

Back-to-Basics



Bridge Structures: Fundamentals for Emerging Engineers

Presented by: Erin Brenneman, PE and Adam Bagriacik, PE
Date: May 5th, 2026



Erin Brenneman (Good), PE

Business Development Leader

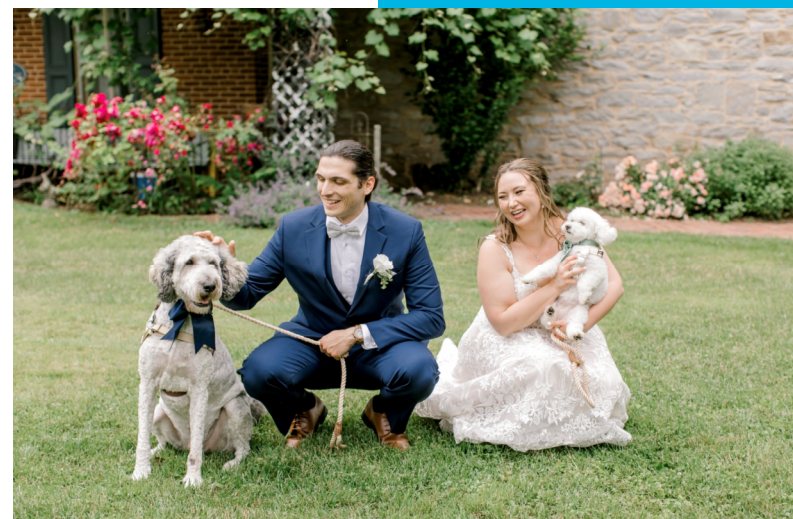
- BS in Engineering, Civil Concentration, 2020
- Joined Modjeski and Masters (M&M) upon graduation
- MS in Civil Engineering, 2023
- Structural engineering from 2020 – 2024
 - Movable and Pennsylvania bridges
- Earned PE and switched into Business Development in 2025



Adam Bagriacik

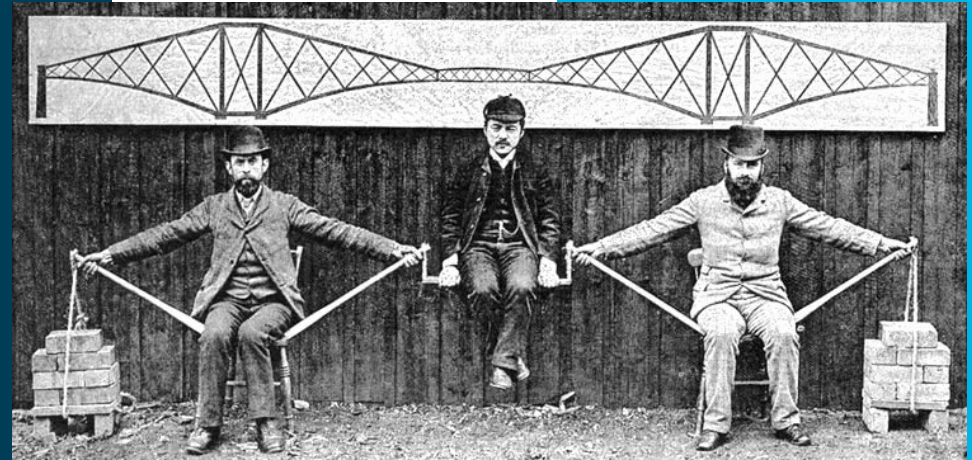
Structural Engineer

- BS in Civil and Environmental Engineering, 2015
- MS in Civil Engineering, 2017
- Joined M&M upon graduation
- Earned PE in 2020
- Worked on a myriad of design and rehabilitation projects
 - West Montgomery Avenue Bridge in Philadelphia
 - South Burlington Bridge in Vermont
 - SR115/I-81 Interchange Project near Wilkes-Barre
 - Fort Duquesne T-1 Steel Repairs in Pittsburgh



Learning Objectives

- Role of a bridge engineer
- Identify various bridge types
- Recognize components of a bridge
- Load paths through a structure
- Loads we consider in bridge engineering
- Governing codes
- Helpful resources



Presentation Outline

- Introduction to Bridges & Bridge Engineering
- Bridge Classifications and Types
- Bridge Components
- Load Types
- Codes and References



Introduction

Introduction

What is a Bridge?

- A structure, including supports, erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads. (**PennDOT PUB 238**)
- Any structure having an opening not less than 20-ft. that forms part of a highway or that is located over or under a highway. (**AASHTO LRFD Bridge Design Specifications**)



Introduction



What is the role of a Bridge Engineer?

- Responsible for the design or rehabilitation of a bridge. Includes developing and reviewing calculations and plan sheets and reviewing design related field submittals when the structure is under construction.
- New structures are designed for a 75-100 year design life.
 - Means bridge should remain functional, with appropriate maintenance and inspections, during that time frame.
- Rehabilitation projects include a wide variety of projects to preserve or increase the structures service life.
 - Possible preservation projects: deck repair/replacement, joint replacement, painting steel, bearing replacement
 - Possible major rehabs: widening the structure, strengthen the structure



Interdisciplinary Interaction



What are the impacts of the project?

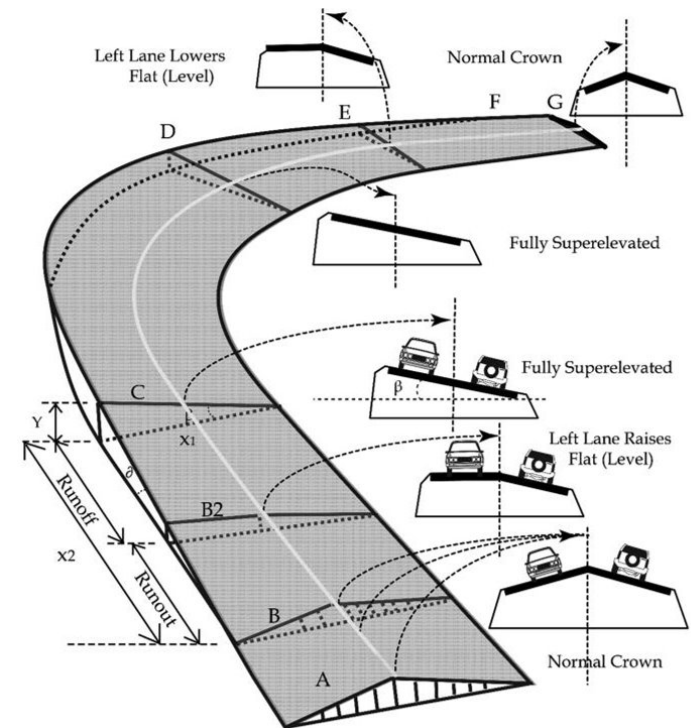
- Highway
- Structural
- Geotechnical
- Survey/ROW
- Hydrology
- Environmental (natural and cultural/social)
- Traffic
- Utilities
- Construction



