

# MPC-565

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**Project Title:**

Study on Structural Performance Evaluation of Double-Tee Bridges

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**Research Needs:**

To better understand structural performance of existing double-tee (DT) bridges, field testing, visual inspection, and structural analysis of DT bridges should be performed.

Many DT bridges have been in service on local road networks across the United States. The rapid deterioration of longitudinal joints between DT girders frequently occurs, and this significantly degrades structural performance of such bridges. Some studies (Jones 2001, Wehbe et al. 2016) attempted to perform laboratory tests of full-scale DT girder specimens to examine their ultimate and fatigue performance. Specifically, Wehbe et al. (2016) found that under fatigue loading the DT girder specimen, with a conventional joint representing an actual DT bridge, quickly deteriorated due to cracks along the longitudinal joint.

Despite the fact that the laboratory tests demonstrated the structural performance of the DT girders, there is a lack of studies focusing on integrated field testing with visual inspection and structural analysis for the examination of structural performance for existing DT bridges. The results from the laboratory testing cannot directly be used to determine actual structural performance of existing DT bridges due to the discrepancy in remaining structural capacity and loading condition between laboratory and field tests. Generally, existing DT bridges quickly deteriorate over time with the increasing traffic demands. It is necessary to examine actual performance of existing DT bridges subjected to real trucks with known weights and configurations.

### **Research Objectives:**

The goal of this project is to provide a better understanding of structural performance of in-service DT bridges loaded with actual trucks.

The objectives of this project to achieve this goal are:

- 1) To identify damage of typically used DT bridges
- 2) To determine live-load distribution and dynamic load allowance factors of the DT bridges; and
- 3) To investigate load-carrying capacity of the DT bridges.

### **Research Methods:**

To complete the objectives, three research methods are presented as indicated below.

**Objective 1:** DT bridge inspections will be performed using instruments, such as calipers, rulers, digital cameras, and a drone. At least two DT bridges located in South Dakota will be selected and inspected. Damage for each bridge will be quantified by the direct measurement, and various images on different types of damage will be captured during the inspection. These images will be analyzed using image tools to measure the damage on each bridge, and the quantifiable damage will be compared to those from the direct measurement. Then, a damage state for each of the major bridge components will be determined based on the analysis of the quantified damage and the AASHTO Manuals for Bridge Element Inspection (AASHTO 2013).

**Objective 2:** Field testing will be performed to determine live-load distribution and dynamic load allowance factors of each DT bridge loaded with the AASHTO load rating trucks. A network of strain sensors will be installed on the bottom stems of the DT girders and linked to a data-logger system. Strain data will be measured via the data-logger system when each test truck is driven across each bridge. Live-load distribution and dynamic load allowance factors for the DT girders will be determined by analyzing the strain data. Analytical models for each bridge under a passage of each of the testing trucks will be created and calibrated with the strain data. Structural simulation will be conducted using the model loaded with each testing truck, and resulting analytical data will be used and analyzed to determine analytical live-load distribution and dynamic load allowance factors. Then, codified live-load distribution factors will be determined following the current AASHTO Specifications (AASHTO 2012) and compared with field and analytical values.

**Objective 3:** The field and analytical data that are obtained from Objective 2 will be used to determine the load-carrying capacity for each DT bridge according to the AASHTO Manuals for Bridge Element Inspection. Structural capacity, with consideration of the damage states for each bridge component that are determined in Objective 1, will be quantified. Specifically, the damage state will be expressed as a function of nominal member resistance, condition factors and system factors defined by the AASHTO Manuals. Relationships between the load carrying capacity and damage states for each bridge will be investigated.

### **Expected Outcomes:**

- 1) This project will provide visual inspection and field testing data focused on the determination of live-load distribution and dynamic load allowance factors of existing DT bridges.
- 2) This project will yield analytical models allowing for the replication of field bridge response.

Outcomes will help bridge engineers better understand actual structural behavior of existing DT bridges and make rational decisions for repair and replacement on them.

