PHILLYSTRAN

SYNTHETIC SUPPORT PENNANTS FOR STRUCTURES

THE INTERNATIONAL BRIDGE CONFERENCE

Mark Pieter Frölich, Commercial Director, Phillystran Inc.

INTRODUCTION

Innovative structures have been designed and built around the world incorporating advanced synthetic support cables. Typically, they are deployed on assets in two types of environments. First, where inspection and maintenance are difficult to execute, for example, hard to reach remote areas where corrosion needs to be eliminated. And secondly, where weight reduction is required, coupled with continuous cyclic strain and high creep requirements. Traditional materials cannot provide the same long term, maintenance free performance. Synthetic cables provide the structural engineer with the ability to optimize designs due to the reduced weight of the suspension cables and additional benefits summarized in this poster.

Figure 1: An example of a cable stay bridge with synthetic pennants

SYNTHETIC SUPPORT PENNANTS

Of the many types of high performance fibers available, Para-Aramids, are particularly relevant to bridge and structural applications. Aramids exhibit high tenacity and creep resistance, even in elevated temperatures. Additional benefits are extremely low elongation characteristics over time and a high stiffness after pre-tensioning.

In comparison to steel, conventional high strength synthetic fiber cables are up to 1/5 of the weight. Table 1 below lists the Minimum Breaking Force (MBF) of synthetic and steel ropes along with the weight per foot of each product. The two products are compared showing the drastic differences in weight. Further weight savings and diameter reduction can be achieved by selection of specific fibers and terminations – these are not shown in the table below.

Figure 2: Custom terminations with synthetic support pennants

Figure 3: High strength synthetic pennants in a fatigue sensitive environment

INDICATIVE VALUES[1]

MBF			Synthetic weight	6x36 Bridge steel rope	Weight Saving	Diameters	
MBF T (2000 lb)	MBF (lb)	MBF (kN)	lb/ft	lb/ft	%	Synthetic[2]	Steel
300	600,000	2,669	2.15	11.62	542%	2-5/8	2-1/4
343	685,000	3,047	2.75	12.74	463%	2-3/4	2-3/8
366	732,000	3,256	3.25	13.90	428%	3-1/4	2-1/2
500	1,000,000	4,448	4.49	21.00	467%	4-1/2	3
780	1,560,000	6,939	5.97	28.50	478%	6	4-1/8

Table 1: Cable Minimum Breaking Force and Weight Comparison

1) Specifications are approximated and require explicit verification
2) Diameter measures larger, in part due to the protective cover braided around the rope.

STRUCTURAL ADVANTAGES

In static structural applications, synthetic fibers have been shown to improve the vibration dampening characteristics of structures. Although a slightly larger diameter rope may be required to match the stiffness and strength of steel rope, the synthetic fibers can provide superior resistance to tension-tension fatigue and have negligible creep effects. An estimated Modulus of Elasticity of 9.2 x 10^6 psi for synthetic cables is close to the elasticity range of steel wire rope. Since 1980, they have been deployed in heavy duty markets. Innovation has continued to reduce pennant cost and maintenance. Today, synthetic fiber's technical and commercial advantages are an on-going source of new product - market combinations.

A synthetic cable is approximately 1/5th of the weight of a steel cable, allowing weight reduction for total bridge design optimization. Even higher weight savings are achievable by selecting specific fibers and terminations.

MAIN ADVANTAGES OF FIBER PENNANTS:

- **No corrosion**
- **Fatigue resistance higher than steel**
- **High stiffness**
- **Higher natural frequency**
- **Vibration absorption relieves contact and bearing points**
- **Easier installation and removal for remote and hard to reach areas**
- **Reduction of overall design weight**
- **High creep resistance**
- **No WiFi / Radio / Cellular network interference**
- **Non-conductive**
- **Recyclability of fibre at end of service life.**

Figure 4: Phillystran synthetic pennants being installed

CONCLUSION

So far, the bridge engineering community has only scratched the surface of the potential offered by synthetic fiber cables. Prospective applications in cable stayed bridges include temporary suspension, greenfield developments and retrofitting existing structures as steel cable needs replacing.

As the span length of a new suspension bridges increases, the weight of the cables required increases in relation to the total weight of the suspended structure. This is applicable to both the main cable and the suspension cables. A higher percentage of the cable stress is, therefore, related to the self-weight of the cables themselves. The use of lightweight synthetic support pennants or cables can greatly reduce the stress in the overall system dynamics, allowing for lighter structures that are capable of longer spans.

General View of Route 29 Tunnel Northbound (Top) & Southbound (Bottom) Portals

The NJ Route 29 Tunnel Northbound Roadway (top image) and Southbound Roadway (bottom image). The Northbound Roadway is full enclosed, while the Southbound Roadway consists of spandrel beams on columns on the west end of the portal, allowing a view of the Delaware River.

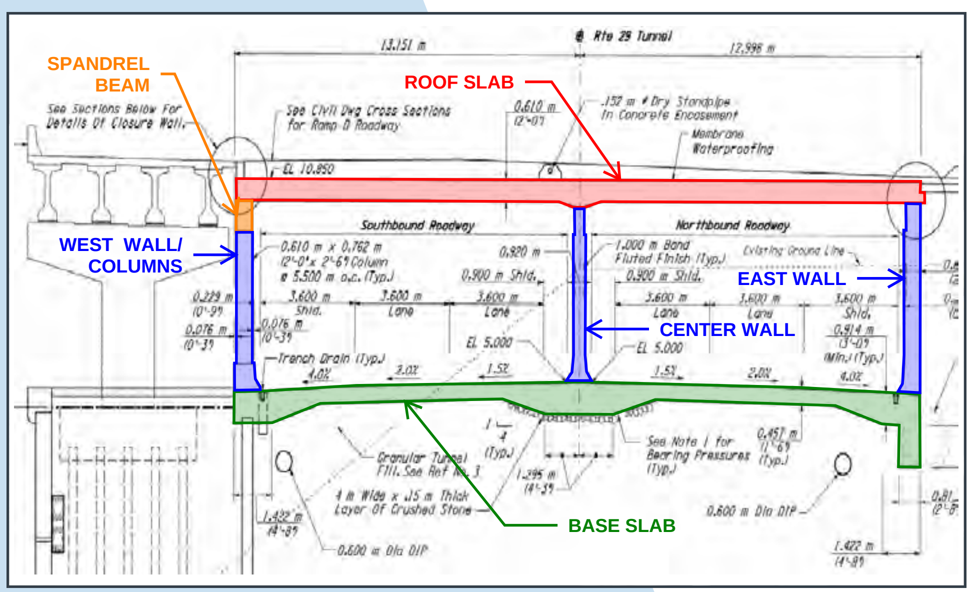
Route 29 Tunnel Aerial Map (Trenton, NJ)

