RESEARCH PAYS OFF

Supporting Construction Loads on Steel Bridges

Kansas Team Develops Tool for Design and Analysis

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Steel is commonly used for bridge members in spans over traffic, particularly if restrictions apply to what are called false work bents—the temporary supports for construction—or if the length of the span exceeds the reach of conventional prestressed concrete members. Steel is more flexible and less massive than its concrete counterpart and offers the advantage of a high strength-to-weight ratio.

Contractors may decide to deploy overhang brackets, which are temporary supports placed outside the bridge's exterior girder, for the concrete forms on a bridge deck (Figure 1). Overhang brackets can speed construction without reducing the clearance under the structure. For this reason, the Kansas Department of Transportation (DOT) almost always uses overhang brackets for placing cantilevered slabs on bridges.

Construction loads, however, can cause eccentric effects or twisting in the exterior girders that support the cantilevered portion of the slab. Although efficient for the contractor, the overhang bracket system is a challenge for the engineer, who must conduct an analysis to ensure that excessive stresses or deflections do not occur from construction loading. According to Kansas DOT specifications, a licensed professional engineer must design and stamp the form work and the false work drawings with a professional seal for the construction of any structure that either spans or carries traffic.

To assist in this task, Kansas DOT and the University of Kansas (KU) have created a design tool, Torsional Analysis for Exterior Girder (TAEG), to aid in evaluating and designing a contractor's false work system.

Problem

During the placement of a concrete deck on a steel bridge with I-shaped beams or girders, the loads from the construction equipment, combined with the overhang geometry, create eccentric forces or torsions. These forces cause stresses and deflections in the bridge girders and cross frames.

The eccentric effects can be difficult to control. Excessive deflections can cause the falsework system to fail, producing a rough-riding bridge deck. In designing the construction support scheme, the contractor's engineer must account for the torsional

FIGURE 1 Typical overhang support (*above*) and installation on bridge (*left*).

loading, as must the Kansas DOT bridge engineers who review the adequacy of the design.

Understanding the bridge and the falsework as a single system acting in three dimensions can be difficult. Torsional analysis of the bridge's I-shaped members will reveal warping stresses that are overlooked in the structural analysis performed by most software packages.

An inherent assumption in calculating stresses using elementary mechanics is that plane sections remain plane; in this case, they do not. As a consequence, determining the torsional response of the exterior girders to the loads on the deck overhang during the placement of the concrete—while also taking into account the construction support scheme—is a complicated task for the bridge engineer.

Solution

Kansas DOT, KU, and Kansas State University have established a cooperative research program, K-TRAN. Through K-TRAN, Kansas DOT and KU worked to address the torsion problem, creating TAEG to be an easy-to-use design tool, available at no charge to all state DOTs and their consultants and contractors. The Microsoft Windows–based, Visual Basic software program includes an extensive help file and a user's manual with working examples, as well as a report documenting the development, the sustaining theory, and the assumptions that led to the program.

First the project researchers measured the strain on full-sized steel bridges in the field to document the effects of the construction loads. Models were created from the strain data for finite element analyses, to develop an appropriate set of mathematical models. The parameters of these models were then varied to determine the effects.

The last step was to write, review, and test the TAEG program code. Refinements then were made, including the ability to add temporary support members to resist the imposed loads.

Application

Designers and engineers now are able to investigate the proposed structure of a new bridge during the design stage, determining if the permanent and temporary systems will work together under the construction loading conditions for the deck placement. Previously, the review had to wait until the contractor had submitted the plans for the falsework.

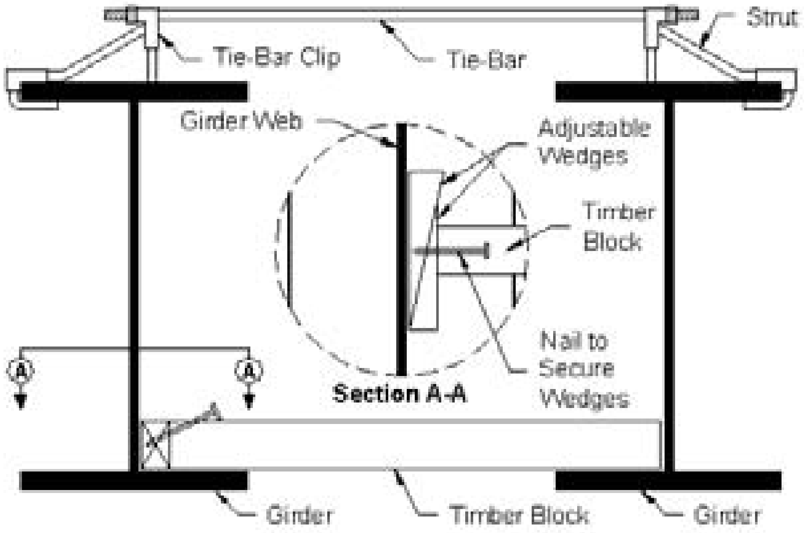

FIGURE 2 Temporary lateral support systems for rehabilitation work are design options in the software package.

For rehabilitation work, such as redecking, the designer can consider the applicability of temporary supports, such as tension tie rods and timber compression struts, to augment the system (Figure 2). In the past, permanent connection stiffeners and cross frames sometimes had to be added for temporary loads.

Because these calculations are complex, a computer design tool is useful and valuable to bridge engineers. TAEG specifically evaluates stresses and deflections of the girder flanges, forces in the brackets, forces in the diaphragms and cross frames, and the effect of tension tie rods and timber compression struts on temporary supports. The software enables the engineer to make adjustments to the bridge members as a system under many variations.

Benefits

The TAEG software has reduced the number of hours that engineers had to spend in analyzing the design of falsework. The accuracy of the calculations has produced bridge decks with increased levels of riding smoothness and has increased safety for contractors and for the public.

According to Kansas DOT estimates, the TAEG software has saved the agency approximately $570,000 over 3 years. More than 60 organizations—state DOTs, consulting firms, and contractors—have acquired the program and are using it for the torsional analysis of exterior girders. The software is available online.

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