### **Relevance to Strategic Goals:**

State of Good Repair –A number of DT bridges are rapidly deteriorating over time due to inappropriate joints between adjacent DT girders; thus, they should be repaired soon. The proposed study will help make better decisions regarding the selection of repair options using the field bridge performance data.

Safety – Assessing actual performance of existing DT bridges subjected to live loads will be of importance to the structural integrity of the bridges and directly related to the safety of the bridge users.

### **Educational Benefits:**

As a graduate research assistant, one graduate student will participate in this project. The student will obtain applied research skills and knowledge on visual inspection, field testing, and analytical modeling and simulation. Significant findings from this project will be incorporated into SDSU engineering courses, such as CEE 792: Bridge Engineering, led by PI Seo.

### **Tech Transfer:**

The research team believes the findings from visual inspection, field testing, and structural analysis can be transferred to bridge engineers. The team will develop partnership with bridge engineers at SDDOT on visual inspection and field testing of the DT bridges. It is anticipated that county transportation agencies use research findings and recommendations for the determination of structural performance of in-service DT bridges. All results from this project will be published in technical journal articles and conferences. Technology transfer activities will also be reported in the Program Progress Performance Reports (PPPR).

### **Work Plan:**

Task 1: Literature search on the structural performance evaluation of DT bridges

Task 2: Existing DT bridge selection and visual inspection

Task 3: Load rating truck selection and field testing

Task 4: Analytical modeling and simulation

Task 5: Load-carrying capacity determination

Task 6: Final report and closeout presentation

Task 1: Perform a detailed literature review on the visual inspection, field testing, and structural analysis of DT bridges. This task is anticipated to be done by the end of the 2nd month.

Task 2: Select at least two existing DT bridges, including one with significant deterioration on longitudinal joints and the other with less deterioration on them. Then, the research team will perform visual inspection to identify any deterioration for each bridge. This task is expected to be done by the end of the 4th month.

Task 3: Consult with bridge engineers at SDDOT to determine appropriate load rating trucks for field testing. Then, the research team will develop a data-logger system with multiple sensors and attach the sensors on the critical sections of each bridge. Field testing with the trucks will be performed for each bridge under a truck passage. All field testing data will be statistically and graphically analyzed to determine live-load distribution factors and dynamic load allowance factors of all the bridges in accordance with the AASHTO Specifications. This task is expected to be done by the end of the 7th month.

Task 4: Create analytical models to replicate field response from Task 3 and calibrate them with field data via finite element analysis software. Using the analytical data, analytical live-load distribution factors and dynamic load allowance factors will be determined following the AASHTO Specifications. The analytical and field live-load distribution factors will be compared to the AASHTO values. This task is expected to be done by the end of the 10th month.

Task 5: Determine the load-carrying capacity of each of the DT bridges using all data from tasks 3 and 4 based on the procedure outlined by the AASHTO manuals. This task is expected to be done by the end of the 11th month.

Task 6: Complete a final report compiling the research results, conclusion remarks, and recommendations. This task is expected to be done by the end of the 12th month.

**Project Cost:**

Total Project Costs:	\$60,300
MPC Funds Requested:	\$29,379
Matching Funds:	\$30,921
Source of Matching Funds:	SDSU Faculty Time and Effort

**References:**

American Association of State Highway and Transportation Officials (AASHTO). (2012). AASHTO LRFD Bridge Design Specification, 6th Ed., Washington, DC.

American Association of State Highway and Transportation Officials (AASHTO). (2013). AASHTO Manual for Bridge Element Inspection, 1st Ed., Washington, DC.

Jones, H. L. (2001). *Lateral Connections for Double Tee Bridges*. Report No. 1856-2. Texas Transportation Institute, College Station, TX.

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Wehbe, N., Konrad, M., and Breyfogle, A. (2016). "Joint Detailing Between Double Tee Bridge Girders for Improved Serviceability and Strength." *Journal of the Transportation Research Board*, No. 2592.