The NJ Route 29 Tunnel is located along John Fitch Way between the Riverview Cemetery and Arm & Hammer Park in Trenton, New Jersey. Access from the Southbound Roadway to Lalor Street is provided through the Ramp D Bridge, which crosses over the tunnel and subjects the frame to live load.

South Riverwalk Park & Lamberton Street Crossing Located Above the Route 29 Tunnel

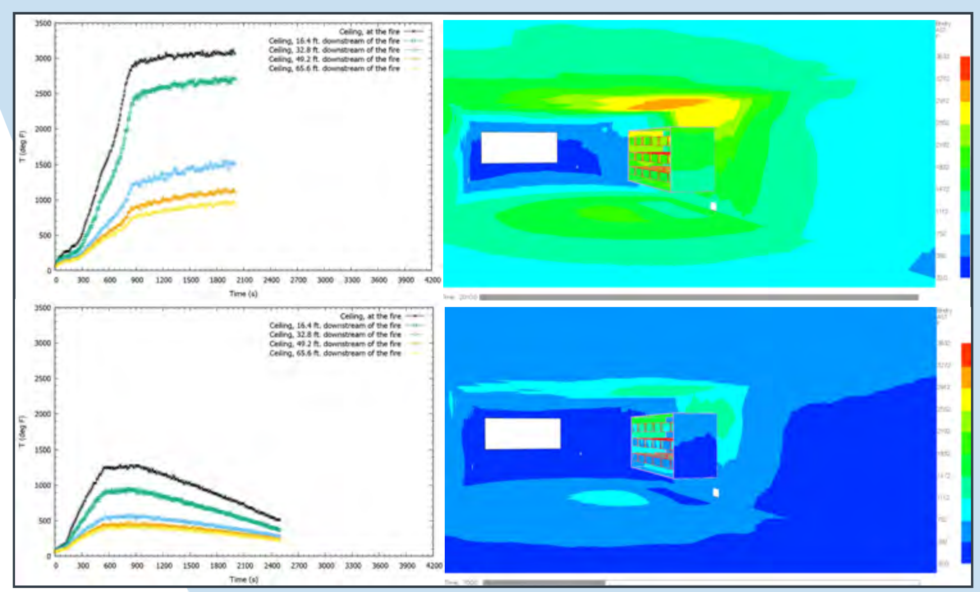
Access to the scenic South Riverwalk Park (top image) is provided by the Ramp D Bridge (bottom image) to the Lamberton Street and Lalor Street intersection. Pedestrian and vehicular live loading were considered for the analysis and load rating.

Tunnel Cross-Section Critical Members



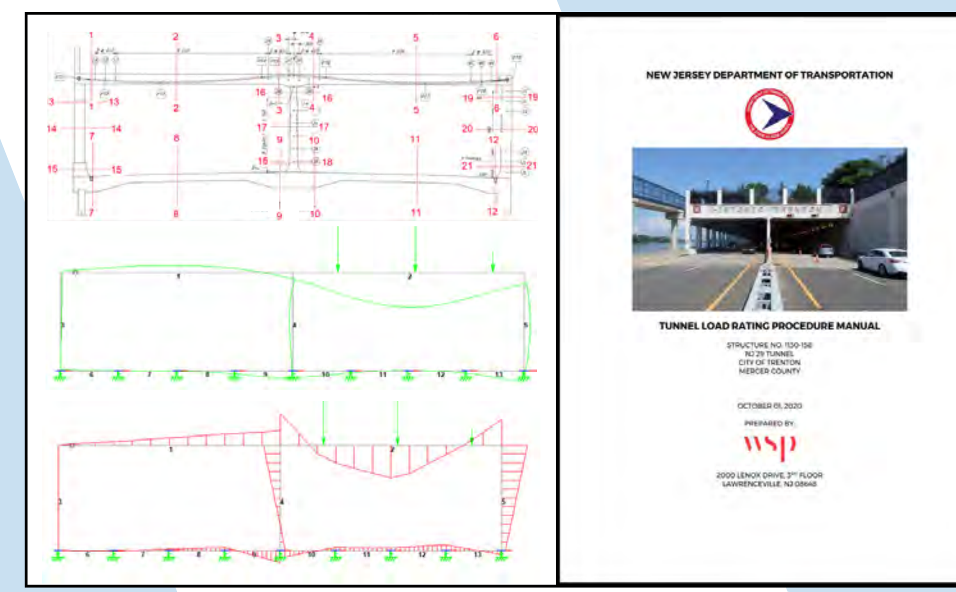
The tunnel cross section (image above) taken from the as-built plans identifies the structural members of interest for the load rating and the fire analysis.

Tunnel Bus & Truck Fire Simulation



Structural durability was assessed with different design fires. A truck fire was modeled in the tunnel (top right image) and adiabatic surface temperature (top left image) was measured at intervals downstream of the fire. A bus fire (bottom right image) was modeled in the tunnel and adiabatic surface temperature (bottom left image) was measured at intervals downstream of the fire. Adiabatic surface temperature was used to determine the change in structural capacity of the tunnel components.

Tunnel Baseline Load Rating Analysis & Procedure Manual



WSP performed the baseline tunnel load rating and developed the NJDOT Tunnel Load Rating procedure manual. Members were analyzed for bending, shear and axial forces at selected critical section locations (top left image). Live load force effects were evaluated using a 2D STAAD model, with vehicular loading assessed for both parallel and perpendicular application to the tunnel span.

