**Study Description**

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| **Background:** |

According to the AASHTO LRFD Bridge Design Specifications, “Fracture Critical members (FCMs) are steel tension members or steel tension components of members whose failure would be expected to result in collapse of the bridge.” It is required that inspection of these bridges be carried out using “arms-length” approach, which is costly and is a drain on the State’s total bridge budget.

Currently, two steel box girder bridges are classified as bridges with fracture critical members. Specifically, the tension bottom flange in the two steel box girder bridges is categorized as a fracture critical element. Inspection of tension bottom flanges over a busy roadway is costly and time consuming, and it causes traffic disruption and potential safety hazards.

Recent research results indicate that two steel box girder bridges could be redundant. The most notable study is the series of full-scale tests carried out by University of Texas-Austin that demonstrated a high level of internal redundancy of two steel box girder bridges. A study carried out by HNTB on the two box girder structures in the Marquette Interchange, through nonlinear numerical analysis also demonstrated the high level of internal and structural redundancy of two steel box girder bridges. NCHRP project 12-87 includes objectives to “(1) develop a methodology to quantify when a steel bridge system is considered fracture critical based on loads, existing conditions, material properties, and bridge configurations, and (2) recommend AASHTO specifications using the methodology in the design of new bridges and the evaluation of existing bridges.” However, “(a) decision was made to discontinue work on the project beyond Phase I.” The remaining work was placed under project 12-87a, the deliverables of which will include “recommended draft AASHTO specifications and examples that cover different bridge types including as examples 2- and 3-girder simple and continuous bridges, and truss bridges.” As a result, there could be an overlap between conclusions made under the proposed pooled fund project and those from NCHRP 12-87a. This possible overlap in conclusions should further strengthen the justification for removing two steel box girder bridges from the list of bridges with FC elements, if analysis warrants.

An additional relevant project related to two steel box girder bridges is a limited numerical study being conducted at Purdue University with limited funding provided by National Steel Bridge Alliance (NSBA). To date, this study has analyzed a few two steel box girder bridges and has developed automated meshing that could be used in conjunction with detailed three dimensional nonlinear finite element analyses.

The most comprehensive recent study is a project sponsored by Florida Department of Transportation with the proposer of this pooled fund as lead investigator, in which extensive experimental, field testing, numerical and analytical studies show that a high level of redundancy exists in two steel box girder bridges. Major conclusions from this study are that two steel box girder bridges have a reserve capacity after the complete fracture of the tension flange on one girder and, potentially, that punching shear capacity of the deck is the weak link. What remains to be accomplished is to take advantage of existing knowledge to conduct the necessary additional work to fill in the knowledge gap and develop a sound methodology, approach, and tools that State DOTs could use to evaluate the redundancy of two steel box girder bridges and eliminate them from the fracture critical list.

The existing guidelines in the AASHTO LRFD Bridge Design specification, as well as the June 20, 2012 memorandum issued by FHWA and very recent discussions with FHWA, allow and provide a roadmap for assessing the redundancy of two steel box girder bridges.

The commentary for Section 6.6.2 of the AASHTO LRFD Bridge Design Specifications provides general guidelines that can be used to evaluate the performance of bridges with Fracture Critical members. The challenge, in evaluating the redundancy of two steel box girder bridges, is that it is implied that each bridge in the State inventory should be analyzed individually before it can be removed from the fracture critical list. The research carried out by Texas provides guidelines for checking the redundancy of two steel box girder bridges. There is, however, a need to improve these guidelines. In particular, the Texas work takes a very conservative approach in assessing the participation of the undamaged girder, in load carrying capacity of the bridge as a system.

Recent discussion with FHWA has opened the door for the possibility of grouping two steel box girder bridges and checking the redundancy of only one “Equivalent” two steel box girder bridge within each group.

**Objective:**

The main objective of this project is to develop a user-friendly methodology and approach, and associated tools, for economically assessing the redundancy of the two steel box girder bridges, implementable by State DOTs so that these bridges can be classified as non-fracture critical for inspection purposes.

**Scope of Work:**

**Task 1 –** Development of an “equivalent” two steel box girder concept. The FDOT sponsored project has developed a preliminary approach to develop an “equivalent” simple span bridge that could represent a series of two steel box girder bridges.

**Deliverable:** Complete the development of the procedure to develop an “equivalent” or notional simple span two steel box girder, representing all the bridges in a given group. This deliverable will be in the form of a short and stand-alone report.

