Evaluation of a Folded Plate Girder Bridge System

tech transfer summary

The evaluation of an innovative folded plate girder bridge system found it to be an effective alternative for the construction of short-span bridges.

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RESEARCH PROJECT TITLE

Buchanan County IBRD Bridge Project: Evaluation of a Folded Plate Girder Bridge System

SPONSORS

Iowa Department of Transportation (InTrans Project 13-458)
Federal Highway Administration Innovative Bridge Research and Deployment (IBRD) Program

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MORE INFORMATION

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Research Objective

The objective of this research was to validate the adequacy of a folded plate girder system for short-span bridge construction. To help achieve this goal, a bridge was designed and constructed using folded plate tub girders on the secondary road system in Buchanan County, Iowa.

Background

Bridge owners and engineers focusing on bridge design, management, and maintenance continue to search for more efficient ways to design, construct, and maintain their bridge inventory. In the past, steel bridges, which are one of the most common types, have been comprised of superstructures consisting of either rolled steel beams or welded steel girders. Recently, a relatively new concept has been promoted as a cost-effective alternative.

This concept consists of what is known as a folded plate girder. The fabrication of a composite folded plate girder module starts with a single steel plate of the desired thickness that is strategically bent into a structural shape. The plate is then cold formed into a U shape with a press brake, with each bend occurring along the plate's longitudinal axis.

After the bending process is complete, diaphragms are welded at the locations specified by the engineer, and shear studs are also welded along both sides of the girder's top flanges. The steel portions of the girders are either shipped to the field or to a precast plant to have a concrete deck cast on them. These folded plate girders offer the potential to be cost-effective due to the relatively low cost of plate steel.

The Amish Sawmill Bridge is a single-span folded plate tub girder bridge with a span length of 52 ft and a roadway width of 30 ft

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The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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Innovative Bridge System Description

With the assistance of the Iowa Department of Transportation (DOT) and the Institute for Transportation (InTrans) at Iowa State University, Buchanan County, Iowa was awarded a grant to construct and evaluate an innovative short-span bridge (i.e., the Amish Sawmill Bridge). This bridge utilizes a folded plate girder superstructure supported on geosynthetic-reinforced soil (GRS) abutments.

Two bid alternatives were deemed feasible to construct the bridge. One alternative was to use precast deck modules connected using ultra-high performance concrete (UHPC) closure pours, and the other was to use a cast-in-place (CIP) concrete deck. The CIP deck alternative was selected.

A GRS-integrated bridge system (GRS-IBS) was utilized due to the merits of this innovative technology, including reduction of bridge construction time and cost, as well as elimination of settlement issues associated with the joint between the approach slab and the bridge deck, which can create bumps in the approach.

The reinforced soil foundation includes alternating layers of compacted granular soil and geosynthetic fabric and provides support to the abutment. The integrated approach eliminates the need for joints, creates a smooth transition between the bridge end and the approach roadway, and alleviates the bump at the bridge end due to differential settlement.

The wing walls are monolithically constructed along with the deck and is integrated with the integral abutment by the steel bars. The girder ends are embedded into the end abutment supports, which have direct interaction with the foundation and provide significant end restraint to the girders.

Research Methodology

To evaluate the structural behavior of the folded plate girder, the researchers conducted three laboratory tests on a folded plate girder specimen similar to the girders that were used on the completed bridge in Buchanan County.

