Iowa Department of Transportation

Strengthening of Highway Bridges by Posttensioning

Problem

Many simple-span, steel beam, composite concrete slab bridges built between 1940 and 1960 are not in complete compliance with today's bridge standards; this problem not only exists in Iowa but also confronts numerous other states in the United States. In Iowa alone, approximately 400 bridges of this type require strengthening to meet current standards. More specifically, the live-load carrying capacity of the steel stringers of these bridges must be increased.

The need for additional strength is the result of increases in legal load limits, changes in AASHTO specifications that require exterior stringers to carry a greater load, and added weight from resurfacing with dense concrete overlays. The alternative to strengthening these bridges is to post them with load restrictions.

These bridges are on low-traffic secondary roadways as well as on relatively higher type primary roadways where a considerable amount of truck traffic is involved. Trucks with loads heavier than the posted limit are required to take alternate routes, and thus must travel additional miles. Strengthening the bridges in question instead of posting them could be extremely cost-effective.

Solution

A feasibility study was undertaken by the Engineering Research Institute of Iowa State University (ISU) with funding from the Highway Division of the Iowa Department of Transportation (DOT). Among various potential solutions to the problem, the procedure of posttensioning of the steel stringers appeared to exhibit the greatest promise. To determine the distribution characteristics of the posttensioning force in a multiple stringer bridge, a half-scale model bridge (26 ft × 15 ft 8-3/8 in.) was fabricated and tested. Steel tendons were tensioned through end anchors affixed to the lower portion of the web and bottom flange at each end of steel stringers. Posttensioning was applied to exterior stringers only. When the tendons were fully stressed and anchored, a compressive force was exerted in the tension area of the stringers, which reduced the live-load tension stresses in the stringers.

Based on the results of the feasibility study, a second project—also sponsored by the Highway Division of the Iowa DOT—was undertaken by ISU. In this phase, two existing bridges were strengthened by using the posttensioning scheme developed in the feasibility

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study. One of the bridges (Bridge 1: 52 ft × 30 ft) was twice the size of the prototype tested in the laboratory. The other bridge (Bridge 2: 72 ft × 30 ft, skewed 45 degrees) is shown in Figure 1; the insert in the lower right corner of this figure is a close-up of the posttensioning bracket used on this bridge. Both of the bridges were instrumented and tested. After a period of approximately 2 years, during which time the bridges were periodically inspected, they were retested. Their behavior was found to be essentially the same as that of the model bridge previously tested.

From the results of the testing plus a finite element analysis, a simplified design methodology was developed by ISU. The design procedure, along with design examples, was published by the Iowa DOT in a design manual, making the procedures readily accessible to practicing engineers.

Application and Benefits

The procedure has been used by several states in addition to Iowa. This past February, two bridges (50 ft × 30 ft) were strengthened by using the posttensioning system, at a cost of $13,400 per bridge. Assuming strengthening extends the service life of the bridge 20 years, thereby attaining the expected 50-year service life, a savings of 40 percent of the cost of replacing the bridge could be realized. At today's construction costs, the savings would be about $28,000 on a 50 ft × 30 ft bridge costing $70,000, with net savings totaling $14,600. Larger savings would be realized on longer spans, inasmuch as replacement costs of the larger bridges would increase considerably faster than strengthening costs. In addition to adding service life, strengthening by posttensioning also creates savings by avoiding costly detours when weight limits on bridges must be reduced. If it is assumed that the posting of a given bridge affects 50 trucks per day and each truck has to detour 10 miles off of a route at a rate of $1.00 per mile, then the posting of one bridge would cost the trucking industry $182,500 per year.

Currently, a third bridge-strengthening research project sponsored by the Iowa DOT Highway Division is under way at ISU, involving the strengthening by posttensioning of continuous bridges. A one-third scale model, three-span bridge (42 ft × 8 ft 8 in.) has been constructed in the laboratory and testing is currently in progress.

FIGURE 1 Photograph of strengthened Bridge 2. *Insert*: Close-up of posttensioning bracket and tendon in position.

Editor's note: NCHRP Project 12-28(4), Methods of Strengthening Existing Highway Bridges, is currently under way at Iowa State University. Posttensioning as well as other techniques to strengthen bridges will be investigated.

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