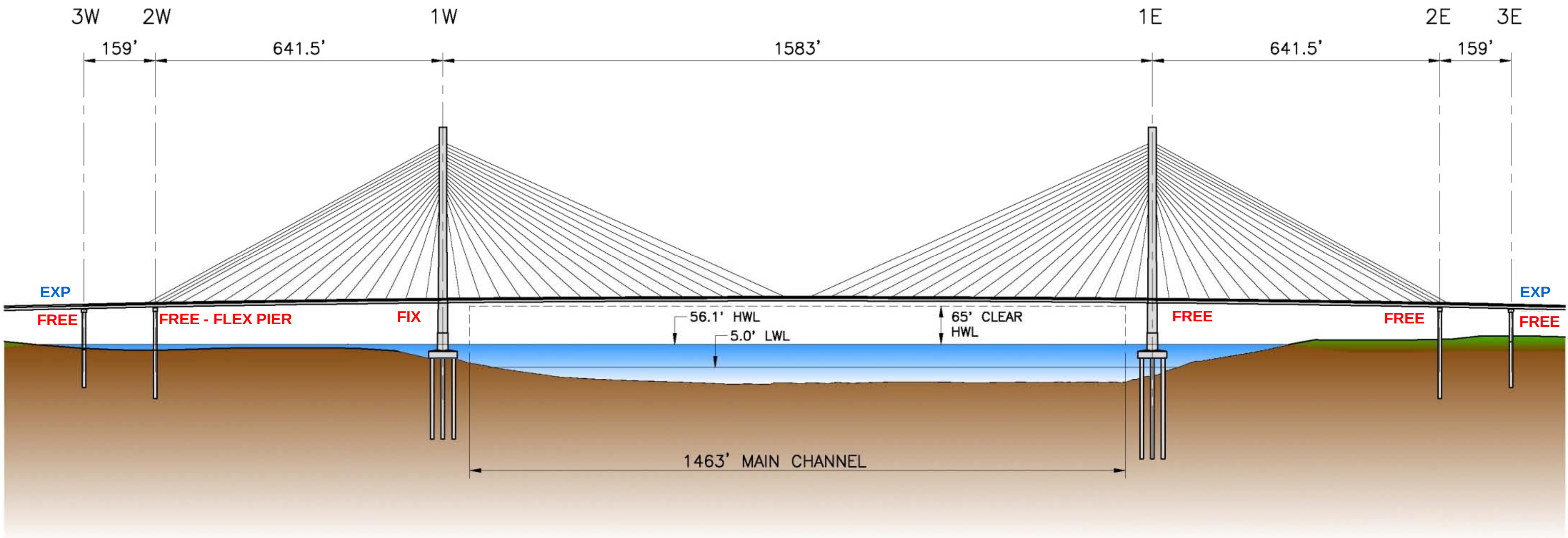
Buffeting

Buffeting



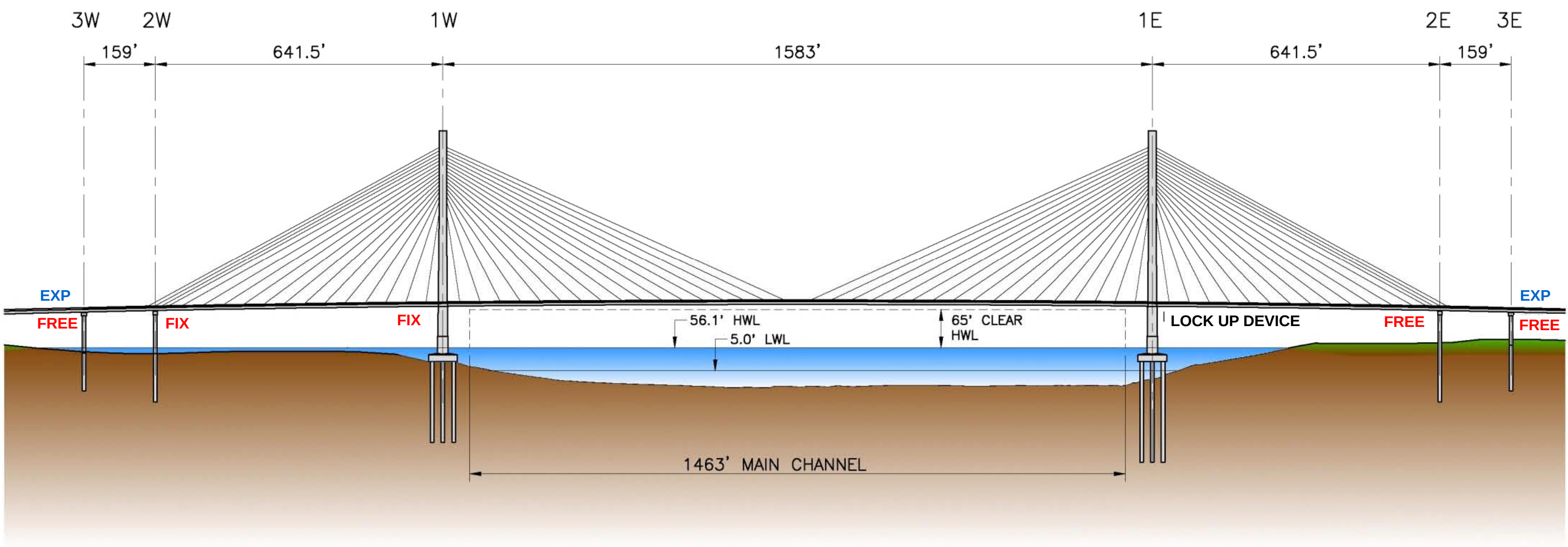
Buffeting - longitudinal response

Proposed Deck Articulation



- Buffeting caused high longitudinal shear forces concentrated at 1W
  - Deck connection details