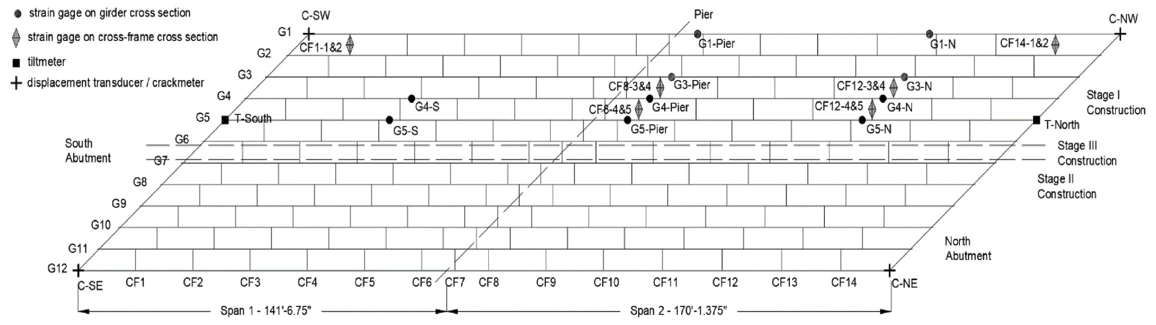
Initial Field Response and Modeling of Two Skewed Steel I-Girder Bridges

Siang Zhou, Larry A. Fahnestock and James M. LaFave
Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign

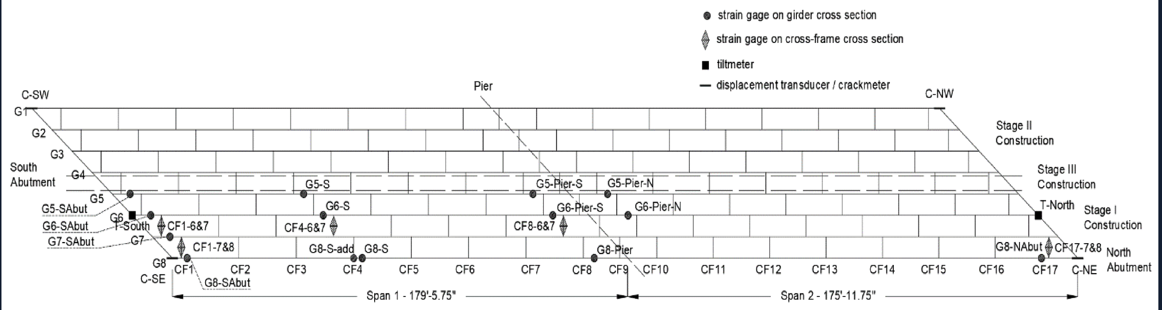
INTRODUCTION

- Short-term bridge response of major bridge superstructure components and long-term thermally-induced stresses and deformations are complicated by skew effects.
- Two two-span continuous steel I-girder bridges are instrumented for field monitoring
  - Skew = 41° with seat-type abutments (Mattis-74)
  - Skew = 48° with integral abutments (Mattis-57)
- Data acquisition system is capable of high frequency sampling up to 20Hz, data collection was started before deck pour.
- 3D finite element analyses are conducted to provide enhanced understanding of the bridge behavior.

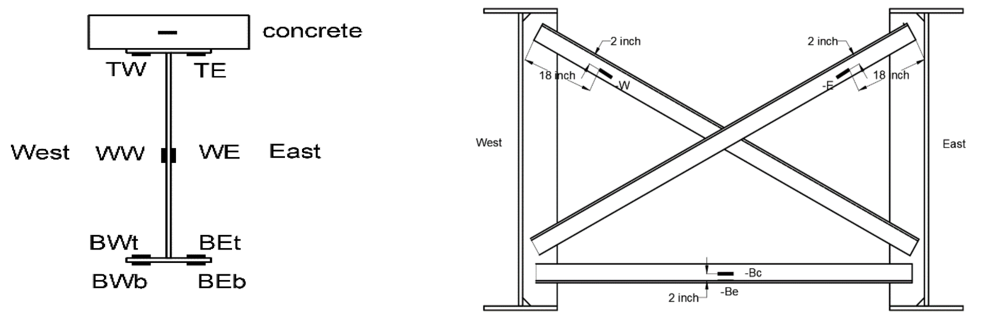
Bridge Instrumentation Plans



Instrumentation Plan – Mattis-74 (seat-type abutment)



Instrumentation Plan – Mattis-57 (IAB)



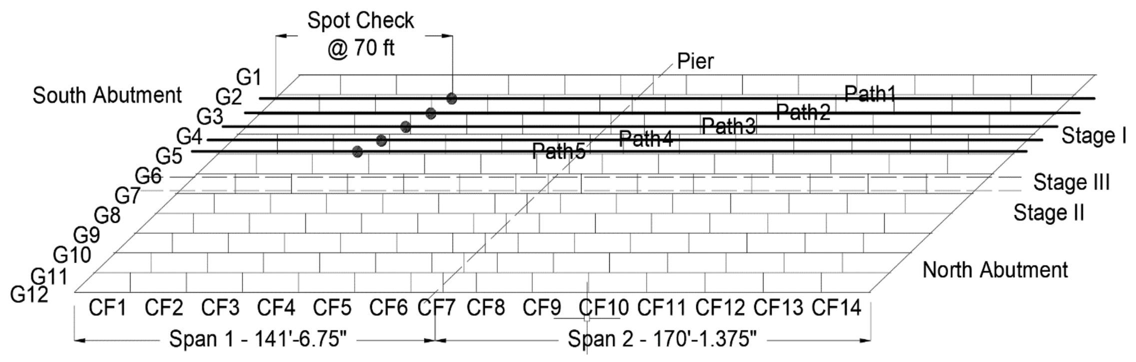
Girder and Cross-Frame Instrumentation Layout

