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Project Title:
Methodology for Load Rating Double-Tee Bridges

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Research Needs:
The most common type of bridge on South Dakota (SD) local roads is double-tee (DT) prestressed girders. More than 700 DT bridges are currently in-service in SD. Structural detailing, aging, traffic volume, and environmental conditions such as a high number of freeze-thaw cycles and use of de-icing agents may significantly affect the structural performance, integrity, and capacity of bridges. These factors are critical for DT bridges located in SD since (1) more than 75% of SD DT bridges are 20 years or older, (2) a recent study by Wehbe et al. (2016) showed that the typical DT girder longitudinal joint detailing is not adequate for long-term performance, and (3) there are more than 100 freeze-thaw annual cycles in SD on average (Haley, 2011), which may expedite the deterioration of this type of bridges. When a bridge is affected by one or more of these parameters, the evaluation and rating of load carrying capacity of the bridge is necessary to ensure the safety of the traveling public and to prevent excessive

bridge damage and collapse. Load rating of a bridge requires reliable estimation of actual capacities of the affected members as well as the knowledge of live load distribution and demands. Due to a lack of specific load rating for South Dakota double-tee bridges, the "posting" of these type of bridges is challenging.

This proposed project will develop a guideline to accurately load rate DT bridges located in South Dakota. To achieve this objective, both field and laboratory testing are recommended. Field tests will provide sufficient information to understand the live load distribution and dynamic load allowance specific to DT. The laboratory testing of full-scale salvaged DT girders will provide information to accurately calculate the actual capacity of deteriorated bridges. A load rating guideline based on visual identification of damage in DT bridges will be developed to further help engineers to rate those bridges in a timely and accurate fashion.

Research Objectives:

1) Review nationally recognized standards for visual and analytical techniques on load rating bridges,
2) Develop a testing plan to investigate the in-place structural integrity of double tee bridges with varying amounts of visible distress,
3) Develop a methodology for engineers and highway superintendents in South Dakota to evaluate the structural integrity of double tee bridges and estimate load limits through visual inspection.

Research Methods:

The AASHTO Manual for Bridge Evaluation (2015) presents load rating, field testing, and posting methods for existing bridges. AASHTO allows three load rating methods: (1) Load and Resistance Factor Rating (LRFR), (2) Load Factor Rating (LFR), and (3) Allowable Stress. These methods are used to comment whether an existing bridge will be safe and serviceable under a specific live load. Since the basis of these three methods are the same, the LRFR method is selected in this project. Another reason for selecting this method herein is that it is consistent with the current AASHTO LRFD Bridge Design Specifications (2014). The AASHTO Manual for Bridge Evaluation (2015) also provides recommendations for nondestructive load testing of existing bridges. Load testing is usually conducted to verify bridge performance under a predetermined live load. Two types of load testing are recognized by AASHTO: (1) "diagnostic tests" that are carried out to determine the bridge response to the applied live load, to determine the live load distribution factors, and to verify modeling methods of the test bridge, and (2) "proof tests" that are performed to determine the maximum safe live load of a bridge in which the bridge remains in its linear-elastic range.

Since the actual load distribution factor for DT is unknown (no specific study has been conducted in SD for this type of bridge), field load testing will be performed to accurately estimate this factor as well as the dynamic load allowance. One of the critical steps to achieve the objectives of the present project will be to categorize the distress types and levels for double-tee bridges by reviewing the SD bridge inventory as well as the project panel feedback. After this step, reliable methods of estimation of shear and flexural capacities should be established (developed or adopted from literature). Since member service (allowable stresses) and ultimate capacities are needed in the load rating, testing of salvaged DT girders with different distress

conditions in laboratory will be considered depending approval by the project panel to measure the actual capacities. Measured data from the laboratory tests can be used to verify the method of estimation of capacities for different distress types and levels. The test girders will be selected based on the damage and conditions. A roadmap for successful execution of the project is shown in **Fig. 1**, which includes both capacity and demand parameters.

Expected Outcomes:
Successful execution of the proposed study will results in guidelines for structural and bridge engineers to analyze and to load rate existing double-tee bridges based on their apparent damage. This could ultimately allow for maximum use of existing structures while providing safe travel to the public and preserving the bridge investment.

Relevance to Strategic Goals:
The expected outcomes of this project are directly related to the following goals: State of Good Repair and Economic Competitiveness.