**Task 2 –** Development of criteria for redundancy and load level. All existing studies have investigated the redundancy of two steel box girder bridges using an arbitrary load level. Arbitrarily selecting the load level that the damaged two steel box girder bridges should be able to carry has been frequently questioned. Therefore, there is a need to develop more rational approaches to establish the load level and application method that the damaged bridge should carry for proper evaluation. Further, there may also be a need to develop additional performance criteria, such as deflection limits for damaged bridges. The establishment of the target safety level will be twofold. One approach will consist of seeking the bridge owners’ input on an appropriate safety level. The other approach will be to establish the safety level inherent in redundant bridges.

**Deliverable:** Design target performance level and safety level for the “Equivalent” bridge. This deliverable will be reported in a short standalone report.

**Task 3 –** Development of simplified criteria for nonlinear finite element analysis. Recent investigation sponsored by FDOT points to the fact that the detailed analysis of “equivalent” simple span bridge for investigating redundancy could be simplified. The NSBA-sponsored work at Purdue has added valuable information to the body of available knowledge and will be utilized in the proposed pooled funded project.

**Deliverable:** Written report on the development of a detail approach for nonlinear finite element analysis of the “equivalent” bridge.

**Task 4 –** Experiment to verify the final modeling recommendations. The recent FDOT-sponsored work indicates that additional limited experimental work at the component level needs to be carried out to better comprehend the possible modes of failure after damage that have been documented in previous research studies, such as punching shear capacity of the deck, pull-out failure of the shear studs, and concrete crushing. Results from Task 2 on the development of the load levels and application methods will be utilized to ensure proper application of the load during the experimental testing.

The focus of this additional experimental work will be to develop the knowledge to fill the gap that exists in the current experimental data to fully verify the procedure to be used in the detailed modeling of the damaged bridge. The test specimen is envisioned to be a modified version of the scale test specimen used in the FDOT sponsored project and small test specimens to comprehend the behavior of deck under concentrated load and in presence of damaged girder.

This task will be carried out in two sub-tasks, of Task 4a and Task 4b as outlined below

**Task 4a** - Experimental Test Planning—Under this task, based on the knowledge gained from other tasks, descriptions of the planned experimental work will be outlined and shared with stakeholders for review and comments. Based on the comments received and in consultation with stakeholders, the details of the test specimen and planned loading regime will be finalized.

Deliverables: Details of the planned test specimen(s) and loading regime for review and comments in a short stand-alone report form.

**Task 4b** - Conducting Experimental Work—Based on the plan developed under task 4a, the experimental work will be carried out.

Deliverables: Summary of experimental work and conclusions. This deliverable will be in the form of a stand-alone report.

**Task 5 -** Investigating feasibility of expanding the recommended simple approach from the University of Texas-Austin research to check redundancy of two steel box girder bridges. The Texas-sponsored work resulted in development of first level simplified hand calculation type approach to check the redundancy of two steel box girder bridges. However, because of the excessive conservativeness incorporated in this approach the methodology has proven to be ineffective. Using the results of this investigation, a study will be conducted to examine the feasibility of reducing the level of conservativeness incorporated in the University of Texas-Austin suggested simple approach and examine its merit to check redundancy of two steel box girder bridges.

**Deliverable**: Report of findings from the Task 5 efforts. This report will include a description of the effort undertaken under Task 5 and if successful, a description of the modified version of the Texas simple approach for checking redundancy of the steel box girder bridges.

**Task 6 –** Development of a comprehensive plan for assessment of two steel box girder bridges. This project will investigate two separate approaches for evaluating the redundancy of two steel box girder bridges. The first approach is the use of “equivalent” simple span two steel box girder bridge that could represent a series of simple and multi-span two steel box girder bridges, then to investigate its redundancy using a probabilistic based procedure to be developed in this study established approach. Based on results of Task 5, the second approach will consist of a simple hand calculation approach to check redundancy of two steel box girder bridges, first suggested by University of Texas-Austin. Summary of the entire work will be provided in a final report to be submitted at the conclusion of the project.

**Deliverable:** Development of the detailed steps for assessing the redundancy of two steel box girder bridges. This deliverable will be in the form of a stand-alone report.

**Task 7** - Final Report – Summary of entire activities within the project will be summarized in a final report to be submitted in both hard copy and digital form.

**Deliverable:** A final report summarizing the entire activities of the project.

During the course of project, monthly meetings, through GoToMeeting, will be held with sponsoring States to discuss the project progress and obtaining their feedback and suggestions. Reports and quarterly progress reports will be submitted per required procedure.