Truck Testing

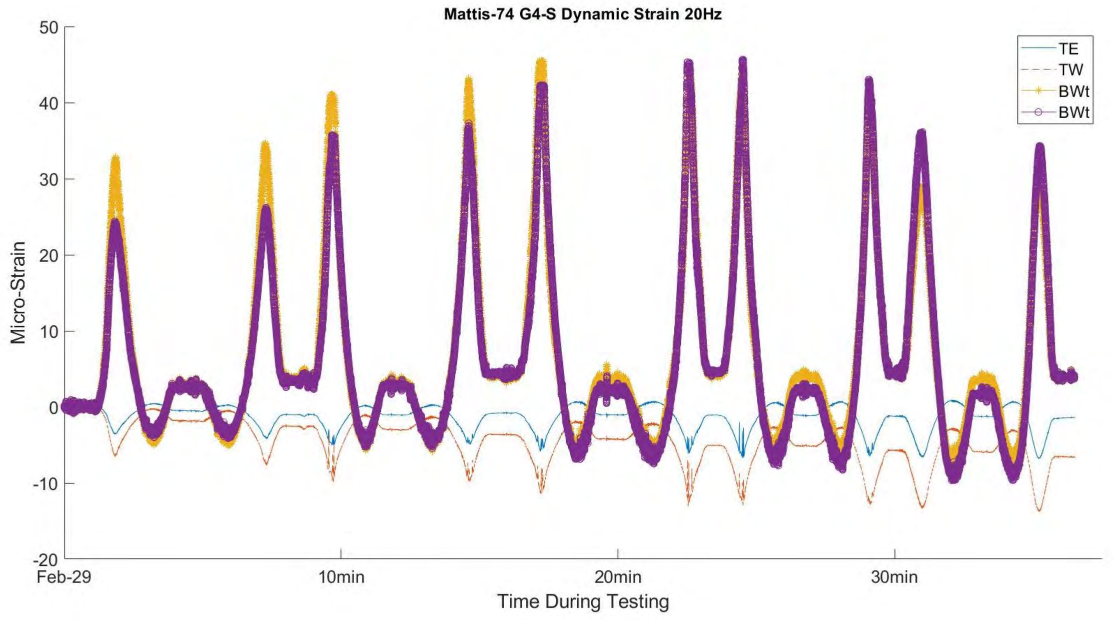
Truck testing was conducted Mattis-74 after the completion of Stage I construction.

Test truck

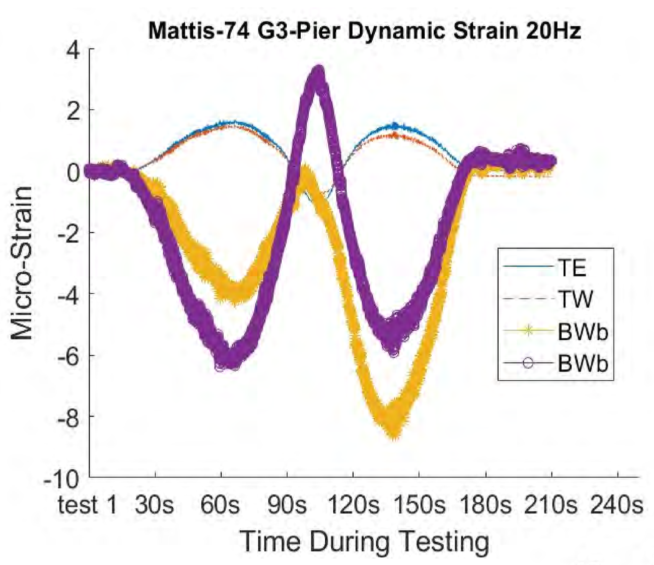
Truck paths



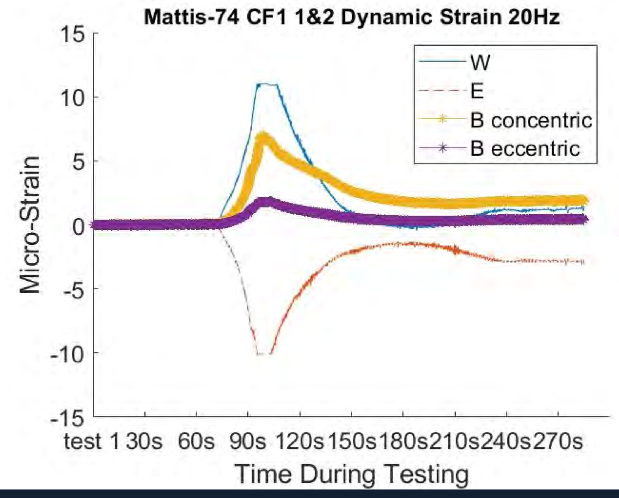
Truck Paths and Spot Check Locations on Mattis-74 Plan View



Dynamic Strain Record of Ten (10) Truck Tests – Girder Location G4-S



Dynamic Record of Girder Location G3-Pier under Truck Path 4 (Test 7)

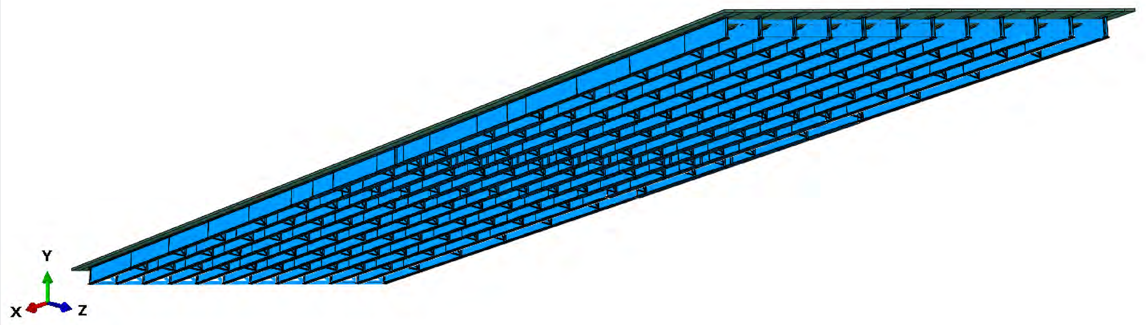


Dynamic Record of Cross-Frame Location CF1 1&2 under Truck Path 1 (Test 1)

