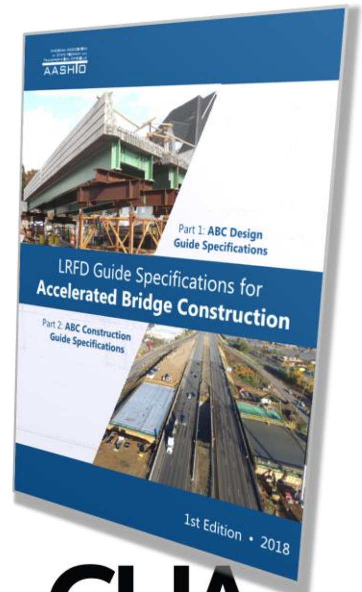
AASHTO Guide Specifications for Accelerated Bridge Construction

ABC for Steel Bridge Using Link Slabs



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NCHRP 12-102 Project Overview

Guide Specification Development

- Significant synthesis project
- No new research involved
- Technology readiness evaluation done for each technology

Approach:

- Not a stand-alone document
- Supplement to:
  - AASHTO LRFD Bridge Design Specifications
  - AASHTO Bridge Construction Specifications
- Separate Design and Construction Parts

Project Status

- Complete

NCHRP 12-102
Project Overview

Sources of provisions

- Significant technology synthesis
  - Dozens of past research projects on ABC
  - NCHRP Research
  - State DOT Research
  - International Research
  - Private research
- Questionnaire to Each State DOT
  - What are they using?
  - What is working? What is not?
  - Lessons Learned

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Specification Overview

Guide Specification Contents

Part 1: ABC Design Guide Specifications

1. Introduction
2. General Design Provisions
3. Design of Prefabricated Elements
4. Detailing Requirements
5. Durability of ABC Technologies

Link slab specifications reside here

Part 2: ABC Construction Guide Specifications

6. Introduction
7. Temporary Works
8. Fabrication and Assembly Planning
9. Layout and Tolerances
10. Concrete Structures
11. Steel Structures
12. Geosynthetic Reinforced Soil / Integrated Bridge System

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Key Definitions

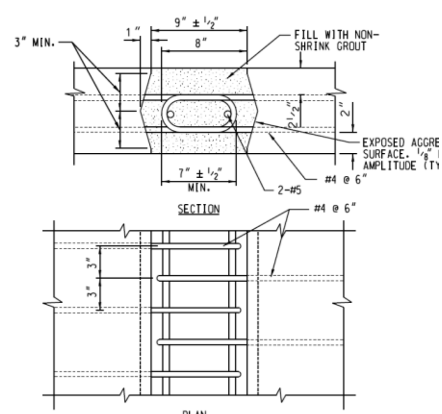
Modular Deck Beam (MDB)

An element that is fabricated with beams combined with an integral composite reinforced concrete deck to form a modular unit. MDBs can be made with steel or prestressed concrete beams. A MDB is typically made with two or three beam elements.

Key Definitions

Closure Joint

A gap between two elements or systems that is filled with materials to form a connection. The joint may or may not include reinforcing. The width of the closure joint can vary based on the type of material used to fill the joint and the reinforcing within the joint. This feature is also referred to as a "closure pour" by some agencies.

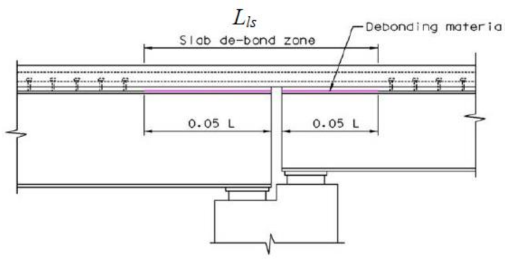


HOOKED BARS WITH NON-SHRINK GROUT

Key Definitions

Link Slab

Links slabs are a transverse deck level connection at piers between the decks of two adjacent spans, providing a jointless bridge without continuity. The deck is made continuous across the pier, but the supporting beams or girders are not connected.