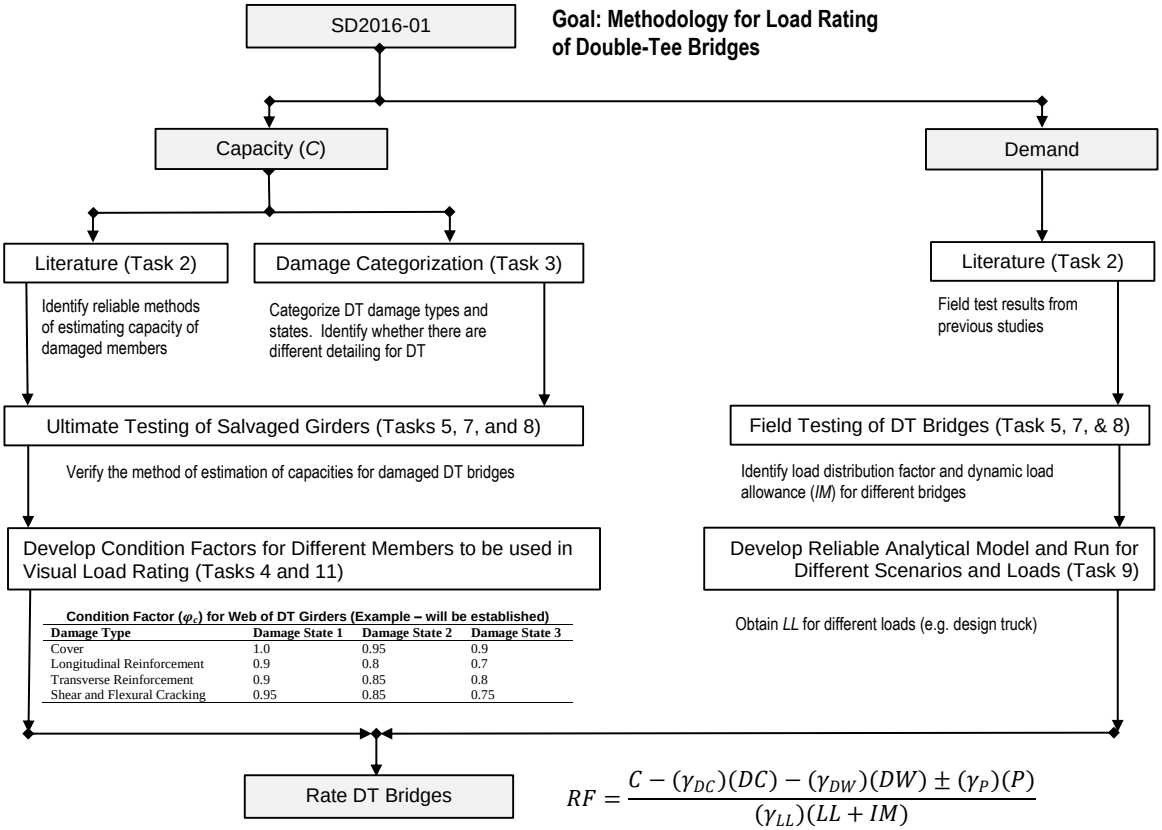

Figure 1. Proposed Project Roadmap

Educational Benefits:
This project will provide a valuable learning experience to both graduate and undergraduate students. A PhD student will be hired to work on this project. An undergraduate student, who will be hired for this project, will benefit from the experimental exposure and will learn the

research process. Results from the study will be incorporated into courses such as Advanced Reinforced Concrete and Bridge Engineering.

Work Plan:

1) Meet with the technical panel to review project scope and work plan.
2) Review literature nationwide pertaining to load rating bridges using visual inspections and instrumentation.
3) From bridge inventory data supplied by SDDOT, summarize the prevalence of distress types and severity on double tee bridges in South Dakota.
4) Propose a methodology to associate load ratings with visible distress type and severity.
5) Assess the need for load testing girders removed from an existing double tee bridge to more accurately associate load ratings with visual inspections.
6) Develop a field experiment plan that proposes bridges to be tested, instrumentation, load test vehicle(s), and procedures for load testing and visual inspection.
7) Submit a technical memorandum and meet with the project technical panel to present the results of Tasks 2-6 and obtain approval for the field experiment plan.
8) Upon approval of the plan by the technical panel, install instrumentation at the selected bridges, providing the technical panel at least two weeks' notice to allow them to observe the installation. (A member of the SDDOT or local authority must be on site during all activities on bridge sites.)
9) Perform visual inspections and load testing at selected bridge sites, providing the technical panel at least two weeks' notice to allow them to observe the testing.
10) Analyze load testing results and develop recommendations for load ratings on tested bridges.
11) Perform load testing on salvaged girders for an existing double tee bridge.
12) Analyze load testing results on salvaged girders to develop recommendations for ultimate capacities and load ratings.
13) Submit a technical memorandum and meet with the project technical panel to present the results of Task 8-12.
14) Using data from the field experiment, refine the method that associates bridge load ratings to visual distress and describe the method's applicability and expected accuracy.
15) Submit a technical memorandum and meet with the project technical panel to present the results of Task 14.
16) Develop a guidance document briefly summarizing the work performed in this study and presenting techniques to estimate structures' load rating through visual inspection.
17) In accordance with *Guidelines for Performing Research for the South Dakota Department of Transportation*, prepare a final report and executive summary of the research methodology, findings, conclusions, and recommendations.
18) Make an executive presentation to the SDDOT Research Review Board at the conclusion of the project.

Project Cost:

Total Project Costs:	$164,125
MPC Funds Requested:	$74,245
Matching Funds:	$89,880

Source of Matching Funds: SD DOT

TRB Keywords:
Load Rating, Apparent Damage, Double-Tee Precast Girders, Field Testing, Ultimate Testing.

References:

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3. Haley, J.S. (2011). "Climatology of Freeze-Thaw Days in the Conterminous United States: 1982-2009", MSc Thesis, Kent State University, 82 pp.
4. Wehbe, N., Konrad, M., and Breyfogle, A. (2016) "Joint Detailing Between Double Tee Bridge Girders for Improved Serviceability and Strength", J*ournal of the Transportation Research Board* (TRR), DOI: 10.3141/2592-12, 13 pp.