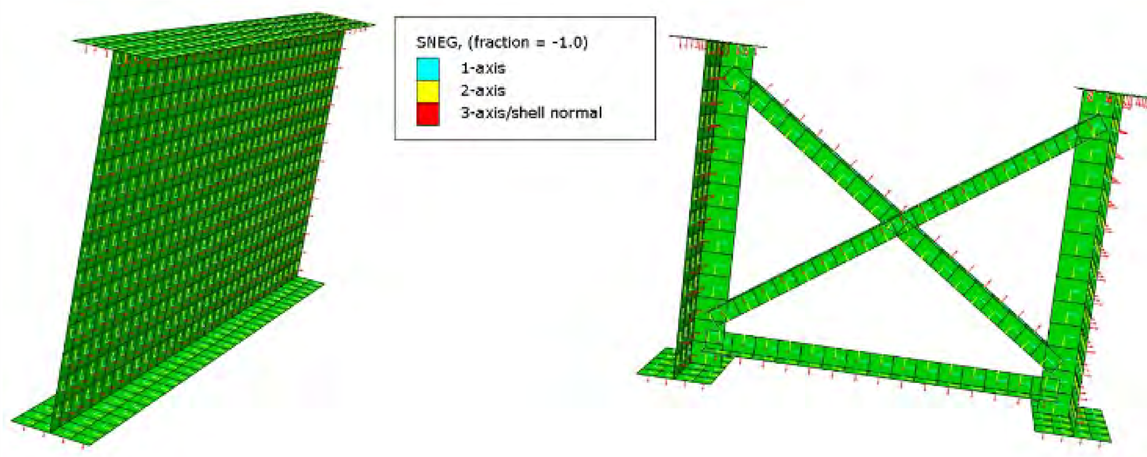
Numerical Simulations

3D finite element analysis was conducted using ABAQUS/CAE.

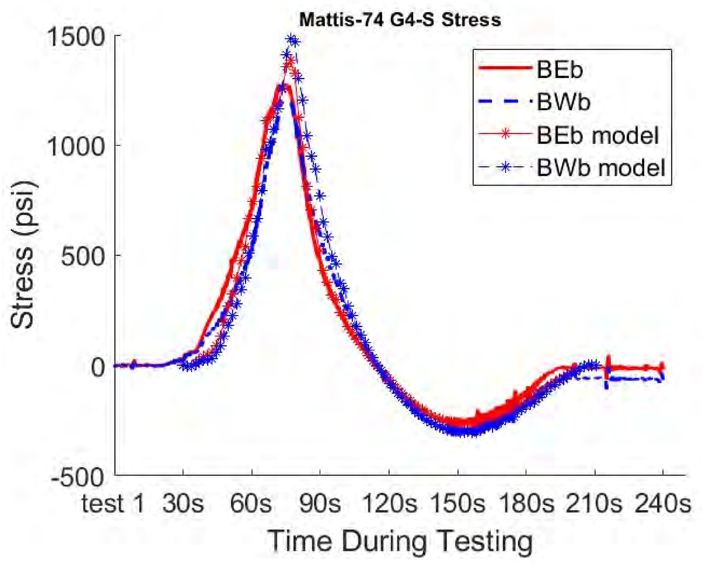
- Shell elements: steel I-girders, concrete slab and haunch, cross-frames, stiffeners
- Beam elements: bearing diaphragms
- Tie constraints: composite behavior between girders and slab, steel connection components
- Spring elements: bearings
- DLOAD user-subroutine: truck load