Most Common uses of Steel in ABC

SPMT and Lateral Slide Installations

- Steel Superstructures
- Less weight = fewer axle lines & lighter temp. works = less cost
- Can handle negative moments better than concrete

Modular Deck Beams

- Less weight for cranes and transport
- Can accommodate any geometric configuration

Most Common uses of Steel in ABC

Modular Deck Beams

- Less weight when compared to concrete
- Weekend superstructure replacements are feasible
- Spans up to 135’ +/-

Modular Deck Beam Design

3.5.2.2—Modular Decked Beams

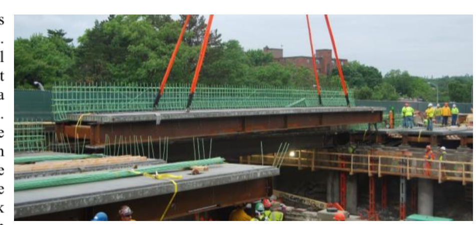
The design of modular decked beams shall follow the provisions in the *AASHTO LRFD Bridge Design Specifications* for beams with a CIP concrete deck. The deck level connections between the adjacent deck beams shall be designed as reinforced moment connections. The provisions for maximum skew of primary reinforcement are applicable to modular deck beams.

Primary reinforcement and distribution reinforcement are typically designed using the Strip Method as specified under the “Alternate Methods of Analysis” article in Chapter 4 of the *AASHTO LRFD Bridge Design Specifications*. Designers shall also design the deck for serviceability and deck overhang reinforcement.

C3.5.2.2

Modular decked beams (MDB) are also referred to as Prefabricated Bridge Units (PBUs) in some states. Modular steel decked beams consist of two or more steel beams that are connected to a concrete deck which is cast in a fabrication facility (off-site or near site). This forms a modular unit that is similar to a precast double tee beam. The most common modular decked beam has been made with steel beams. It is also possible to make a MDB with concrete beams. The provisions contained in this article would still be applicable to a MDB made with concrete beams. It is also possible to use an orthotropic steel deck connected to the top of a steel beam. This steel deck option is a specialized system that is not well documented, therefore this article focuses on the concrete deck option.

The behavior of an integral deck on steel beams is akin to a cast-in-place deck on independent beams.



Link Slab Connections

3.6.9 LINK SLABS

Links slabs shall be designed to resist dead load and live load (deck) forces as well as forces induced by beam end rotation. Links slabs can be used for steel beam superstructures and concrete beam superstructures.

In general, link slabs can be designed and detailed with normal deck concrete.

The detailing of link slabs involves the debonding of a portion of the bridge deck at the ends of the spans. Designers need to verify the design of the beam in this zone based on non-composite action.

The skew of the bridge may be neglected in link slab design.

C3.6.9

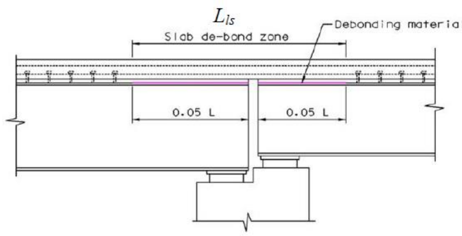
Links slabs are a means of providing a jointless bridge without continuity. The deck is continuous across the substructure element, but the supporting beams or girders are not. The basic design approach for link slabs is to design them to accommodate anticipated beam end rotations (Caner, A. and Zia P. 1998).

Links slabs are applicable to Accelerated Bridge Construction because they allow for the use of span-by-span construction as opposed to span continuity. This provides the potential to build multi-span jointless bridges quickly without the need for girder splicing or casting of integral end diaphragms. Modular Deck Beam bridges are particularly well suited for this technology.

Special concrete mixes with favorable properties have been used by some agencies. Designers should consider the impacts of special mixes on the construction process and the cost implications of special mixes (Li et al. 2005).

In most cases, a non-composite section at the ends of a bridge can be accommodated in the design, since the bending moments are small at the non-continuous beam ends.

Studies have shown that in general, the bending moments in link slabs decreases with increases in bridge skew (Aktan et al. 2011). In general, reductions were found to be limited for skews up to 20 degrees and more pronounced for higher skewed bridges. Based on this study, it is conservative to assume zero skew in the design of link slabs.



Link Slab Connections

3.6.9.1 **Primary Reinforcement**

The primary reinforcement shall be designed and detailed to resist dead load and live load forces as specified in the *AASHTO LRFD Bridge Design Specifications* including the provisions for deck overhangs.

C3.6.9.1

In a typical bridge with longitudinal beams or girders, the primary reinforcement runs transversely across the bridge deck. The design of this transverse reinforcement is not different than the design of normal deck reinforcement. The design of the transverse reinforcement must account for the overhang forces including barrier impacts.