Interdisciplinary Interaction

Highway

- Typically done majority of their work prior to Structures involvement
- Stationing and total bridge length
- Vertical and Horizontal Geometry
- Superelevation/Cross Slope
- Clearances
- Transitioning on/off bridge
 - Barriers, approach slabs, guiderails



Interdisciplinary Interaction



Geotechnical

- Site investigation before Structures is involved
- Geotechnical provides soil properties for foundation and substructure designs
- Structures provides foundation loads and pile layout (if applicable)
- Usually takes a few iterations

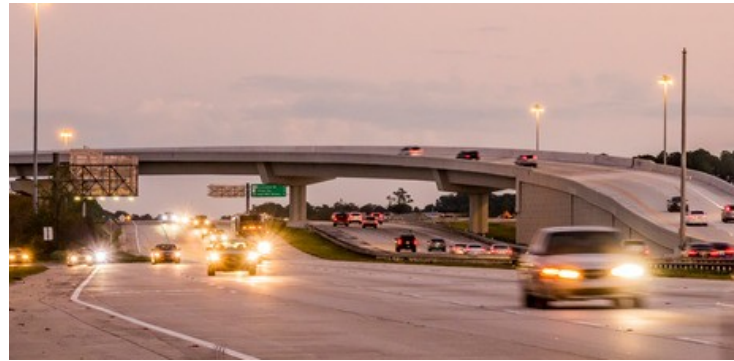


Bridge Classifications and Types

Bridge Classifications



Classification by What the Structure Carries



Railroad Bridges



Pedestrian Bridges



Highway Bridges



Utility Bridges

Bridge Classifications

Classification by Geometry



Straight

Curved

Skewed

Bridge Classifications



Classification by Span Length



Culvert (not a bridge): Span Length, $L < 20$ ft



Medium Span Bridges: $100 \text{ ft} < L < 250 \text{ ft}$ (approx.)



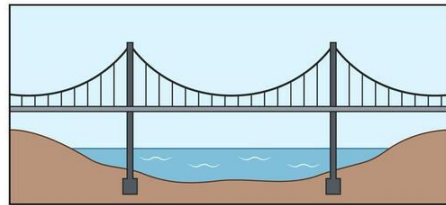
Short Span Bridges: Span Length, $L < 100 \text{ ft}$ (approx.)



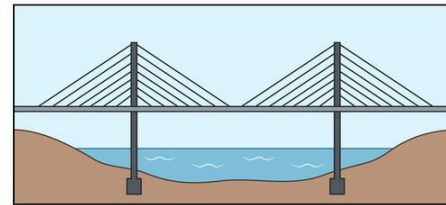
Long Span Bridges: $L > 250 \text{ ft}$ (approx.)

Bridge Types

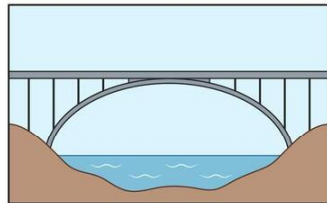
Common Bridge Types



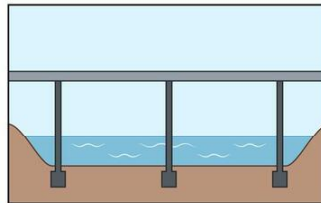
Suspension bridge



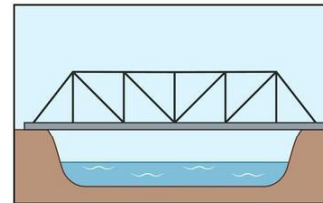
Cable-stayed bridge



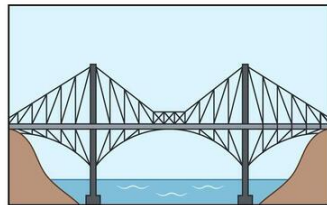
Arch bridge



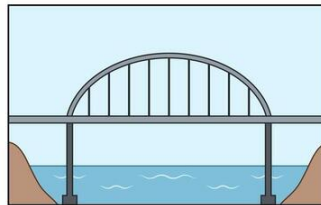
Beam bridge



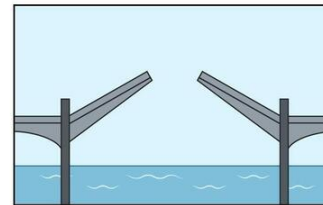
Truss bridge



Cantilever bridge



Tied-arch bridge



Drawbridge

Bridge Types

Beam/Girder Bridge

- Simplest and most common bridge type
- Typically used for highway bridges
- Longitudinal beams (steel or concrete) supported at each end by piers or abutments
- Loads carried primarily through bending
- Common for short to medium spans



Bridge Types

Truss Bridge

- Framework of interconnected triangular elements to distribute loads efficiently
- Axial member forces (tension or compression) only
- Medium to long spans
- Many existing bridges, but not typically used for new bridges



Bridge Types



Arch Bridge

- Transfers loads into horizontal thrust at the supports
- Primarily carries compression
- Effective for short, medium, or long spans
- Large foundations required
- Open spandrel or closed spandrel



Bridge Types



Tied-Arch Bridge

- Variation of arch
- Outward thrust resisted by horizontal tie (bottom longitudinal section)
- Eliminates need for large foundations
- Effective for medium or long spans
- Network tied arch or traditional tied arch



Bridge Types



Suspension Bridge

- Deck suspended from main cables draped over towers
- Cables anchored at the ends
- Loads carried through tension in the cables and compression in the towers
- Ideal for long spans and signature crossings



Bridge Types

Cable-Stayed Bridge

- Superstructure supported by cables connected to one or more towers.
- Cables run straight from tower to deck – no main cables like suspension bridges
- Suitable for medium to long spans
- More commonly used today for new, signature long span crossings



Bridge Types

Movable Bridges

- Move to allow passage of marine/rail traffic
- Commonly used where navigation clearance is required but a fixed bridge is impractical
- Types:
 - Bascule – span(s) hinged to rotate upwards
 - Swing – span rotates horizontally
 - Vertical-Lift – span raises vertically



Bridge Types



How to decide what bridge type?

