Phase 1: Development of County Bridge Standards for Single Span Concrete Slab Bridges

Tech Transfer Summary

Project Objective

The objective of this project was to investigate the current practices, needs, benefits, economy, constructability, and design criteria for new county bridge standard plans incorporating cast-in-place (CIP) single span concrete slab (SSCS) bridges. This investigation will facilitate a future project including final design and developing standard plans.

Figure 1. An example of a single span concrete slab bridge.

Problem Statement

Concrete slab bridges are typically used for single span (20-50 feet) or multiple span small stream crossings. They are generally regarded as a cost-effective option over bridges with beams for short spans. As a result, they are used widely in the United States. Nearly 10.5% of all highway bridges are classified as concrete slab bridges according to the U.S. 2020 National Bridge Inventory (NBI). Currently, county bridge standard plans maintained by the Iowa Department of Transportation (Iowa DOT) do not have an option for single span concrete slab bridges. Single span concrete slab bridges may be a preferred option over other standardized short span structures including box culverts and box beam bridges due to improved hydraulic performance, less required right-of-way, and reduced streambed disturbance. Recent regulatory changes may drive a shift from culverts to bridges for small streams. Due to the number of short span bridges on secondary roads throughout the state in need of replacement and the limited resources for design, there is a need for additional bridge standards that can be easily and economically employed by Iowa counties and cities.

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Research Project Title
Phase 1: Development of County Bridge Standards for Single Span Concrete Slab Bridges

Sponsors
Iowa Highway Research Board (IHRB Project TR-812)
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Project Summary

Research and analysis conducted for this project included the following:

- An investigation of current Iowa DOT practices including a review of example plans of current SSCS bridges and an inventory of structure types, lengths, skews, and year of construction for all short span bridges (less than 70 feet) in Iowa.
- An investigation of other state DOT practices for the design of short span bridges including a review of available design manuals and standard bridge plans.
- A survey of Iowa county engineers requesting input on preferred SSCS bridge features (e.g., abutment types, railing types, skew, etc.) and opinions on the benefits and drawbacks of SSCS bridges.
- A preliminary analysis and design of SSCS bridges to determine viable span lengths, slab thickness, and slab reinforcement for various spans and roadway widths.
- A review of the effects of bridge skew on the design of longitudinal and transverse slab reinforcement including slab thickness of SSCS bridges.
- A cost analysis to compare SSCS bridge costs with other short span structure types used in Iowa.
- A summary of design criteria for SSCS bridges and steps to implement research for the development of standard bridge plans.

Key Findings

Review of Current Practices

Key findings from the review of current SSCS design practices include:

- Many Iowa bridge structures between the lengths of 20' and 70' are concrete culverts and steel stringer bridges as shown in Figure 2. Only 5.1% of the total number of structures are concrete slab bridges. This may indicate that a lack of standard design policies and plans are inhibiting greater use in Iowa.
- Iowa routinely builds and maintains standard plans for three-span continuous concrete slab (CCS) bridges in lengths of 70' to 150' and skews of 0 to 45 degrees. The design of short span SSCS bridges (less than 70' spans) is performed on a case-by-case basis by licensed engineers following the policies in the Iowa DOT *Bridge Design Manual*.
- SSCS bridges are widely used in other states and are generally included in standard plans. For example, Wisconsin, Texas, Ohio, and Kentucky maintain standard plans for SSCS bridges. They generally have span lengths between 20-40 feet and skews between 0-30 degrees.
- The Illinois DOT designs SSCS bridges following AASHTO's simplified method except for the design of transverse distribution reinforcement. They determined transverse steel depends on bridge length and skew and increases with increasing skew. This policy was introduced in 2015 in response to instances of atypical cracking in several slab bridges.
- A strong majority (70%) of respondents from the county engineers survey favored the development of new Iowa DOT county bridge standards for SSCS bridges. Preferred abutment types, railing types, and skews are shown in Figure 3.