A link slab still needs to support wheel loads

Link Slab Connections

3.6.9.2 **Link Slab Reinforcement**

Longitudinal link slab reinforcement shall be designed to resist the induced rotations in the adjacent beams.

Links slabs shall not be assumed to provide any continuity of composite dead loads or live loads.

The link slab shall be detailed as non-composite over its entire length through the use of a physical bond breaker between the link slab and the supporting beam. The minimum recommended length of the link slab shall be equal to the total of 5 percent of each span length that is connected to the link slab, measured from the end of the supporting beams.

C3.6.9.2

Link slab reinforcement is not designed for typical live load forces. Instead, it is designed to accommodate the beam end rotations. The rotation of the beams leads to forces that are result of the stiffness of the link slab.

Links slabs do not provide measurable resistance to negative bending moments, and their stiffness is significantly less than the adjacent composite beams, therefore the joint can be assumed to be a theoretical pinned connection. This approach is similar to the assumption made with the design of an integral abutment bridge.

Figure C3.6.9.2-1 shows a typical link slab debond zone.

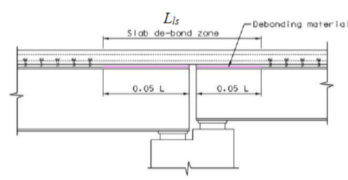


Figure C3.6.9.2-1 Links slab debond zone

Link Slab Connections

The design bending moment in the link slab per beam M_{ls} shall be calculated as follows:

$$M_{ls} = 2E_{ls}I_{ls}\Theta/L_{ls} \qquad (3.6.9.2\text{-}1)$$

where:

E_{ls} = *modulus of elasticity of the link slab (ksi)*

I_{ls} = *moment of inertia of the link slab using gross gross section properties (in^4)*

The design bending moment can be derived from the theory that the slab is fixed at each end of the link slab. A rotation is applied to the slab from either end resulting in a maximum bending moment at the fixed end. Figure C3.6.9.2-2 shows the free body diagram for this situation.

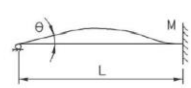


Figure C3.6.9.2-2 Links slab free body diagram

The moment of inertia of the link slab is calculated in the same plane as the adjacent girders. For an interior beam the calculation would be as follows:

$$I_{ls} = S\,d^3/12 \qquad (C3.6.9.2\text{-}1)$$

where:
S = *beam spacing (in.)*
d = *gross section depth of the link slab (in.)*

Similar calculations would be used for fascia beams accounting for the width of the overhang. The use of gross section properties is conservative since it results in a larger section property than a cracked section.

Designers should not increase the thickness of the link slab in order to provide a more robust connection. Increased thickness will lead to increased stiffness, which will develop more bending moment in the link slab, potentially leading to more cracking. Maintaining the same thickness as the adjacent span slab is recommended. Likewise, the use of higher strength concrete is not recommended since it will have a higher modulus of elasticity, which will lead to higher link slab moments.

Link Slab Connections

Θ = maximum girder end rotation applied to the link slab (rad.)

The maximum girder end rotation is the largest end rotation that would be applied to the link slab zone after the casting and curing of the link slab region. Provisions for continuous spans may be used for the application of the vehicular live load.

L_{ls} = total length of link slab (in.)

The total length of the link slab shall be the debond zone as shown in Figure C3.4.9.2-1.

The links slab shall be designed to resist the induced bending moment. The section shall also be checked for serviceability using the "Control of Cracking by Distribution of Reinforcement" provisions in the *AASHTO LRFD Bridge Design Specifications*.

The loads factors used to calculate rotations need to be consistent with the design provisions being used (strength vs. service). These provisions will ensure that the crack width in the link slabs will provide a durable structure. The provisions for Class 2 exposure are recommended.