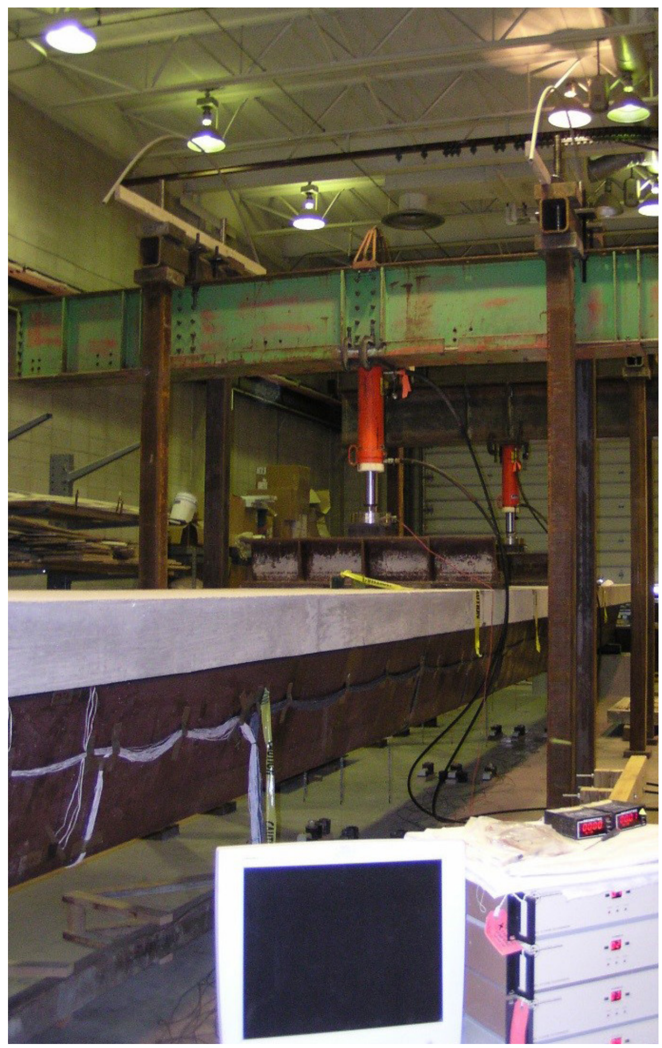
For the first test (Test A – Constructability), the research team tested a single folded plate girder under two-point bending to assess the behavior of the folded plate girder during construction prior to acting compositely with the deck. The girder was tested up to a moment that was equal to a moment that would be created by two times the girder's own self-weight.

For the second test (Test B – Flexure), a concrete deck was cast on the folded plate girder that was used to perform Test A. The researchers then tested the specimen under two-point bending to determine the composite flexural behavior of the folded plate girder system in the elastic region.

For the last test (Test C – Shear), the researchers tested the same folded plate girder with the CIP composite deck from Test B by loading the girder with two line loads located close to one of the supports. This test was completed to study the shear behavior of the folded plate girder system and its ultimate capacity.

To evaluate the behavior of the bridge and its components in Buchanan County, the researchers conducted live load field tests immediately after completion of the bridge (Test I) and about one year after bridge construction (Test II).

Strains were measured on the four folded plate girders during fielding testing. Full bridge models were established to interpret the test results and further study the behavior of the bridge under the tested loading conditions.



The girder specimen used for laboratory testing had the same material and geometric details as the girders used for the bridge constructed and field tested in Buchanan County

Key Findings

Laboratory testing results were as follows:

- For Test A, no noticeable, unwanted deformations or strain levels were found, and the strains and displacements were well predicted by the design calculations.
- For Test B, at the loads comparable to the design truck (HS-20) and the design truck (HS-20) plus lane load, no noticeable, unwanted deformations or strain levels were found, and strains and displacements were similar to the predictions from the design calculations.
- For Test C, the bent plate girder performed similarly to that of Test B in respect to predictions. In terms of the shear data, all the shear strain data were much lower than predicted for the yield load. Due to the boundary conditions (the load points were relatively farther away from the support), the beam ultimately failed in flexure with the deck concrete crushing, which was consistent with the results using hand calculations.

Conclusions

The researchers drew the following conclusions based on the field measured data and the predictions using the finite element (FE) models:

- Due to the shear lag effects, the strains near the bottom corners of the bottom flanges are larger; due to biaxial bending effects, strains in the bottom flanges vary from one side to the other.
- The GRS-IBS and abutments provide significant restraint to the girder ends. And, the end supports have restraint characteristics of an intermediate support condition, between the pinned and fixed support conditions.
- The strong-axis bending moment is the major contributor to the stress/strain in the girders. The weak-axis bending moment, which is small in the bridge but large in individual girders, causes a linear change in strains in the bottom flanges. Torsion exists in the full bridge cross-section and individual girders.
- Due to the biaxial bending moments in the folded plate girders, it is feasible to use the strain in the center of the girder bottom flanges to calculate live load distribution factors (LDFs).
- American Association of State Highway and Transportation Officials (AASHTO) equations were reasonably accurate at estimating the LDFs for interior and exterior girders of the folded plate girder bridge.

Implementation Readiness and Benefits

Test B – Flexural Capacity was useful in better understanding how the composite girder behaves up to the lower bounds of design limits, and Test C – Shear Capacity was valuable in understanding how it behaves up to the upper bounds of design limits.

In summary, based on the laboratory and field test results and FE simulation results, the researchers concluded that the folded plate girder is an effective alternative for construction of short-span bridges that are designed based on the AASHTO LRFD specifications for bridges.

Given this girder has two webs with large associated shear capacity, the shear strength of the folded plate girder when placed is not a point of concern for design considerations.