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Performance Evaluation of Isotropic Bridge Decks

A Comparative Study of AASHTO and Isotropic Bridge Deck Designs

"MDOT is a dynamic and changing organization preparing to meet the challenges of the next decade with a leaner, downsized staff. The Materials and Technology Division (a.k.a. Testing and Research) is no more. We have joined with the former Construction Division to form the Construction and Technology Division. The recent early retirement program and other internal mandates fostered this combination. The department's new regional structure is taking shape and the research staff looks forward to our function as a technical service organization. We will continue our leadership role as we improve our ability to investigate problems, offer solutions, and conduct or manage research for the Michigan Department of Transportation."

-- Jon Reincke
MDOT Engineer of Research

Bridge engineers in Michigan often find themselves in an interesting dilemma—how to decrease costs while maintaining a high level of quality and safety for the public. The ever-increasing number of vehicles traveling on Michigan bridges and the harsh environmental conditions present throughout the state only add to the problem.

In a continuing effort to provide a solution, engineers in the Construction and Technology Division (C&T) of the Michigan Department of Transportation (MDOT) are studying alternative bridge deck designs. C&T engineers are six years into a study which could eventually save Michigan motorists a considerable amount of tax dollars. The study compares the performance of isotropic bridge decks with decks designed using the American Association of State Highway and Transportation Officials (AASHTO) *Standard Specifications for Highway Bridges*.

Isotropic vs. AASHTO

There are a number of factors that differentiate isotropic bridge decks from those of conventional AASHTO design. In a AASHTO design bridge deck, the amount of steel reinforcement per square meter increases as the beam spacing increases. Furthermore, a typical AASHTO bridge deck design typically calls for different sizes of rebar in the top and bottom of the slab, spaced at varying intervals (refer to Table 1 for rebar sizes and intervals for each bridge in the MDOT study). The variance of rebar size and spacing is dependent on whether the rebar is used as transverse or longitudinal reinforcement, and on the beam spacing.

Isotropic bridge decks contain steel reinforcement bars that are equally spaced on both axes in both the top and bottom of the slab. In addition, the rebar is generally of smaller diameter and is spaced farther apart than that of conventional AASHTO deck. Due to this fact, isotropic decks use roughly 40% less steel than those of AASHTO design, which accounts for a considerable cost savings. Adding to the savings is the fact that, "Construction crews prefer the isotropic deck over the conventional AASHTO deck because they are quicker to construct," stated Doug Needham, transportation engineer in the Structural Research Unit of MDOT, " due to the fact that they use consistently sized and spaced rebar."

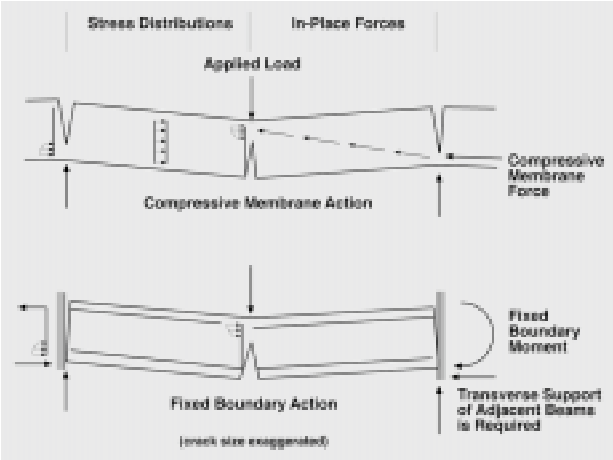

Figure 1: Arching action in bridge deck slabs.

Background

Bridge decks have traditionally been designed based on the AASHTO Bridge Code. This code requires that bridge decks be designed so that flexure is the primary mode of failure. Flexure refers to the bending, or flexing, of the bridge deck. The Ontario Ministry of Transportation and Communications (MTC) challenged this traditional design with the introduction of a isotropic bridge decks in Ontario, Canada starting in 1975. The MTC constructed a test bridge in 1975 which included decks that contained steel reinforcement varying from 20 to 100% of the amount normally used. After more than 10 years of service, even the decks with the most severe reduction in steel reinforcement were performing satisfactorily (*TR News* 18).

The promising performance of the test bridge, combined with the results from studies conducted by the Ontario MTC and Queen's University in Ontario, were included in the first edition of the Ontario Highway Bridge Design Code (OHBDC), which was published in 1979. The results of the studies indicate that punching shear is the primary mode of failure for concrete slabs. Furthermore, the results suggested that bridge decks could be designed with reduced amounts of steel reinforcement (*TR News* 18). The researchers believe that once the bridge deck cracks, compressive membrane forces create arching action (refer to Figure 1). The studies also demonstrated that in order for the arching action to develop, the bridge deck needs proper lateral support supplied by transverse bottom reinforcement. This transverse bottom reinforcement can be supplied internally through any proven means, such as rebar or fiber reinforcement, or externally (*Journal of the Institution of Engineers (India)* 124).

Since the OHBDC design became the standard bridge deck in Ontario, the province has saved roughly $1 million (Canadian) in steel reinforcement costs yearly (*TR News* 19).

Spurred by the success of the design in Canada, other states, including New York and Florida, have been experimenting with the isotropic design. Both states are reporting satisfactory performance results, with the isotropic decks performing comparably with AASHTO decks. Florida is still experimenting with the design, and New York has included the isotropic design in their standards.

The State of New York has utilized the isotropic design on 41 bridge decks, and, according to 1993 figures, "projected savings in New York with (the) implementation of isotropic decks is $1.3 million/year" stated Sreenivas Alampalli, head of Structures Research, Transportation R&D Bureau, New York State Department of Transportation.