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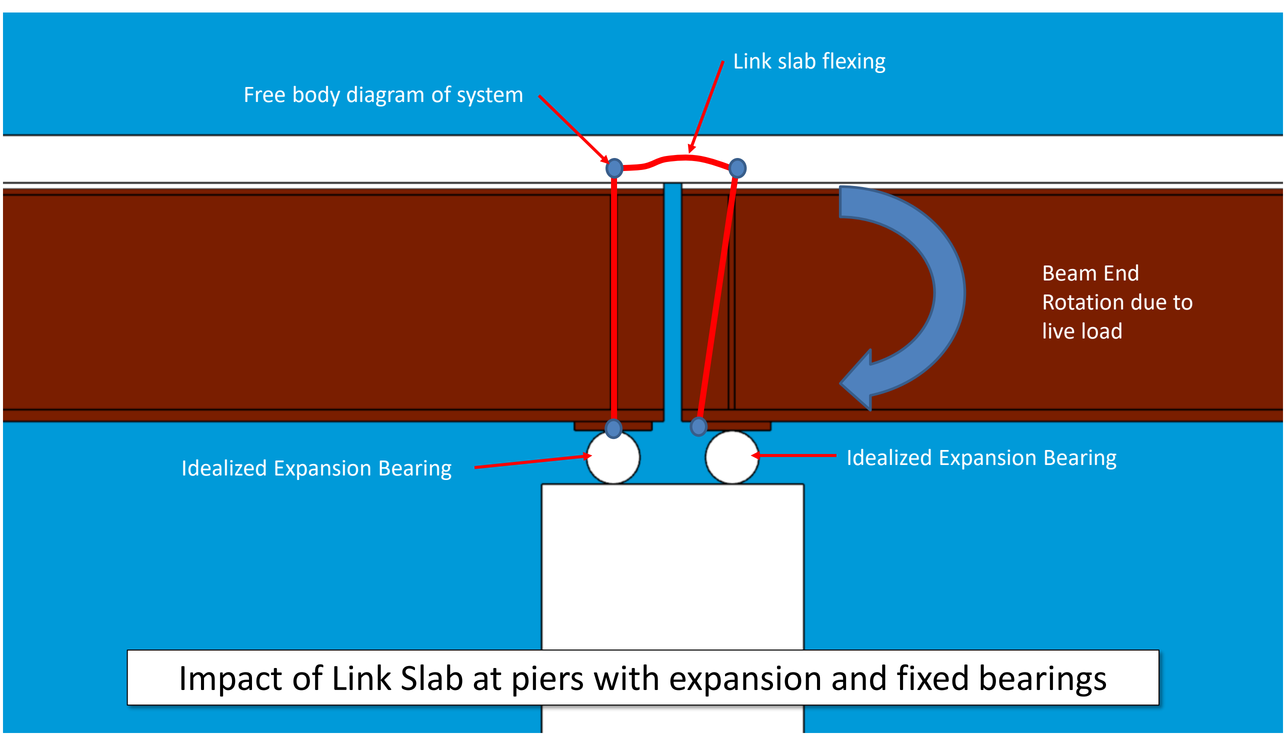

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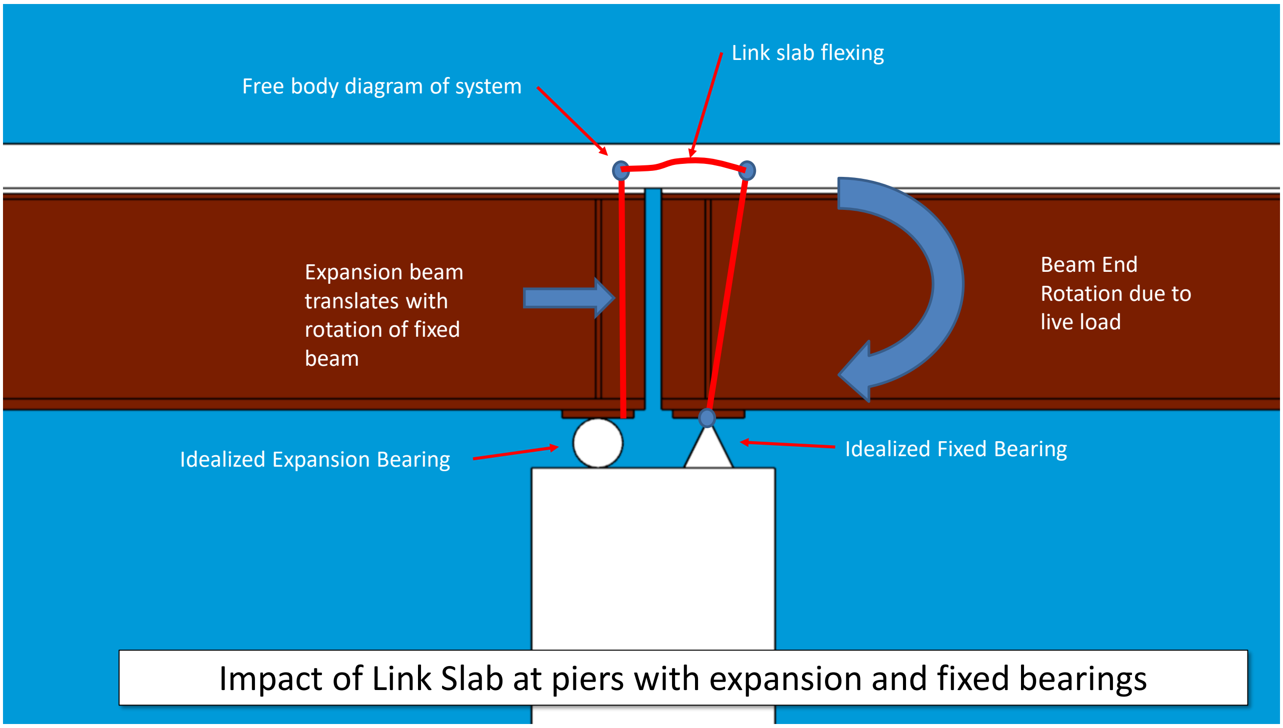