- "Rule of thumb"/Experience
- Client/Community preference
- Economics
- Span length
- Navigation openings
- Signature bridge
- Site conditions
 - Soil conditions
 - Constructability
 - Clearances
- Load demands

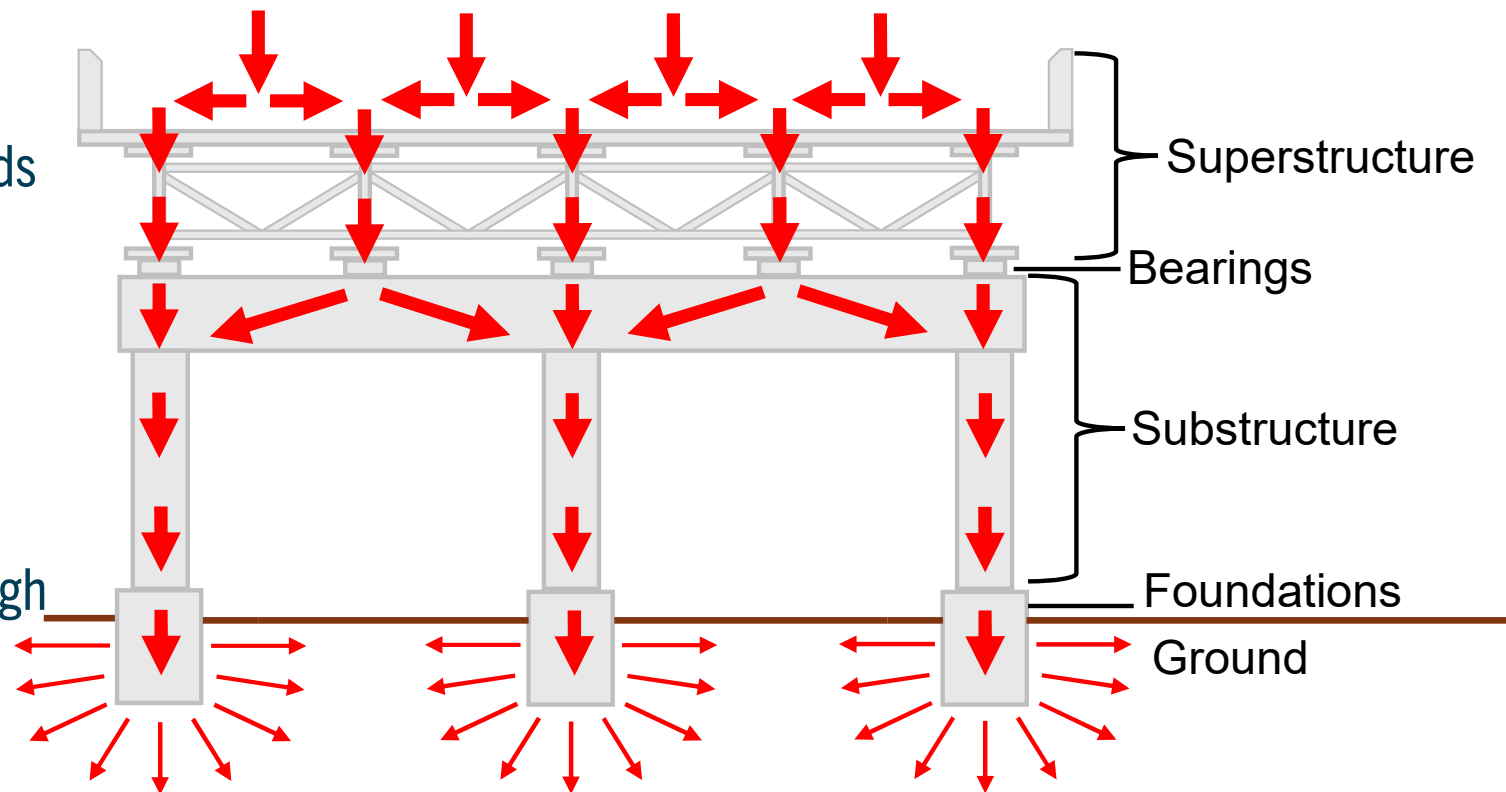


Bridge Components

Bridge Components

Load Path

- First step in any evaluation or design.
- Understanding the loads (forces) and how they move through a bridge is very important.
- It helps us understand how to evaluate each part of the bridge and ensure they have enough capacity.



Bridge Components



Terminology

- Typical highway bridge
- Superstructure – holds up traffic and includes:
 - Deck, wearing surface, beams/girders, diaphragms/cross-frames, barriers/rails, deck joints, bearings
- Substructure – holds up superstructure and includes:
 - Abutments, piers, wingwalls, bents
- Foundations – holds up substructure and consists of:
 - Piles, pile cap, micropiles, spread footings, drilled shafts, caissons

Superstructure

(above line)

(below line)