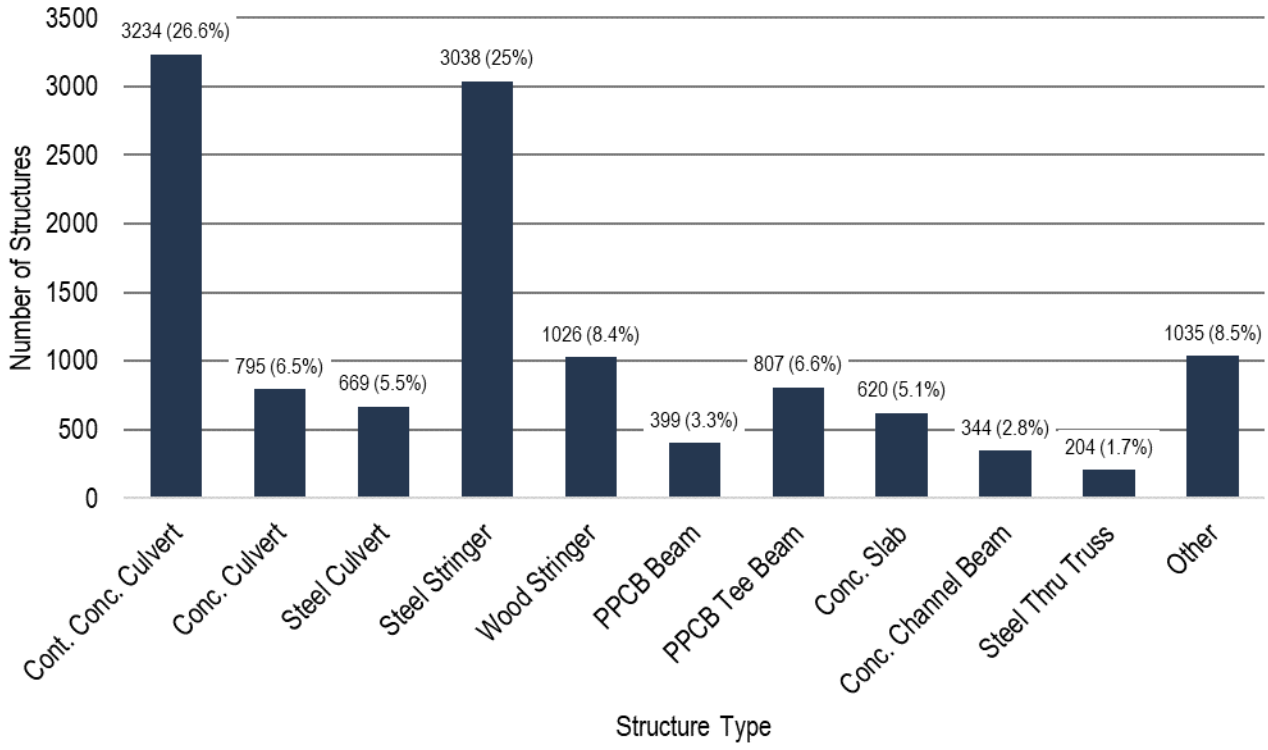

Figure 2. Number of Structures In Iowa with Lengths 20'-70'