Impact of Link Slab at piers with expansion and fixed bearings

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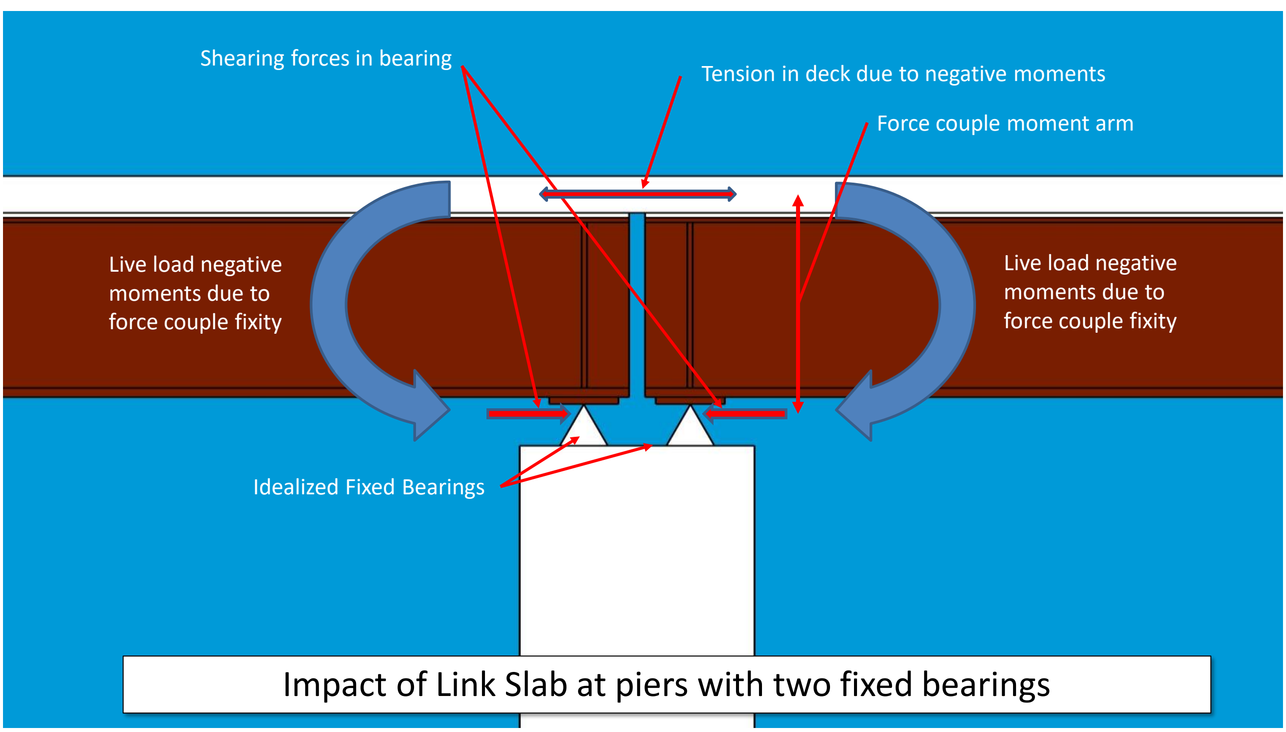