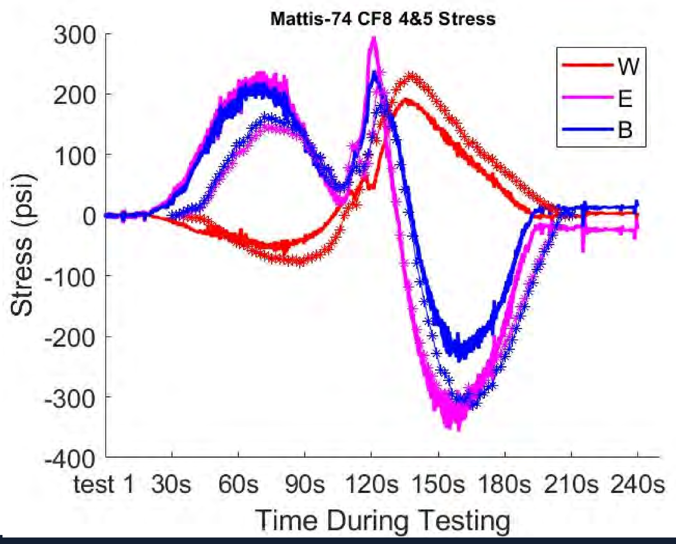
3D FEM Model of Mattis-74



Sample Mesh for Girder and Cross-Frame

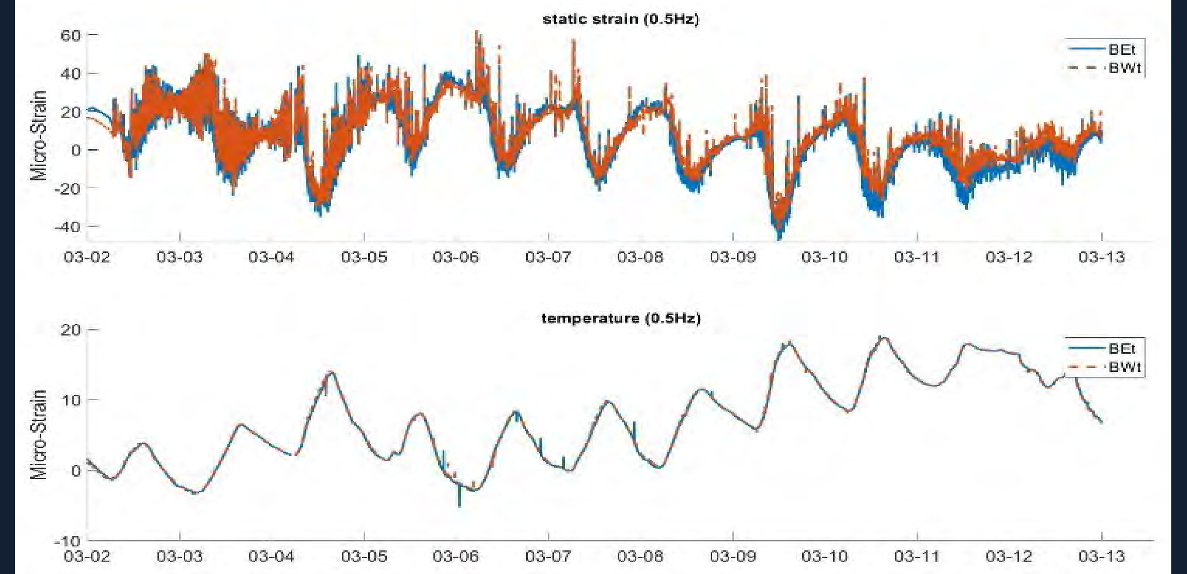


Model Validation for Bottom Gage Locations of Girder Location G4-S under Truck Path 3 (Test 5)

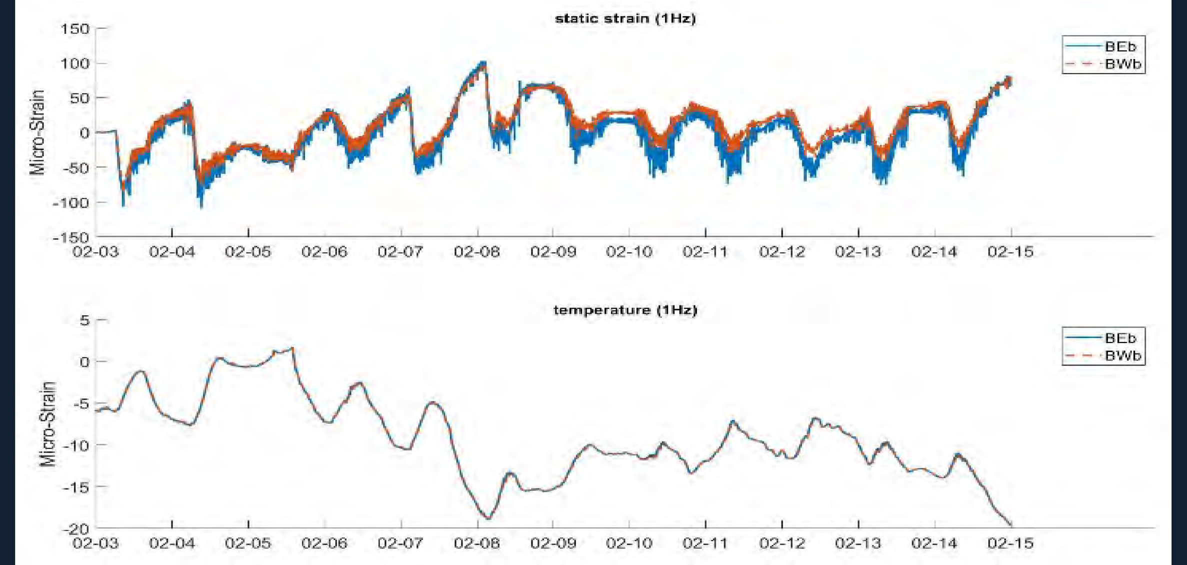


Model Validation for Cross-Frame Location CF8 3&4 under Truck Path 3 (Test 5)

Bridge Service Response



Strain and Temperature Data vs. Time – Mattis-74 G4-S Bottom Flanges Gages (in-service)



Strain and Temperature Data vs. Time – Mattis-57 G8-SAbut Bottom Flanges Gages (in-service)

CONCLUSIONS

- This study enriches the database of superstructure response for steel I-girder bridges and furthers the understanding of skewed steel I-girder bridge behavior.
- Numerical simulation results match well with data from field testing, which facilitates future parametric studies.

ACKNOWLEDGEMENTS

- Illinois Department of Transportation
- Illinois Center for Transportation, Project R27-194

