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DEPARTMENTAL INFORMATION EXCHANGE

BRACING OF STEEL BEAMS IN BRIDGES

PROBLEM STATEMENT

Periodically, the Texas Department of Transportation (TxDOT) must rate the capacity and condition of the state's approximately 1,000 rural, short-span steel bridges. These off-system bridges typically consist of a timber or concrete deck supported by horizontal steel beams called stringers, which sit atop concrete abutments (see Figure 1). Because of the heavy loads these short bridges must carry over the years, the stringers are susceptible to a kind of failure referred to as lateral-torsional buckling—a condition in which the steel beams supporting the deck move laterally and twist.

Present TxDOT formulas used to rate the capacity of these off-system bridges suggest that, if the stringers are unbraced laterally, then they are theoretically incapable of supporting even the lightest vehicles. But the fact that these unbraced bridges do carry substantial loads (with no evidence of strain) indicates that current formulas grossly underrate the carrying capacities of these short-span bridges. More interestingly, this phenomenon has led engineers to believe that the steel beams used to support these bridge decks are in fact partially braced by the very loads they carry. Specifically, the deck, having no positive attachment to the stringers, provides lateral buckling strength by restraining both lateral and torsional (twisting) movement at the wheel location.

Such an assumption, because it runs contrary to theory, provokes a number of questions regarding the actual lateral bracing effect of bridge decks. What are the requirements for lateral bracing? To what extent do bridge decks provide this bracing? And is a wheel-load location a brace point? These questions, along with many others, have prompted a reevaluation of the bracing formulas used in the Texas Bridge Rating Manual—formulas based on the 1983 bridge specifications of the American Association of State Highway and Transportation Officials (AASHTO). Because the AASHTO specifications were revised in 1990, there is now a need to revise those specifications used by TxDOT in rating off-system bridge capacities. This was the issue addressed in a recent Center for Transportation Research report prepared by Joseph Yura, Brett Phillips, Swarna Raju, and Stuart Webb, all of The University of Texas at Austin.

CTR
in cooperation with
Texas Department of Transportation
and the FHWA

Summary Report

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OBJECTIVES

The report, "Bracing of Steel Beams in Bridges," documents the findings of Project 1239, conducted by the Center for Transportation Research (CTR) of The University of Texas at Austin for the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). Specifically, the project set out (1) to determine the amount of bracing required for increasing the lateral buckling capacity of beams, and (2) to determine the bracing contribution of typical bridge decks. Also under investigation was the concept of the truck wheel location as a brace point.

RLA

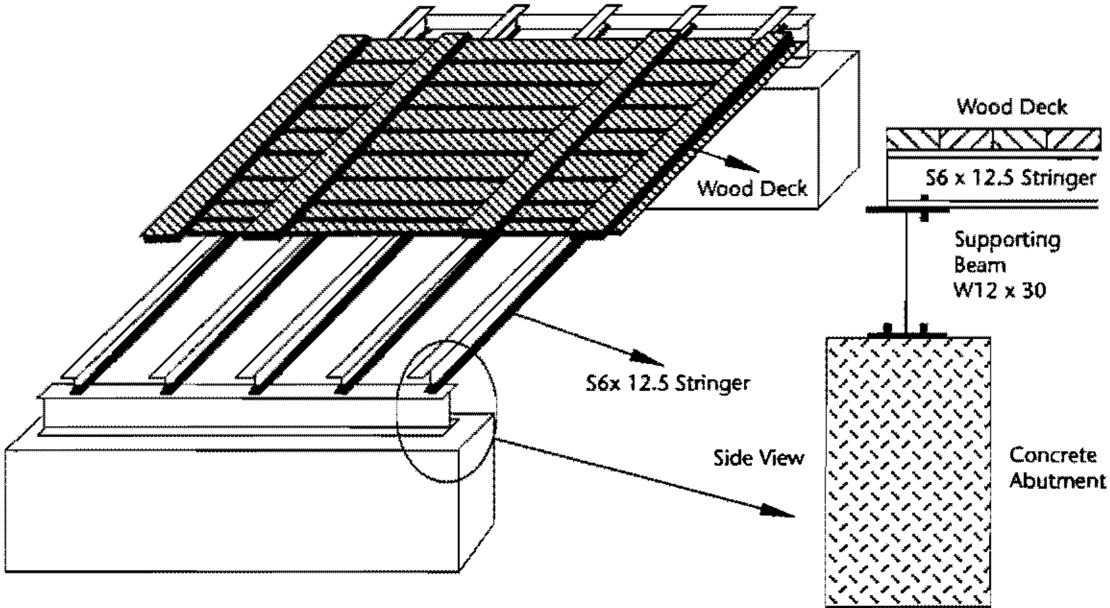

Figure 1. Typical plan of a short-span steel bridge with wooden deck.

FINDINGS

The study group approached these objectives through theoretical studies, beam experiments, and through full-size bridge tests. In the first phase, the researchers conducted theoretical studies on beams having various bracing arrangements; specifically studied were the effects of brace type, size, location, and number on the lateral buckling of beams subject to different loading conditions. These various configurations were analyzed using the Buckling Analysis of Stiffened Plates (BASP) program, a finite-element computer program developed at The University of Texas at Austin by Akay and Johnson in 1977. The results of these analyses then formed the basis for the design formulas recommended by the study.

In the second phase, an experimental program consisting of 76 laboratory tests was conducted in University of Texas structural engineering laboratories using twin 24-ft long W12x14 steel beams. These tests, which applied a load to the two simply supported beams until buckling occurred, were designed to evaluate the effects of lateral and torsional brace stiffness, brace location, and stiffener size. Additionally, the experimental tests were an attempt to validate the results achieved in the theoretical phase using the BASP program.

In the third and final stage of the study program, the researchers designed, constructed, and tested (again, in the University of Texas structural engineering lab) a full scale, 24-foot span multi-girder, wooden-decked bridge (somewhat similar in construction to that illustrated in Figure 1). A steel cart containing concrete blocks was used to load the bridge. To test bridge capacity, increasingly heavy loads were applied until failure occurred.

CONCLUSIONS

The theoretical and experimental studies revealed that the bracing equations developed in this study could be used to predict the buckling strength of beams that are braced (either through design or through the bracing effects of the deck). In the experiments conducted on the lab-assembled bridge, the researchers found that the timber decks not positively attached to the steel stringers are capable of providing lateral bracing at the wheel load location (through friction). In particular, the timber decks in use demonstrated sufficient lateral bracing stiffness to allow the stringers to reach yielding points without buckling (though a stiffness check on the deck is recommended). With respect to concrete decks, these bridges can be considered laterally supported at the wheel load location near midspan.

The study also verified the new lateral buckling equation provided in the 1990 AASHTO Bridge Specification. And because the current TxDOT bridge rating system is based on an older (1983) AASHTO Bridge Specification (one that gives conservative capacity ratings for unbraced bridge lengths), the state specification should be updated to reflect AASHTO modifications.

Finally, while the study focused primarily on short-span steel bridges, the researchers are confident that the bracing principles and design recommendations yielded by this investigation are applicable to steel beams in general. Also of value are the simple design formulations for stability bracing of steel beams, which are suitable for the AASHTO Bridge Specification.

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The information provided in this summary is reported in detail in Research Report 1239-4F, "Bracing of Steel Beams in Bridges," by Joseph Yura, Brett Phillips, Swarna Raju, and Stuart Webb (October 1992). The contents of the summary report do not necessarily reflect the official views of the FHWA or TxDOT.