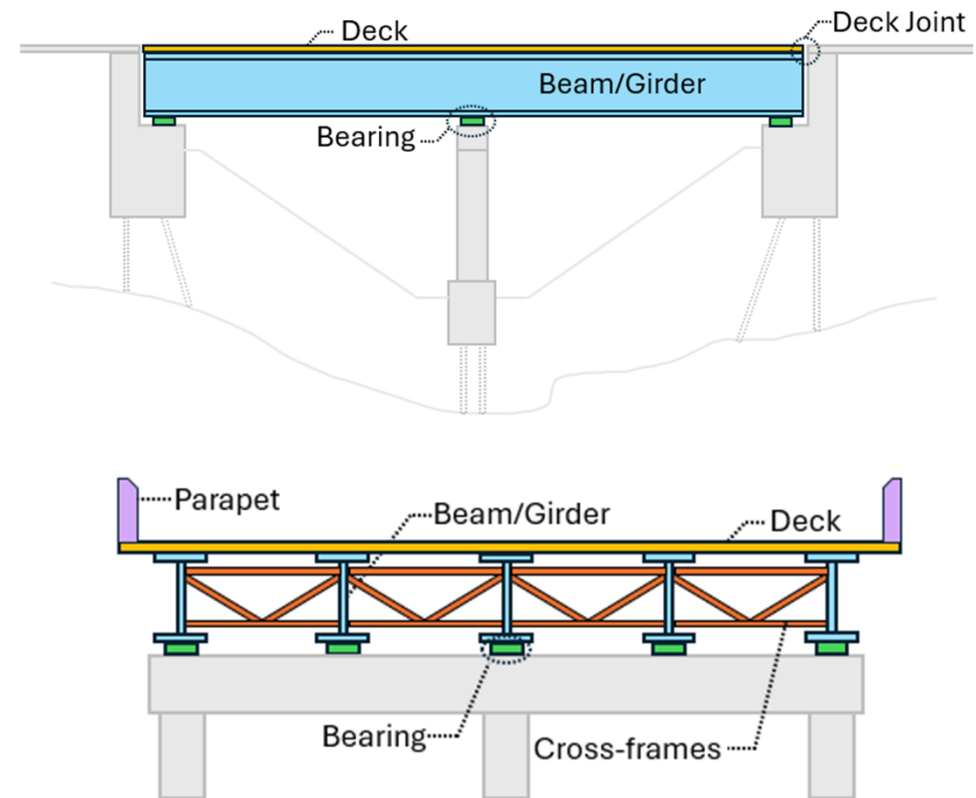
Substructure



Bridge Components

Superstructure - Deck

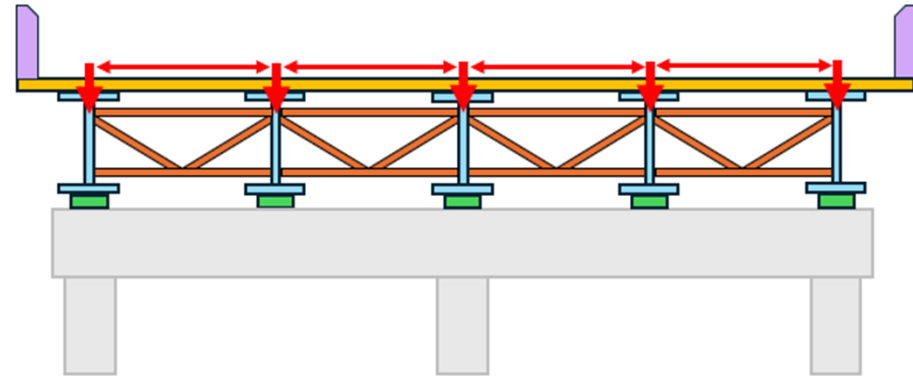
- Superstructure components
- Deck is the roadway you drive on
- Deck carries loads and distributes them transversely to the girders
- Parapets, sidewalks
- Reinforced concrete



Bridge Components

Superstructure – Girders/Beams

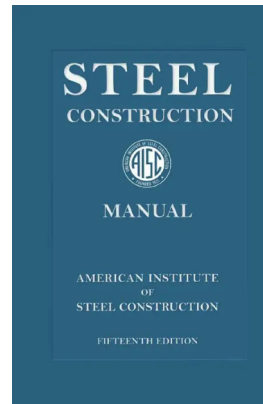
- Beams carry loads from the deck to the bearings
 - Resist bending/moments and shear forces
 - Size, shape, and spacing depends on the following:
 - Geometry
 - Load
 - Economy
 - Clearances
 - Constructability
- Cross-Frames/Diaphragms



Bridge Components

Superstructure – Girders/Beams

- Steel
 - Rolled beam (short to medium span)
 - “I” shaped
 - Standard shape
 - Quicker fabrication
 - Plate girder (short to long span)
 - “I” shaped
 - Economical
 - Customizable
 - Most common
 - Tub girder (short to long span)
 - “U” or box shaped
 - Curved bridges
 - Twisting



Practical Steel Tub Girder Design, NSBA April 2005

Bridge Components



Superstructure – Girders/Beams

- Concrete
 - Precast Prestressed I-girder/bulb-tee (short to medium span)
 - Precast Prestressed adjacent box beams (short span)
 - Precast Prestressed spread box beams (short to medium span)
 - Segmental box girder (medium to long span)



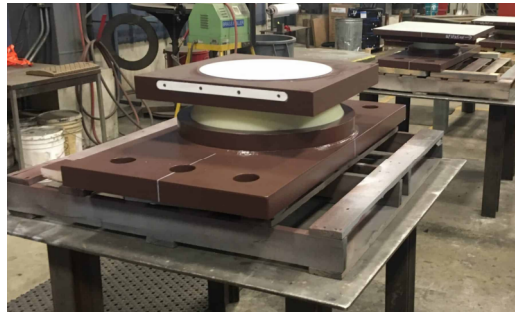
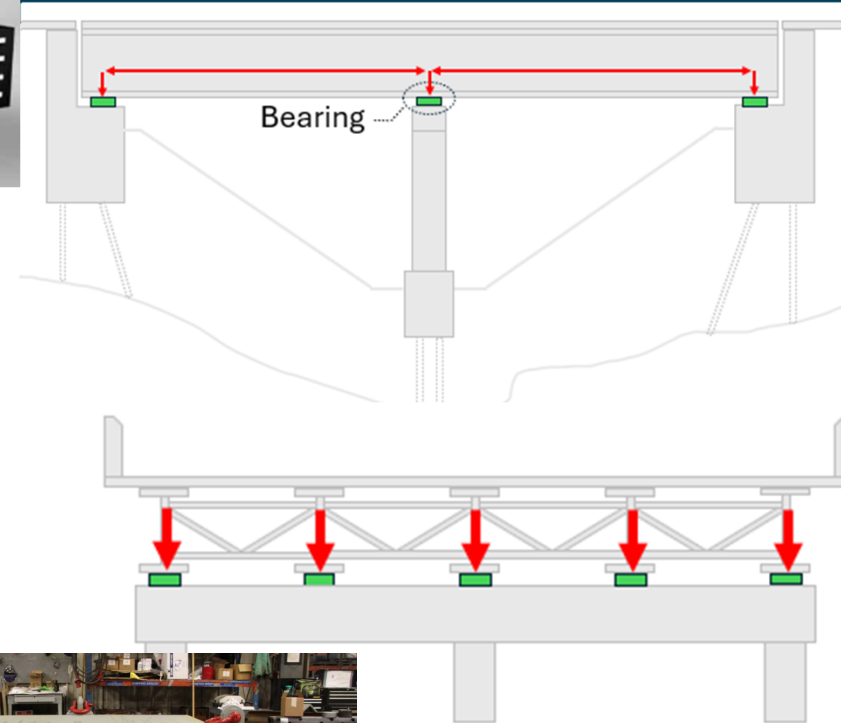
Bridge Components

Bearings

- Elastomeric Bearing Pad
 - Most common and easiest to design
 - Reinforced/laminated neoprene
- High Load Multi-Rotational Bearing
 - Used for long-span and/or curved bridges
 - More complex, typically designed by the manufacturer
 - Disc Bearing
 - Pot Bearing