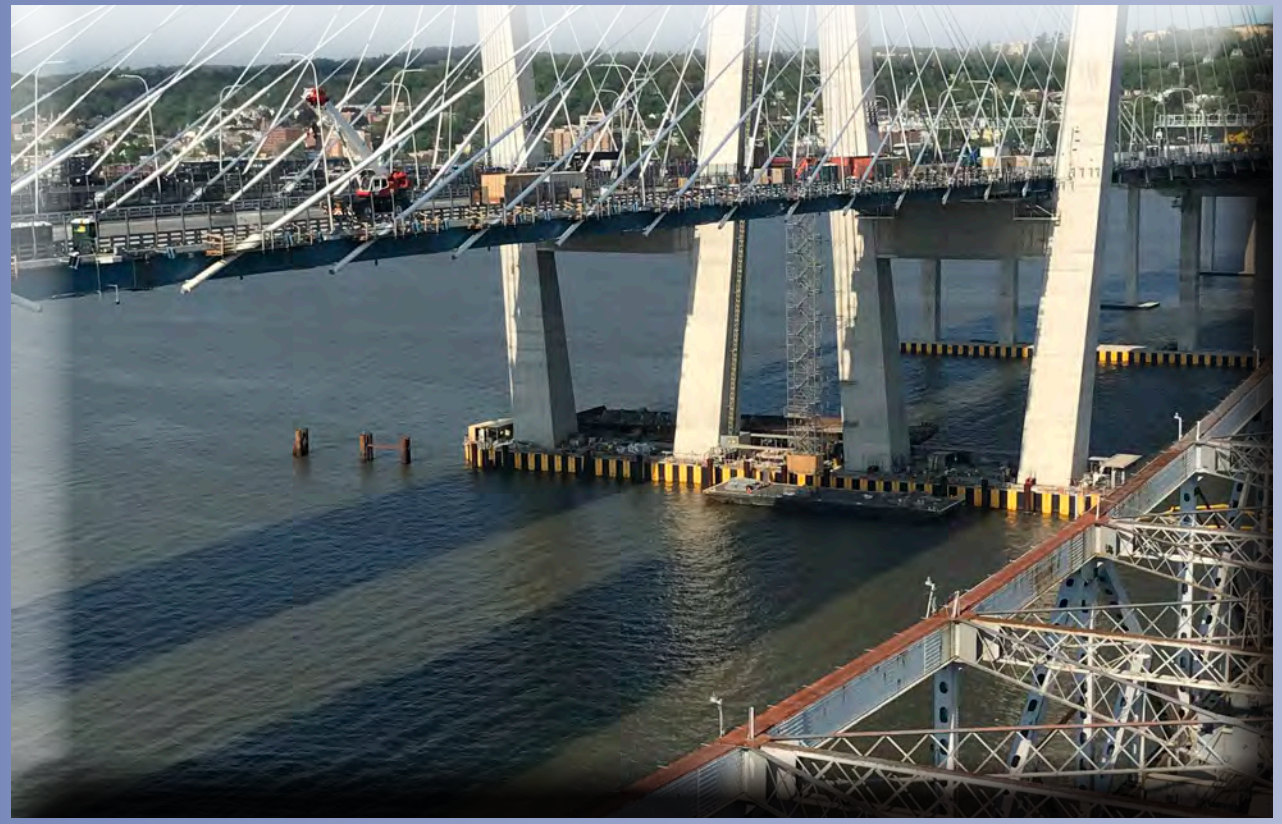
ILLINOIS

Alternative Accelerated Erection and Demolition Solutions

Tunnel Jacking under Live Traffic, GA 2019

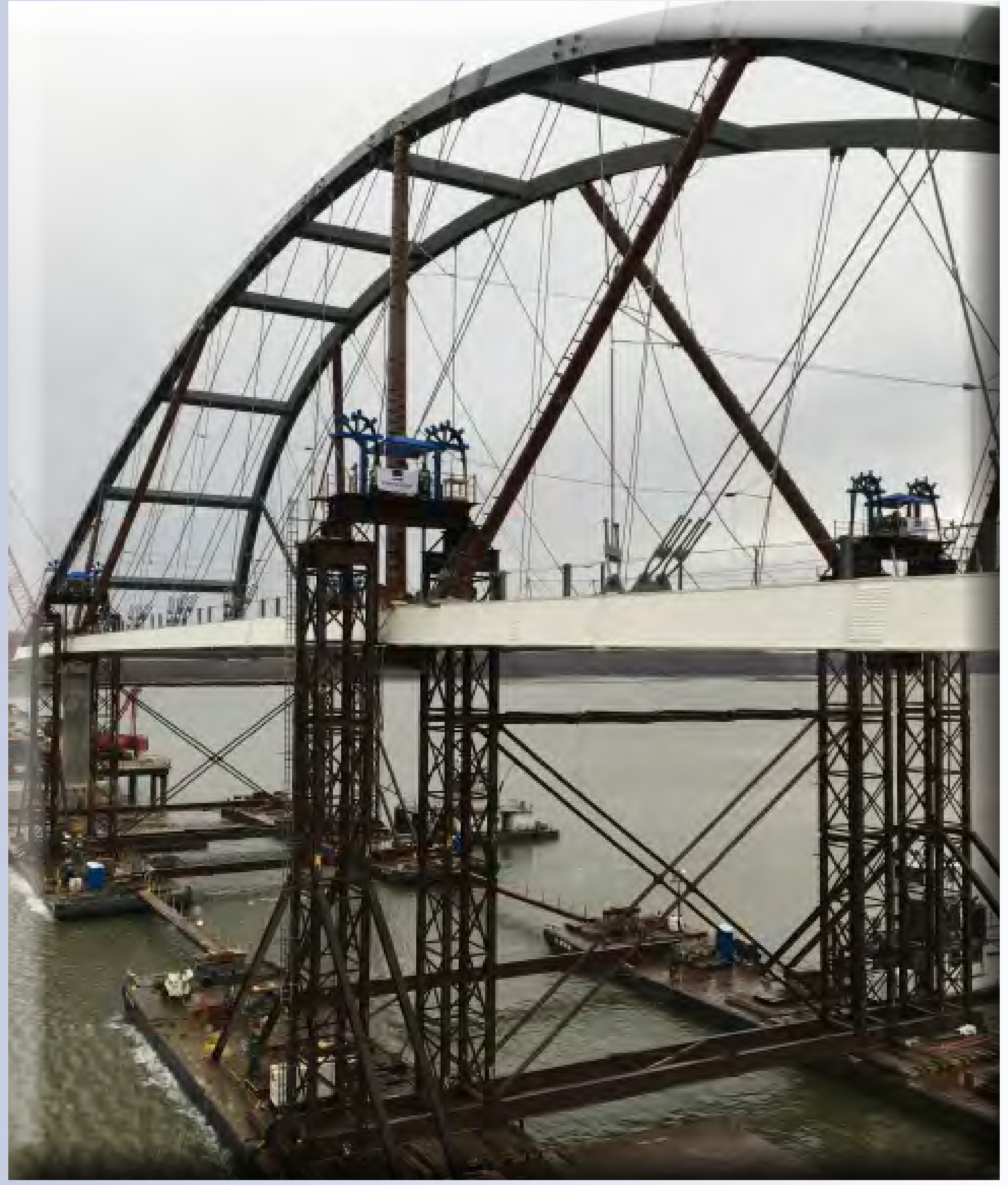
Lifting Precast Beams for the Sargent Bridge, TX 2020

As traveler convenience becomes a more important consideration for bridge owners, contractors and engineers are inclined to employ creative methods to minimize impact on travelers. Accelerated sequences then become a sought after feature in bids to perform the work.



Lowering of the Tappan Zee Suspended Span, NY 2018

The heavy lifting, lowering, and sliding options presented here can be very effective solution to tackle challenging projects.



Float-in of the Lake Barkley Tied-Arch, KY 2017

FREYSSINET
SUSTAINABLE TECHNOLOGY

OHIO GRATINGS, INC.

