Determination of Load Ratings for Non-Composite Steel Girder Bridges through Load Testing

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ABSTRACT

This project was Phase II of the recently completed Iowa Highway Research Board project, "Alternative Solutions to Meet the Service of Low-Volume Bridges in Iowa" (TR-452). In Phase I, the overall objective was to develop a state of the practice in the area of bridge maintenance/rehabilitation/ strengthening. Information was obtained from extensive literature reviews and from two questionnaires, a national questionnaire and a questionnaire sent only to Iowa county engineers (ICEs). The questionnaire to ICEs obtained information on unique solutions to various bridge problems they have encountered, including problems specifically associated with low-volume road (LVR) bridges. Based on the evaluation of the information obtained from Phase I and input from several county engineers, common problems with substructures and posted steel stringer bridges were identified, and Phase II was initiated. This paper presents a brief summary of the scope of the research and results for both the superstructure and substructure portions of the study.

Bridge testing (diagnostic or proof load) is becoming an increasingly viable tool for evaluating the response of a bridge to live load and thus determining performance-based ratings. Bridge testing is

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relatively costly compared to the conventional rating process and thus can not be used on all bridges. Recent research has focused on determining if the physical structural performance of bridges within a family or fleet that have similar physical characteristics can be predicted from testing a representative sample of similar bridges in the fleet and using that information to better evaluate bridges in the family that are not load tested. This would eliminate the need to test all bridges but would still retain some of the benefits gained through physical testing for providing more accurate ratings.

In this study, a family of single-span non-composite steel girder bridges with cast-in-place concrete decks was chosen to determine if predictable superstructures characteristics could be identified. These bridges lack a shear connection between the concrete deck and steel girders and were commonly built prior to 1950. Past testing has shown that these bridges will often produce a live load response lower than analytical models due to various factors, including partial composite action between the deck and girders, edge stiffening of the exterior girders due to the presence of curbs and railings, bearing restraint due to connection details partially restraining the end rotation of the girders, and more precise live load distribution factors. The study results were based on the testing and evaluation of six bridges using diagnostic load testing. Conventional load ratings of the six bridges were performed by three different rating agencies, and the results were compared to performance-based load ratings determined through diagnostic load testing. The test results showed that the diagnostic load test ratings were larger for all six bridges compared to the conventional ratings. There were some behavior characteristics that were predictable, and thus extrapolation of these performance characteristics could possibly be extrapolated to other bridges in the fleet. It is recommended that a more statistically significant sample group of fleet bridges be tested and evaluated before widespread application of fleet results can be reliably extrapolated.

Current conventional bridge rating systems rely primarily on superstructure information, and the rating process of the substructure is typically not as detailed or quantifiably rigorous as that for the superstructure. The substructure condition, however, can be a governing factor in bridge integrity, particularly in cases of bridges with unknown foundations or bridges supported by timber piling. With most of these bridges, there are no design or as-built bridge plans and no documentation of the type, depth, geometry, or materials incorporated in the foundation. In addition to the lack of design information, timber piles exhibit deterioration with time due to different biological and physical factors (Figure 1). If not detected and mitigated, pile deterioration can considerably reduce the pile bearing capacity.

Figure 1. Timber pile deterioration

Currently, there are no reliable means to evaluate timber substructures. The lack of reliable evaluation methods often leads to conservative and costly maintenance practices. Therefore, this study was completed to develop procedures for assessing bridge substructures and propose various procedures for rehabilitating/strengthening/replacing inadequate substructure components. In this study, problems with timber substructures in Iowa were identified by inspecting 49 low-volume bridges with poor performing substructures. Furthermore, the six bridges previously noted that were load tested to evaluate the superstructure performance were also tested and evaluated to determine the live load distribution and performance of deteriorated bridge foundations. During load testing, the timber piles and backwall were instrumented with strain gages (Figure 2). Pile and backwall strain responses were used to make inferences on the substructure performance. By using nondestructive and destructive static load testing, it was possible to identify deteriorated pile sections and evaluate the overall performance of the bridge substructures. In future static load testing, it is recommended that pile movement parallel and perpendicular to the backwall be measured so that it is possible to separate pile strains induced by axial and bending loads. In addition to evaluating the structural performance of substructures for rating purposes, additional work was performed at one of the load tested bridge abutments, where several pile integrity tests were performed in an attempt to estimate the unknown pile length below ground (Figure 3).

Figure 2. Timber substructure instrumented with strain gauges (south abutment, Bridge No. 237350, Mahaska County)

Figure 3. Pile integrity testing (Bridge No. 237350, Mahaska County)

To estimate the residual bearing capacity of deteriorated pile sections, a laboratory study was carried out correlating the pile elastic modulus determined by axial compression tests and the dynamic elastic modulus determined using the nondestructive ultrasonic stress wave technique. The ultrasonic stress wave technique was also used to produce two-dimensional tomography images of internal pile deterioration (Figure 4). Test results indicated that the ultrasonic stress wave test is capable of predicting the residual capacity of deteriorated timber piles and detecting internal pile damage; however, the method has a tendency to overpredict the area of the internal defect. An additional laboratory study was conducted where selected pile repair methods were evaluated to determine the effectiveness of the method in restoring axial and bending capacities of timber piles (Figure 5). The repair methods investigated were capable of partially restoring the axial and bending capacity of damaged piles.

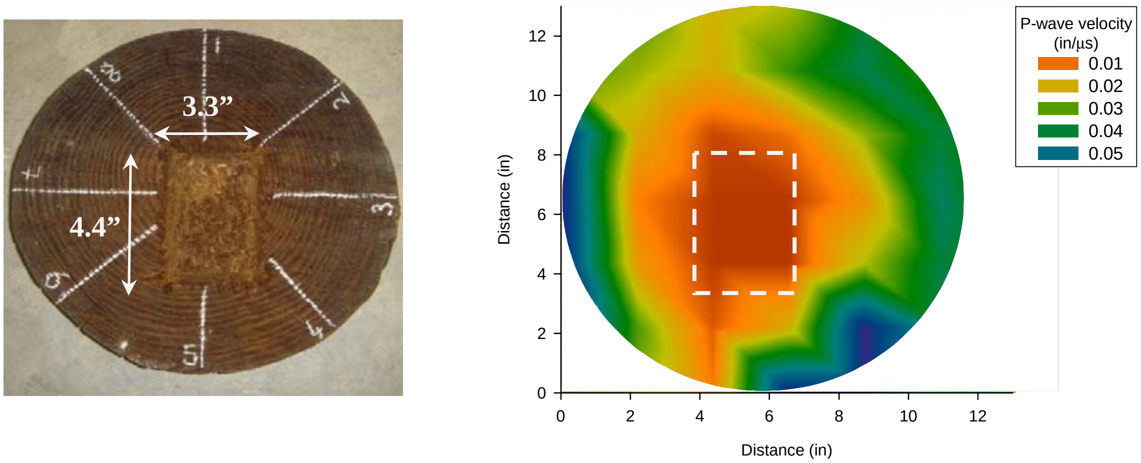

Figure 4. Tomography image showing the pile internal condition

Figure 5. Timber pile repaired using filler epoxy and fiber-reinforced polymer