DS Brown – Bearing Assemblies



DS Brown – Bearing Assemblies

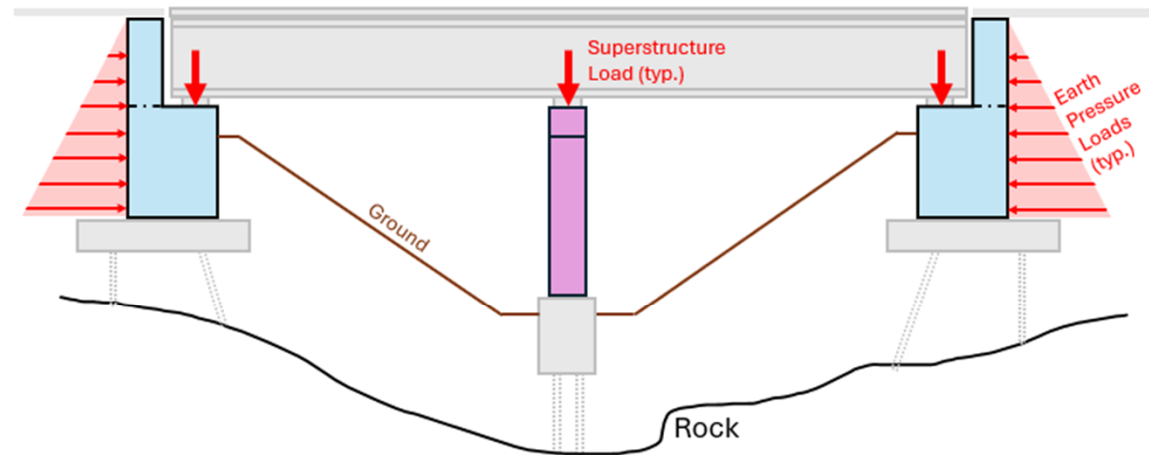
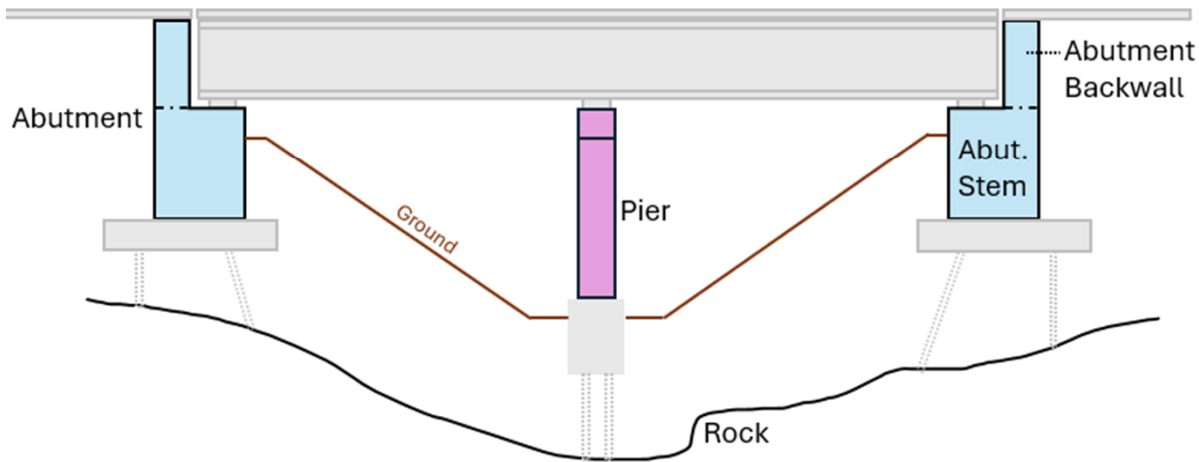


DS Brown – Bearing Assemblies

Bridge Components

Substructure – Abutments

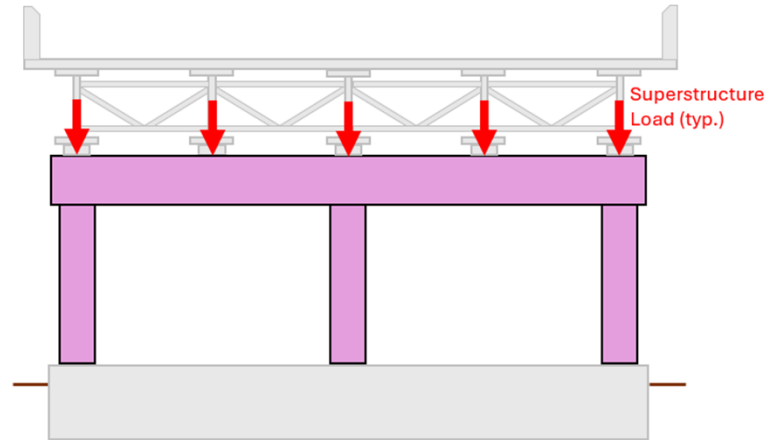
- Abutments
 - Backwall
 - Stem



Bridge Components

Substructure - Piers

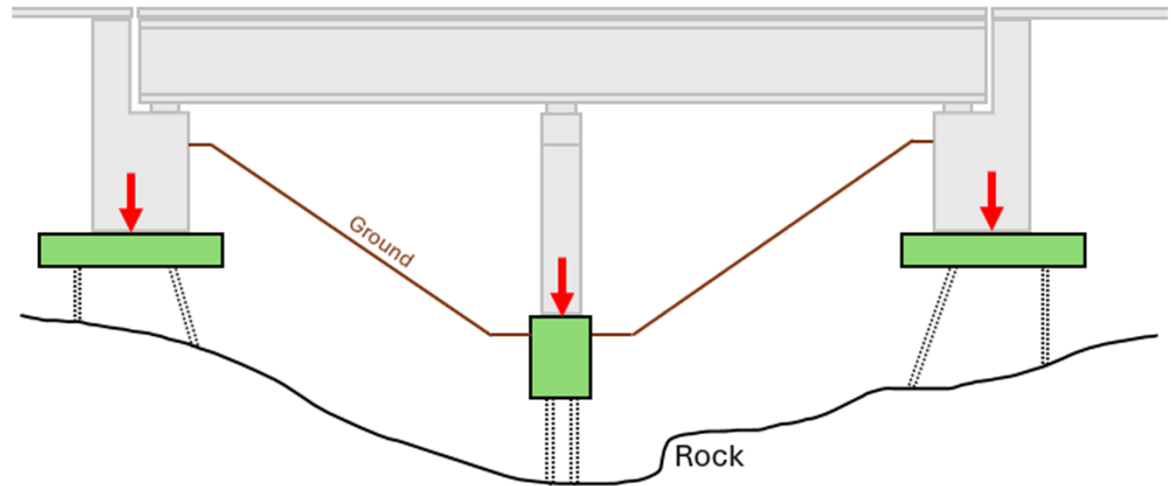
- Piers
 - Multi-Column
 - Pier Cap
 - Column
 - Wall
 - Hammerhead
 - Pier Cap
 - Column