  - Tower diaphragm details
  - Foundation demands

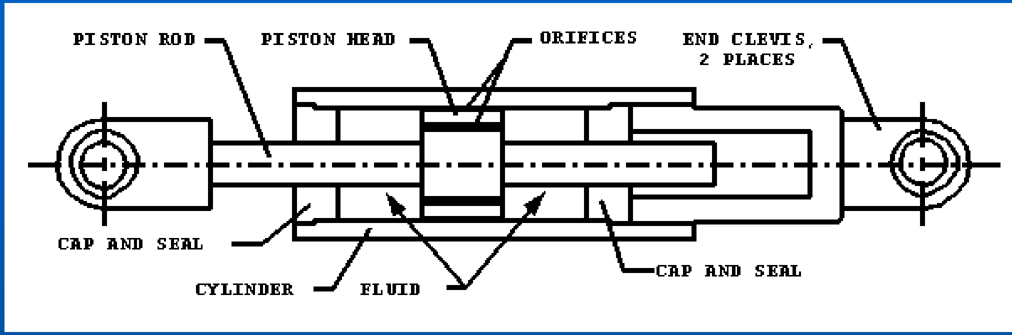
Final Deck Articulation



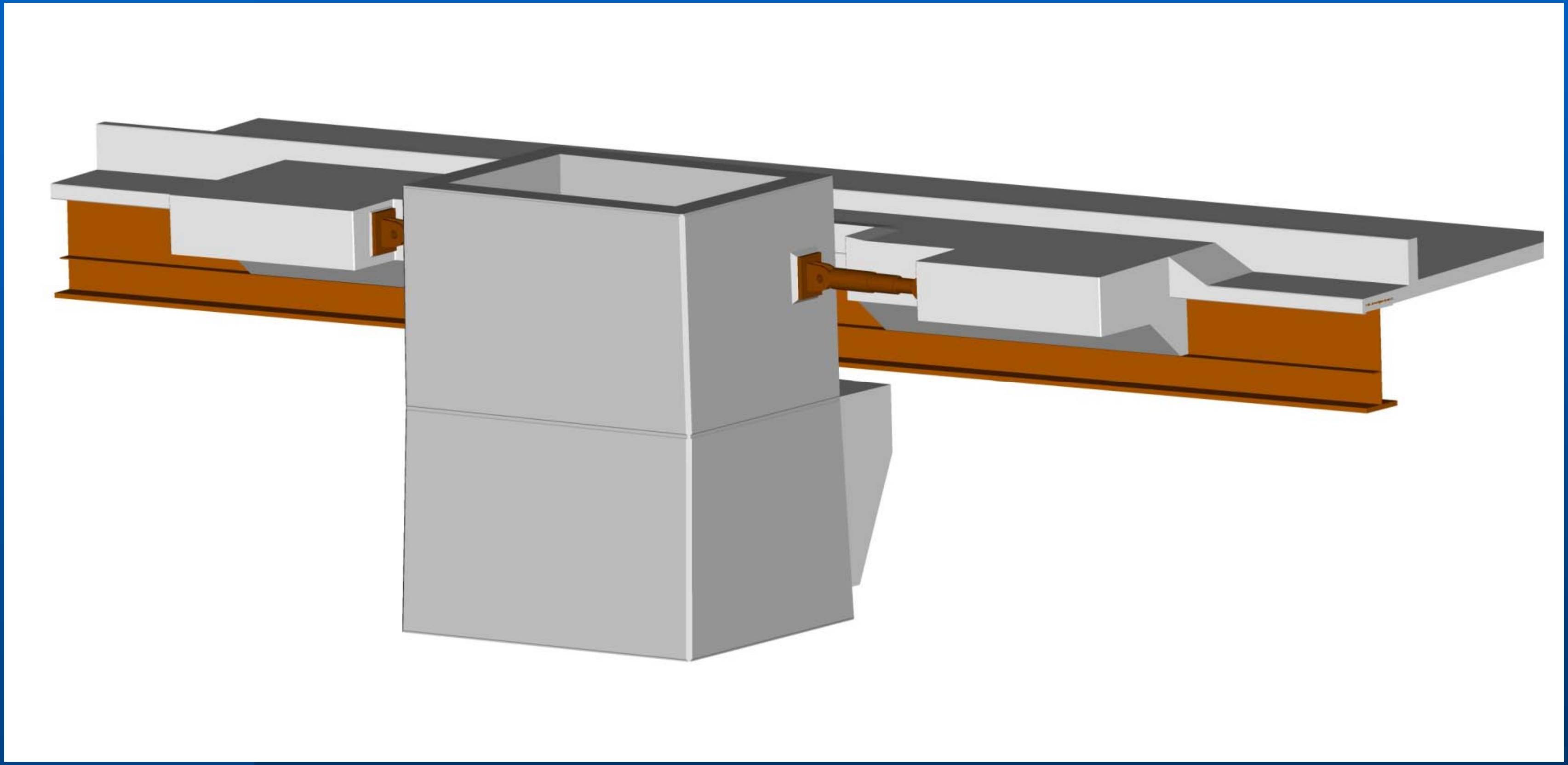
- **Longitudinal fixities**
  - Pier 1W fixed bearing
  - Pier 1E lock up device
  - Pier 2E free and 2W fixed to flexible pier