Impact of Link Slab at piers with two fixed bearings

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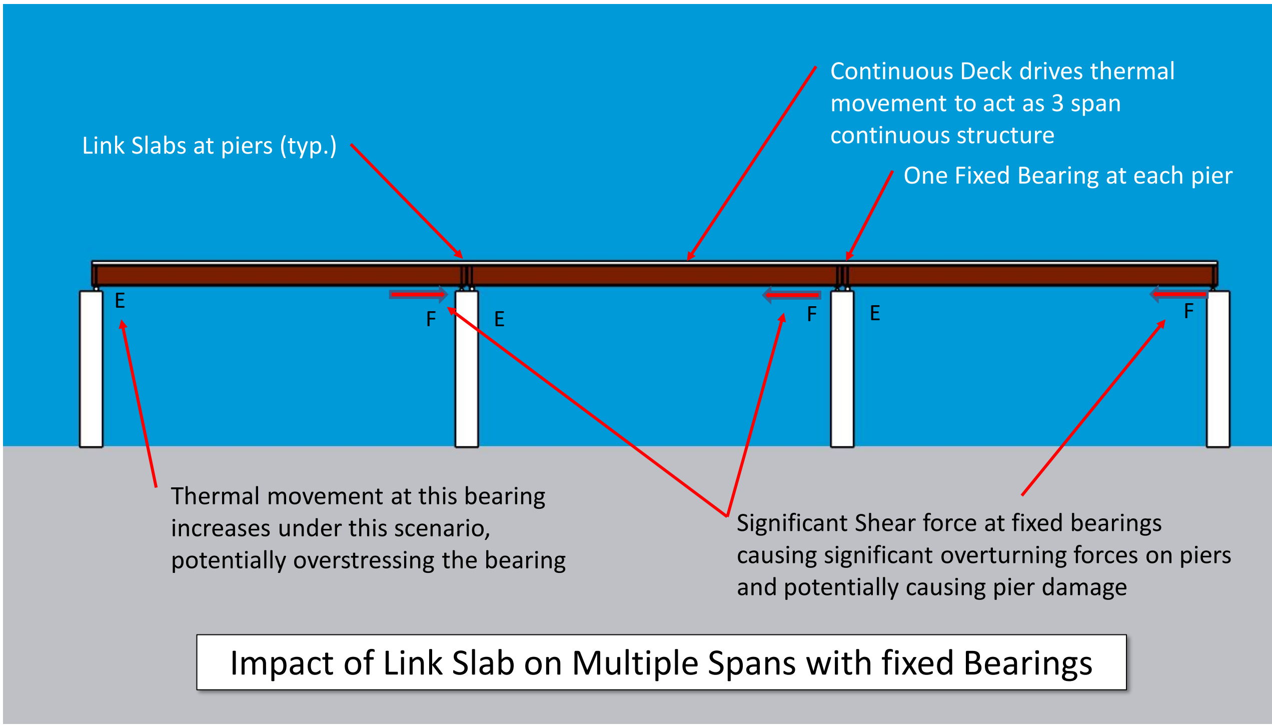

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Link Slab Durability

- MassDOT 93Fast14
  - Over 175,000 ADT
  - In service since 2011
  - No issues

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Span-by-Span Efficiency

- Modern Steel Construction Article
  - September 2014
  - Cost comparison - Advantages

Item	Continuous Spans	Span-by-span
Structural Steel	Less steel required ✓	
Bearings	Fewer Bearings at pier ✓	
Bolted Splices		None required ✓
Construction Speed		Much faster ✓
Deck Reinforcing		Less long. Rebar ✓
Erection		Much easier ✓

  - Result: Similar costs


Piece BY Piece

Span-by-span bridge construction, using modular steel bridge elements, can serve as a viable and economical bridge-building alternative.

Summary – Why Consider Steel for ABC?

Modular Deck Beams
- Less weight for cranes and transport
- Can accommodate any geometric configuration

Simplified and Durable Construction
- Span-by-span construction with link slabs – no deck joints

Efficiency
- Span-by-span construction can be competitive with continuous girder design when total costs are included


Questions?