Bridge Components

Foundations

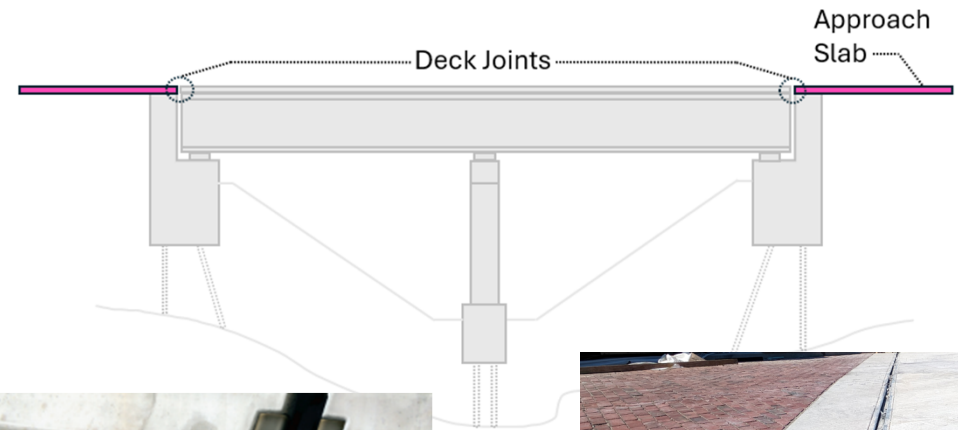
- Deep Foundations
 - Pile Cap
 - Piles – usually steel
 - Typically extends to bedrock
- Shallow Foundations
 - Component soil
 - Footing



Bridge Components

Deck Joints and Approach Slabs

- Deck Joints
 - Allow the bridge to "breathe" for the following:
 - Temperature changes
 - Construction tolerances
 - Live load
 - Location varies
 - Type depends on amount of movement expected – Strip seal, modular
- Approach Slabs
 - Reinforced concrete – similar to a deck
 - Transition from bridge to roadway



DS Brown – New Construction Brochure

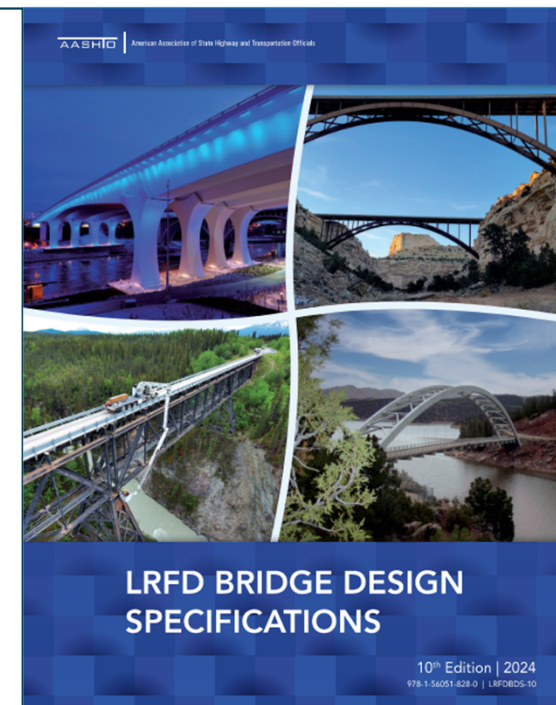
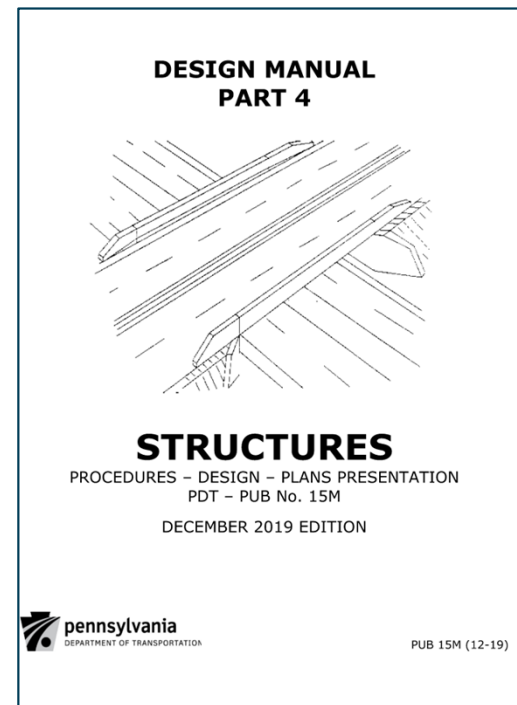
Load Types

Bridge Loading



American Association of State Highway and Transportation Officials (AASHTO)

- Load and Resistance Factor Design Bridge Design Specifications (LRFD BDS)
 - LRFD methodology
 - Federal governing code
 - Defines loads, load combinations, etc. (and capacities)
- PennDOT Design Manual 4 (DM-4)
 - State governing code
 - Supplements LRFD BDS



Bridge Loading

Load Demand

- Permanent Loads
 - DC: Dead Load of Structural Components and nonstructural attachment.
 - Self-Weight of all components
 - Deck, Sidewalk, Barrier/Parapet
 - Girders/Beams
 - Substructure concrete
 - Utilities
 - DW: Dead Load of Wearing surface
 - Overlay
 - FWS



Bridge Loading

Load Demand

- Transient Loads
 - LL: Live Load
 - Vehicular – federal, state, local specific
 - Pedestrian
 - IM: Vehicular Dynamic Load Allowance (Impact)
 - Hammering effect of wheels hitting surface discontinuities such as deck joints, cracks, pot holes, etc.
 - BR: Braking