BIG RIVER CROSSING - REPURPOSING A PORTION OF THE HARAHAN RAILROAD BRIDGE

BIG RIVER CROSSING

INTRODUCTION

Big River Crossing is a public bicycle and pedestrian bridge spanning the Mississippi River from Memphis, TN to West Memphis, AR. Opened in 2016, it's part of the existing Harahan Railroad bridge structure that was originally constructed in 1916. The structure includes two active train tracks and the Big River Crossing pedestrian crossing which was originally a vehicle crossing. The vehicle crossing was closed in 1949 when the 4-lane Memphis and Arkansas Bridge opened.

The vehicle crossway was refurbished with Ohio Gratings **extruded aluminum perforated planking** for the walkway and **Press Lock galvanized steel bar grating** for the handrail and fencing system to protect pedestrians from falling debris from the active railroad tracks above. The **aluminum plank walkway** surface is perforated to allow rainwater to drain and includes a high traction surface to meet **American with Disabilities Act** guidelines.

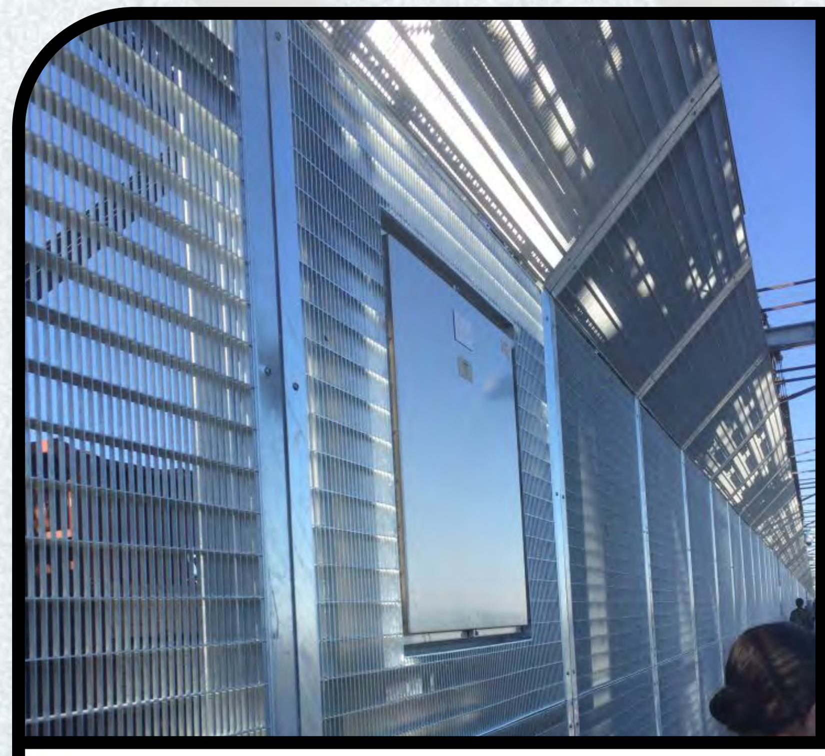
Big River Crossing is the longest pedestrian bridge across the Mississippi River at nearly a mile long.

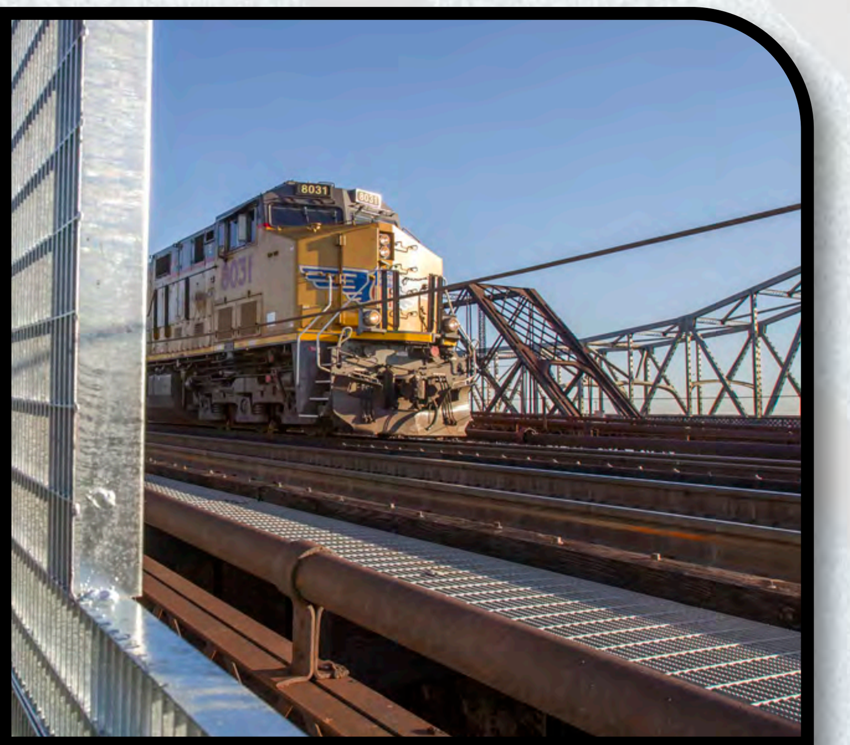
WALKING SURFACE

The walking surface is constructed from **6105-T5 extruded aluminum plank** with a diagonal punch with ***8% open area***. The surface also includes a high traction metal spray surface which meets ***Americans with Disabilities Act*** guidelines for slip resistance.

HANDRAIL SYSTEM

The handrail system is constructed from **galvanized carbon steel**. The mesh pattern prevents small children from climbing while offering a **90% open** area for a good view of the Mississippi and Downtown Memphis.





FENCING SYSTEM

The fencing system is constructed from **galvanized carbon steel**. The fence design includes a vertical section with a small mesh pattern to prevent people from climbing. The top section has a **45 degrees** tilt to help prevent small rocks and debris from falling on pedestrians. There is an **85% open area** to see the Mississippi River and trains passing safely by.

CONCLUSION

Ohio Gratings, Inc. provided the superior solutions that make this iconic pedestrian bridge safe for all **joggers, bikers, strollers and families**.