MDOT's Study

MDOT is currently monitoring two bridges, each with sections constructed of both conventional AASHTO design and isotropic design decks. The first bridge is the Franklin Street bridge over U.S. 131 in Grand Rapids, Michigan. The second bridge is U.S. 127 over the Grand River, located south of Jackson, Michigan.

Franklin Street over U.S. 131

The Franklin Street bridge has been in service since the spring of 1991. According to 1995 average daily traffic (ADT) volume statistics, 7,400 vehicles travel over the bridge daily, with 19% commercial traffic. The bridge had two spans (13 and 14) that were replaced with simply supported isotropic decks and two spans (8 and 9) that were replaced with simply supported AASHTO decks. The isotropic decks have a span length of 9.8 m. The AASHTO decks have span lengths of 14.4 m for span 8 and 10.5 m for span 9. All of the decks have an out to out width of 17.8 m and a deck slab thickness of 230 mm.

The bridge was monitored monthly for the first three months, then quarterly for two years, and annually since that time. The initial observation of the bridge was extensive to observe the cracking resulting from shrinkage and live loads.

In the summer of 1996, a crack map survey of both the AASHTO and isotropic designed decks was performed. The results of the crack survey indicate that the isotropic and AASHTO decks contain similar crack densities, with the AASHTO deck having a slightly higher density. The higher crack density present in the AASHTO deck could be due to variances in construction.

After more than six years of service, the Franklin Street isotropic deck is showing great potential. When compared to the AASHTO deck, the isotropic deck is performing satisfactorily, and the study has found nothing that would indicate that the isotropic deck will not continue to perform similarly.

On the Franklin Street bridge, the isotropic deck used roughly 50% less reinforcing steel than the AASHTO deck. Designing the entire bridge deck as isotropic would save roughly $186,000 in steel costs over the AASHTO design.

U.S. 127 over the Grand River

The U.S. 127 bridge over the Grand River consists of northbound and southbound structures and has been in full service for approximately one year. According to 1994 ADT statistics, 23,000 vehicles travel over the structure daily, with 9% commercial traffic. The northbound structure is constructed using AASHTO designed decks and the southbound structure is constructed with isotropic designed decks. Both structures have three simply supported spans of 11.14 m, 13.7 m, and 11.13 m. The total length of the spans is 35.98 m. All of the decks have an out to out deck surface width of 13.84 m and a deck slab thickness of 230 mm.

Due to the fact that the bridge has been in service for a relatively short time, both the isotropic and AASHTO decks exhibited very few cracks and were virtually crack free during the initial crack map survey. The few cracks that were present in both deck types were of similar size and number.

Although it is too early to estimate the long term performance of the isotropic decks on the southbound structure, to date the decks are performing satisfactorily when compared to the AASHTO decks. As with the Franklin Street bridge, the U.S. 127 bridge will be

Franklin Street over US-131					
AASHTO			Isotropic		
Transverse	Top	#19 rebar spaced at 191 mm	Transverse	Top	#13 rebar spaced at 229 mm
	Bottom	#19 rebar spaced at 191 mm		Bottom	#13 rebar spaced at 229 mm
Longitudinal	top	#10 rebar spaced at 267 mm	Longitudinal	top	#13 rebar spaced at 229 mm
	Bottom	#16 rebar spaced at 216 mm		Bottom	#13 rebar spaced at 229 mm
US-127 over Grand River					
AASHTO			Isotropic		
Transverse	Top	#16 rebar spaced at 216 mm	Transverse	Top	#13 rebar spaced at 305 mm
	Bottom	#16 rebar spaced at 216 mm		Bottom	#13 rebar spaced at 203 mm
Longitudinal	top	#10 rebar spaced at 238 mm	Longitudinal	top	#13 rebar spaced at 305 mm
	Bottom	#16 rebar spaced at 305 mm		Bottom	#13 rebar spaced at 203 mm

Table 1: Comparison of rebar size and spacing for two monitored bridges with conventional AASHTO and Isotropic designed bridge decks.

Bridge Number	Type of Beams	Beam Spacing	Approximate Angle of Crossing	Estimated Construction Plan Completion Date
S01 of 83033	1,524 mm Plate Girder	2,667 mm	43°	7/98
R01 of 83033	1,778 mm PCI Girder	2,591 mm	102°	7/98
S06 of 83033	1800 PCI Girder	1,829 mm	78°	7/98
S03 of 83033	1,676 mm Plate Girder	2,616 mm	76°	7/98

Table 2: Future bridge projects selected to receive isotropic designed decks in conjunction with AASHTO designed decks.

monitored over the course of the next five years to help determine the feasibility of the use of isotropic bridge decks in other locations throughout the state.

Questions Yet To Be Answered

In an effort to help develop MDOT policy regarding the design and use of isotropic bridge decks, four additional bridges have been selected to receive isotropic decks in conjunction with AASHTO decks in the near future (see Table 2). As with the two bridges that are currently in service, these decks will be closely monitored over the course of the next few years. There are still criteria that need to be developed for isotropic bridge deck design, analysis, and use including the following:

1. The maximum beam spacing that can be used with an isotropic deck
2. How an isotropic deck responds to an acute angle of crossing that is less than 65° or more than 115°
3. How an isotropic deck responds to a bituminous overlay placed over a waterproofing membrane
4. Isotropic deck performance differences if placed on steel beam compared with concrete beams
5. How an isotopic bridge deck is load rated.

Although the study is not yet completed and a number of criteria still need to be determined, it is evident that isotropic bridge decks show enormous potential. Isotropic decks, with their promising performance and significant cost savings when compared to AASHTO designed decks, could prove to be the solution that bridge engineers have been looking for.

For additional information regarding the design, analysis, and use of isotropic bridge decks, contact Doug Needham at (517) 322-1979. Additional information can also be obtained by contacting LTAP at (906) 487-2102.

Reference Material

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