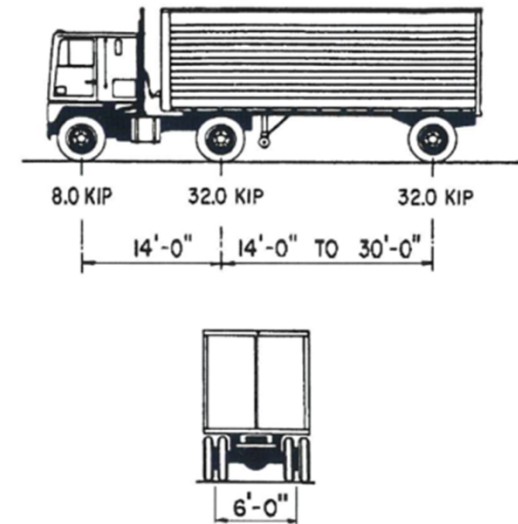


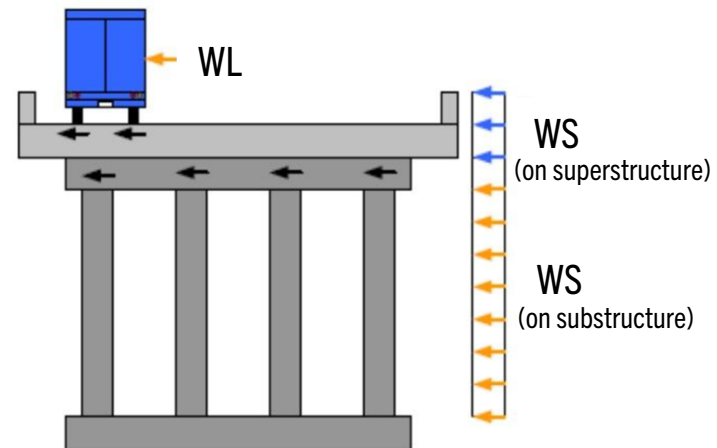
Figure 3.6.1.2.2-1—Characteristics of the Design Truck
AASHTO LRFD BDS

Bridge Loading

Load Demand

- Wind
 - WL: Wind on Live Load
 - WS: Wind Load on Structure
 - Applied directly to superstructure
 - Applied directly to substructure
 - Separated because of load paths

Wind Loads (WS, WL)



Bridge Loading

Load Demand

- Temperature Changes
 - TU: Uniform Temperature
 - TG: Temperature Gradient
- Other
 - EQ: Earthquake Effects
 - EH, ES, LS: Earth Pressures
 - CE: Centrifugal Forces



Bridge Loading



Limit States

- **Construction Limit State**
- **Strength Limit State**
 - Checks strength and stability of all design components
 - Used to design most components
- **Service Limit State**
 - Restrictions on stress, deformation, deflection, and cracking under regular service load
 - Rideability, user-related limit state

Table 3.4.1-1—Load Combinations and Load Factors

Load Combination Limit State	DC DW EH EV ES EL PS CR SH	LL IM CE BR PL LS	WA	WS	WL	FR	TU	TG	SE	DR	Use One of These at a Time				
											EQ	BL	IC	CT	CV
Strength I (unless noted)	γ_F	1.75	1.00	—	—	1.00	γ_{TU}	γ_{TG}	γ_{SE}	γ_{DR}	—	—	—	—	—
Strength II	γ_F	1.35	1.00	—	—	1.00	γ_{TU}	γ_{TG}	γ_{SE}	γ_{DR}	—	—	—	—	—
Strength III	γ_F	—	1.00	1.00	—	1.00	γ_{TU}	γ_{TG}	γ_{SE}	γ_{DR}	—	—	—	—	—
Strength IV	γ_F	—	1.00	—	—	1.00	γ_{TU}	—	—	—	—	—	—	—	—
Strength V	γ_F	1.35	1.00	1.00	1.00	1.00	γ_{TU}	γ_{TG}	γ_{SE}	γ_{DR}	—	—	—	—	—
Extreme Event I	1.00	γ_{EQ}	1.00	—	—	1.00	—	—	—	1.00	1.00	—	—	—	—
Extreme Event II	1.00	0.5/ 1.00	1.00	—	—	1.00	—	—	—	1.00	—	1.00	1.00	1.00/	1.00
Service I	1.00	1.00	1.00	1.00	1.00	1.00	γ_{TU}	γ_{TG}	γ_{SE}	1.00	—	—	—	—	—
Service II	1.00	1.30	1.00	—	—	1.00	γ_{TU}	—	—	—	—	—	—	—	—
Service III	1.00	γ_{LL}	1.00	—	—	1.00	γ_{TU}	γ_{TG}	γ_{SE}	1.00	—	—	—	—	—
Service IV	1.00	—	1.00	1.00	—	1.00	γ_{TU}	—	1.00	1.00	—	—	—	—	—
Fatigue I—LL, IM & CE only	—	1.75	—	—	—	—	—	—	—	—	—	—	—	—	—
Fatigue II—LL, IM & CE only	—	0.80	—	—	—	—	—	—	—	—	—	—	—	—	—

Notes: For Service I, the load factor for *EV* equals 1.2 for Stiffness Method Soil Failure as shown in Table 3.4.1-2.
The value of γ_F shall be taken from Tables 3.4.1-2 and 3.4.1-3.
The value of γ_{LL} shall be taken from Table 3.4.1-4.
The value of γ_{SE} shall be taken from Table 3.4.1-5.
The value of γ_{TU} shall be taken from Table 3.4.1-6.
For Structural Strength, the load factor for *DR*, γ_{DR} , equals 1.10 and for Geotechnical Strength, γ_{DR} equals 0.00.

Bridge Loading



Limit States

- **Fatigue Limit State**
 - Steel
 - Caused by cyclical live loading
- **Extreme Event**
 - Ensures structural survival-life safety
 - EQ, vehicle collision, Ice loading (if applicable)
 - Rare occurrence