Lock Up Devices

- Low velocity movements permitted at low force
- High velocity movements generate large force or the device essentially locks up



Lock Up Devices



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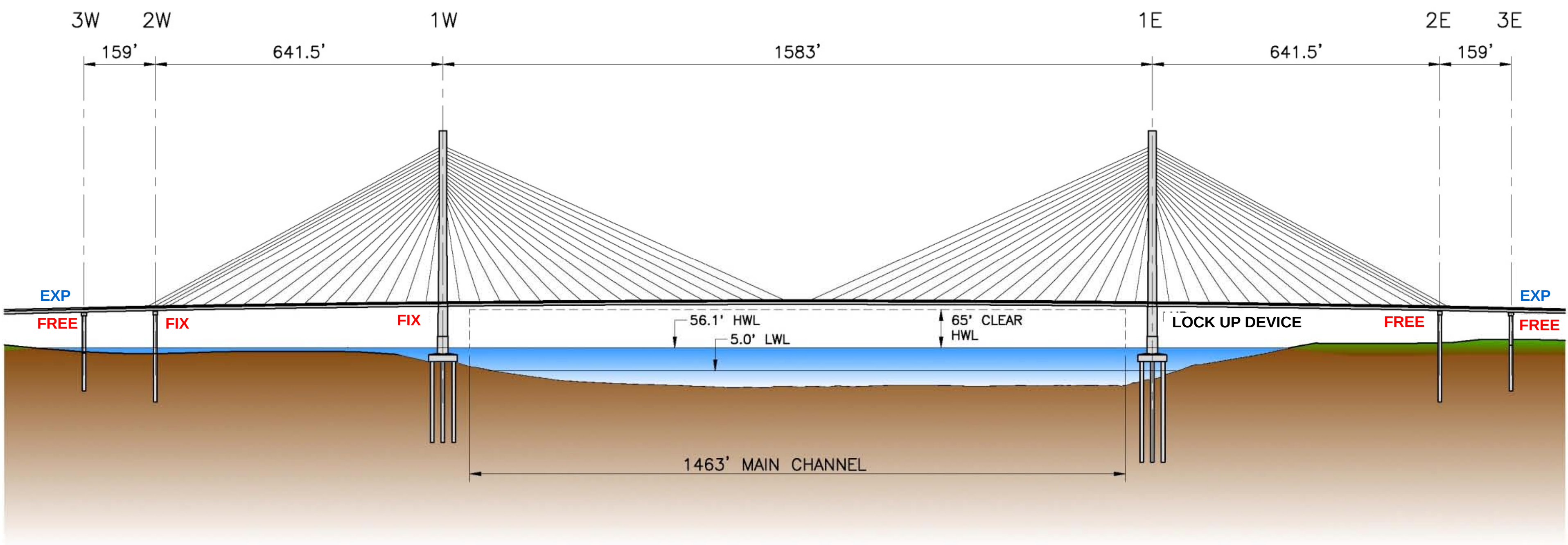

- Advantages
  - Maintain flexibility for temperature movements
  - Spreads longitudinal wind shear between two towers
  - Lower shear demands in each tower and foundation

John J Audubon Bridge