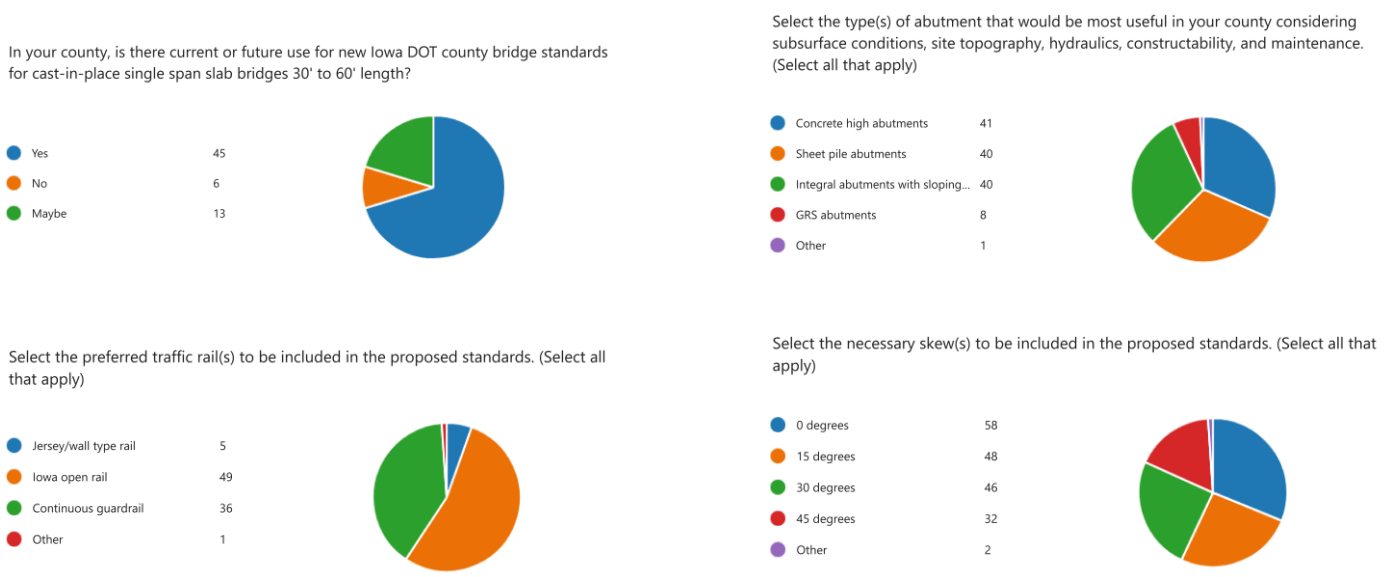

Figure 3. Sample of Responses to the County Engineer Survey

Preliminary Design

The following conclusions can be drawn from the preliminary analysis and slab design. Recommended bridge design parameters are shown for use in further development of the standard plans.

- Based on preliminary analysis, spans ranging from 20’ to 50’ were found to be viable (see Table 1 for recommended design parameters).
- Analyses using minimum slab depth exceed AASHTO’s maximum live load deflection limit which may be attributed to the design assumptions used including simple supports (free to rotate) at the abutments and ignoring the stiffness of the barrier rails.
- In addition to the typical Iowa DOT open and parapet bridge rails, a continuous guardrail attached to the edge of slab should be considered for inclusion in the standards.
- AASHTO’s simplified design procedures for skewed SSCS bridges is conservative for longitudinal steel but is unconservative for transverse (distribution) steel and shear in the slab. Using two-dimensional analysis for the design of transverse steel and shear would improve the design for skewed bridges and may result in more efficient design.
- Analysis and design of the bridge abutments was not part of the scope of the project, but based on results of the county engineer survey, integral and high abutments are recommended for inclusion in the standards.

Roadway Width	Bridge Length	Slab Thickness	Needs Deflection Check?	Skews	Rail Type	Abutment Type
24’	50’	24”	Yes	0° 15° 30° 45°	• MASH TL-4 Open Concrete Bridge Rail • MASH TL-4 Single Slope Barrier • MASH TL-3 Top (B-262) or Side-Mounted Guardrail (B-264)	• Integral • High Abut. w/ Sheet Pile Backwall
	40’	20”	Yes			
	30’	18”	Yes			
	20’	14”	Yes			
30’	50’	24”	Yes			
	40’	20”	Yes			
	30’	18”	Yes			
	20’	14”	Yes			

Table 1. Recommended SSCS Bridge Design Criteria

Cost Analysis

Based on a cost analysis, SSCS bridges are about the same cost as box culverts with 4' tall sidewalls and steel stringer bridges but less expensive than box culverts with 12' tall sidewalls and precast box beam bridges (see Figure 4).