Table 3.4.1-1—Load Combinations and Load Factors

Load Combination Limit State	DC DW EH EV ES EL PS CR SH	LL IM CE BR PL LS	WA	WS	WL	FR	TU	TG	SE	DR	Use One of These at a Time				
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Strength I (unless noted)	γ_F	1.75	1.00	—	—	1.00	γ_{TU}	γ_{TG}	γ_{SE}	γ_{DR}	—	—	—	—	—
Strength II	γ_F	1.35	1.00	—	—	1.00	γ_{TU}	γ_{TG}	γ_{SE}	γ_{DR}	—	—	—	—	—
Strength III	γ_F	—	1.00	1.00	—	1.00	γ_{TU}	γ_{TG}	γ_{SE}	γ_{DR}	—	—	—	—	—
Strength IV	γ_F	—	1.00	—	—	1.00	γ_{TU}	—	—	—	—	—	—	—	—
Strength V	γ_F	1.35	1.00	1.00	1.00	1.00	γ_{TU}	γ_{TG}	γ_{SE}	γ_{DR}	—	—	—	—	—
Extreme Event I	1.00	γ_{EQ}	1.00	—	—	1.00	—	—	—	1.00	1.00	—	—	—	—
Extreme Event II	1.00	0.5/ 1.00	1.00	—	—	1.00	—	—	—	1.00	—	1.00	1.00	1.00/ —	1.00
Service I	1.00	1.00	1.00	1.00	1.00	1.00	γ_{TU}	γ_{TG}	γ_{SE}	1.00	—	—	—	—	—
Service II	1.00	1.30	1.00	—	—	1.00	γ_{TU}	—	—	—	—	—	—	—	—
Service III	1.00	γ_{LL}	1.00	—	—	1.00	γ_{TU}	γ_{TG}	γ_{SE}	1.00	—	—	—	—	—
Service IV	1.00	—	1.00	1.00	—	1.00	γ_{TU}	—	1.00	1.00	—	—	—	—	—
Fatigue I—LL, IM & CE only	—	1.75	—	—	—	—	—	—	—	—	—	—	—	—	—
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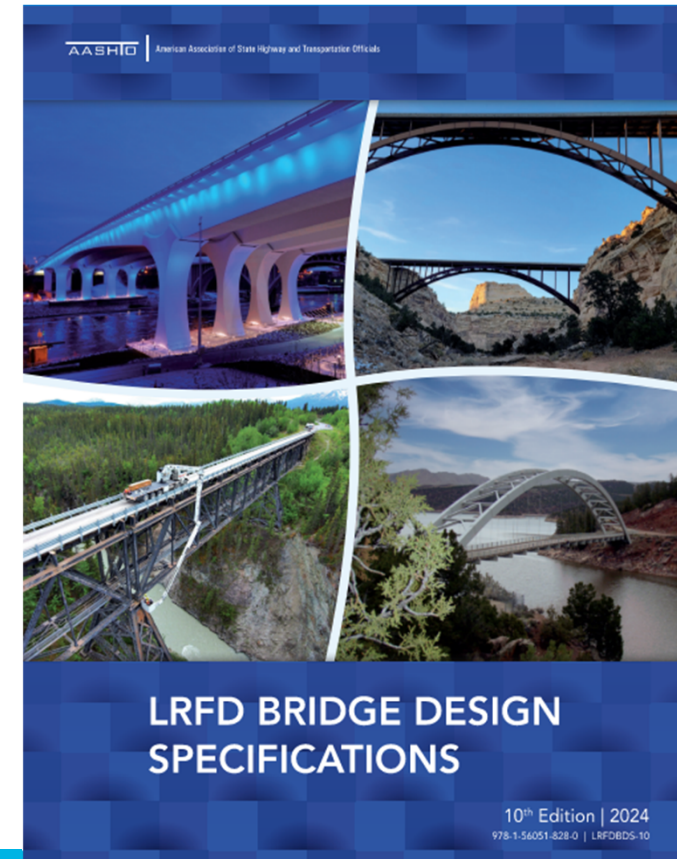
Codes and References

Governing Codes



American Association of State Highway and Transportation Officials (AASHTO)

- Load and Resistance Factor Design Bridge Design Specifications (LRFD BDS)
- Load and Resistance Factor Design Guide Specifications for the Design of Pedestrian Bridges
- Load and Resistance Factor Design Movable Highway Bridge Design Specifications



Governing Codes



State Specific

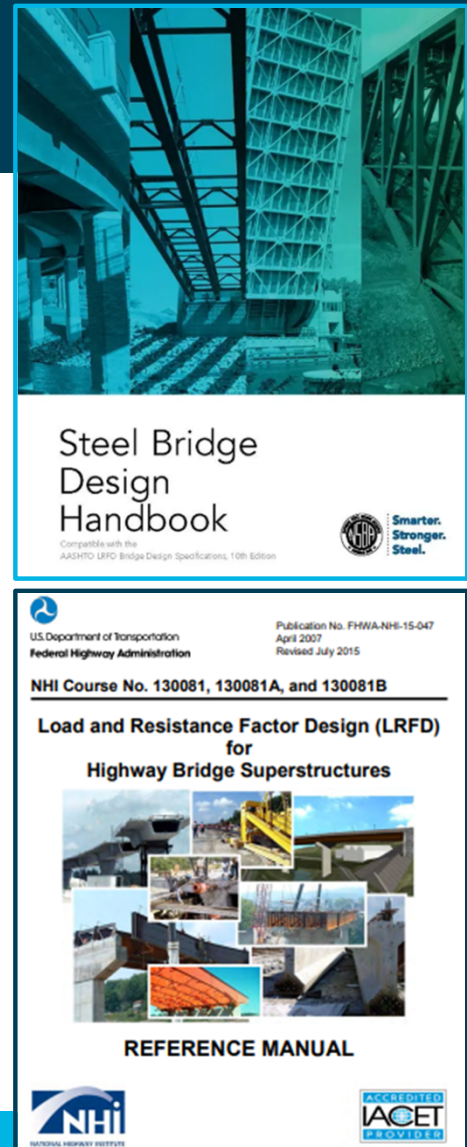
- PennDOT Design Manual – 4 (DM-4)
- PennDOT Bridge Design Standards (BD's)
- PennDOT Bridge Construction Standards (BC's)
- Publications (PUB's)
 - Inspection
 - Specifications
 - Load Rating



Design Resources

Helpful Resources to be Aware Of

- National Steel Bridge Alliance (NSBA) Steel Bridge Design Handbook (<https://www.aisc.org/bridges/bridge-resource-center/steel-bridge-design-handbook/>)
- Federal Highway Administration: Load and Resistance Factor Design (LRFD) for Highway Bridge Superstructures Reference Manual (<https://www.fhwa.dot.gov/bridge/pubs/nhi15047.pdf>)
 - Flowcharts for design: Archived - Load and Resistance Factor Design (LRFD) for Highway Bridge Superstructures, Design Examples (<https://www.fhwa.dot.gov/bridge/pubs/nhi15058.pdf>)



*Thank you for your
time and attention!*



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Erin: EMBrenneman@modjeski.com

Any Questions?

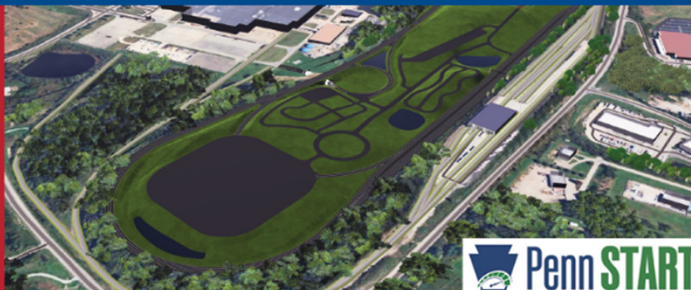
Upcoming ASHE Events



ASHE JUNE MEETING

WED
3
JUNE

11:30AM – 1:30PM



ANNUAL GOLF OUTING

FRI
7
AUG

RANGE END
Dillsburg



YOUNG MEMBER VOLUNTEER EVENT

SAVE
the date

TUES
16
JUN
5 PM to 7 PM



ANNUAL PICNIC

FRI
21
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LISBURN
FIRE
COMPANY