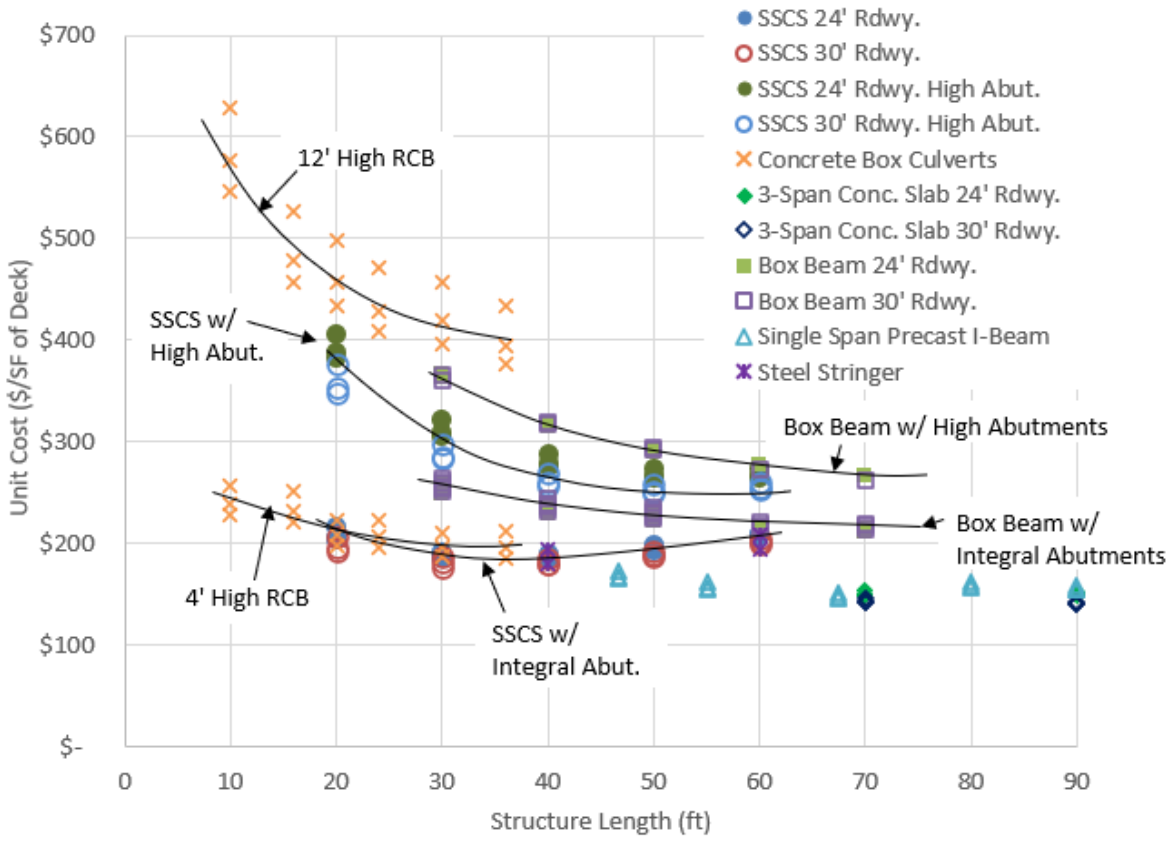

Figure 4. Cost Estimates for Various Structure Types and Span Lengths

Recommendations and Implementation

It is recommended to proceed with final design and development of the SSCS standard bridge plans (Phase 2). Based on the findings of this project, there is a demand for more standard county bridge options for spans between 20 and 50 feet. It was found that SSCS bridges are a cost-effective option within this range. The Iowa DOT Bridges and Structures Bureau (BSB) will maintain oversight and updates for the SSCS standard plans. The standards should be published to the BSB website to make them available to county engineers.

Based on the findings, future work is recommended for the following areas:

- Incorporating the stiffness of the barrier rails and bridge supports in the final design. This will help to accurately calculate the live load deflections and verify minimums are being met.
- AASHTO simplified design methods are conservative for primary longitudinal reinforcement for skewed bridges but can be significantly unconservative for transverse distribution reinforcement and shear. A two-dimensional analysis and calibrated distribution factors, similar to the Illinois DOT method, is recommended to improve the design for distribution reinforcement and verify adequate shear strength in the slab.
- Further review by Iowa DOT may determine if other widths for use on the primary highways should be included in development of the standards.