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Project Title

Sustainable Alternative to Structurally Deficient Bridges

University

South Dakota State University

Principal Investigator

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Research Needs

This project is intended to enhance bridge sustainability and performance using Cross Laminated Timber (CLT) products. Successful implementation will promote environmentally sustainable and diversified wood production opportunities, ensure public safety, and increase bridge construction efficiency.

According to the 2017 ASCE Infrastructure Report Card (ASCE 2017), 9.1% of the bridges in the U.S. bridges, and, of greater significance, more than 19% of bridges in South Dakota are structurally deficient. These bridges include structures maintained by state, county and other local agencies. A majority are specifically located on low-volume road networks. Replacing these deficient bridges is urgent. As a sustainable and economic solution for replacement, a new bridge system made with CLT is necessary to expand the use of wood products.

Research Objectives

The three objectives of this project are:

1) To conceptualize a new CLT girder bridge system
2) To design and manufacture the bridge system; and
3) To investigate structural performance of the bridge system.

Research Methods

To achieve the objectives, three research approaches are provided.

Objective 1: To conceptualize a CLT bridge system, a literature review will be completed of technical documentation related to current practices, guidance, and information related to timber girder bridges. A significant aspect of this will be a side-by-side comparison of bridge design approaches to those in the USDA Forest Service Report (Ritter, 1990) *"Timber Bridges: Design, Construction, Inspection, and Maintenance"* and in the American Association of State Highway and Transportation Officials (AASHTO) Bridge Design Specifications (AASHTO 2012). To learn more on the current state of the art and practice, the research team will use different online resources, including but not limited to ASCE Civil Engineering database and Google Scholar. Based on the literature review and analysis, the research team will create several conceptualized bridge options that may improve structural integrity of bridges made with CLT products. The research team will consult a CLT producer on the feasibility and economic viability of the bridge options and select the most promising one.

Objective 2: The research team will design the selected system according to domestic (e.g., AASHTO Bridge Design Specifications and National Design Specification (NDS)) and international bridge engineering-based standards. Dimensions for the CLT system will be initially determined, and load effects will be estimated. The research team will discuss the design details with the CLT design team at a CLT producer. With the design details developed, the CLT producer will manufacture one full-scale CLT-bridge specimen for load testing. The research team will visit the producer to supervise all the steps while manufacturing the CLT specimen.

Objective 3: To examine the structural performance of the proposed CLT bridge system, ultimate load testing will be first performed on one specimen. Linear Variable Differential Transformers (LVDTs) and strain gauges will be placed on critical locations of the specimen and load points to measure displacements and strains due to the increase in a load. During testing, strain and deflection data along with image data will be assembled to better understand structural behaviors and failure modes and quantify relationships between load and response per damage state for the specimen. Further, a finite element modeling approach to predict structural response of the CLT system will be created and calibrated with the ultimate load testing data to accurately predict actual behavior. The calibrated model will be employed to perform parametric studies for the determination of the system with improved structural performance.

Expected Outcomes

1) This project will present ultimate testing data of the new CLT bridge system.
2) This project will provide a new numerical model to predict structural behavior of the CLT bridge system.

Findings will allow bridge owners and engineers to understand structural performance of the CLT bridge system and potentially use the system as a sustainable alternative to structurally deficient bridges. Prefabricated CLT bridge products enable accelerated bridge construction, which saves money and time for future bridge replacement projects.

Relevance to Strategic Goals

The U. S. carries a large inventory of structurally deficient bridges, and they must be replaced soon. This work will help improve structural performance and support environmental health of our communities, which are critical for the following strategic goals: Safety and Environmental Sustainability.

Educational Benefits

As a graduate research assistant (student) will perform this project and work on his/her thesis. The student will gain knowledge and practices on new bridge conceptualization, design, ultimate testing, and numerical modeling. Key findings from this work will be integrated into an SDSU structural engineering course (i.e., CEE 792: Bridge Engineering) taught by PI Seo.

Technology Transfer

All results from this project will be published in journals and conferences. Technology transfer activities will also be reported in the Program Progress Performance Reports (PPPR).

Work Plan

Task 1: Conduct a comprehensive literature review on the application of new timber bridge systems and on ultimate load testing and structural analysis of timber bridges. Expected be done by the end of the 3rd month.

Task 2: Conceptualize a CLT bridge system with the information from the literature review. Then, the research team will make several conceptualized CLT bridge options in terms of feasibility, sustainability, and design practice. Expected to be done by the end of the 6th month.

Task 3: Select the best CLT bridge system among the created CLT options. The research team will consult with CLT producers and bridge engineers to determine the most implementable and practical CLT system. Expected to be done by the end of the 8th month.

Task 4: Design the selected CLT bridge system in accordance with bridge codes such as AASHTO Bridge Design Specifications. Structural parameters for the bridge system will be selected to satisfy the strength and serviceability limit states. The research team will also discuss the design details with a CLT producer and bridge engineers, and details will be modified as necessary. With the final design details, the CLT bridge system specimen will be manufactured at the CLT producer. Expected to be done by the end of the 12th month.

Task 5: Determine the ultimate load capacity of the designed CLT bridge system specimen by conducting the load test. A network of LVDTs and strain sensors will be attached to structurally critical sections of the specimen, allowing for measurements of displacements and strains resulting from the increase in a vertical load. For the load test, a point load will be applied to the specimen by a hydraulic actuator and monotonic under the displacement-based control until structural failure. The results of the test in this task will be used to determine the ultimate strength of the proposed CLT system. The strength will be compared to test results of conventional bridge systems through the AASHTO-compliant procedure. Expected to be done by the end of the 16th month.

Task 6: Create a numerical model to reproduce actual load testing data from Task 5 and calibrate it with test data. Using the calibrated model, the research team will conduct parametric simulations to determine the system with better structural performance. Expected to be done by the end of the 22nd month.

Task 7: Prepare and submit a final report including the technical findings, conclusions, and recommendations. Expected to be done by the end of the 24th month.

Project Cost

Total Project Costs:	$137,496
MPC Funds Requested:	$68,748
Matching Funds:	$68,748
Source of Matching Funds:	Sun Grant and SDSU Faculty Time and Effort

References

ASCE (American Society of Civil Engineers). (2017). "Infrastructure report card." https://www.infrastructurereportcard.org/cat-item/bridges/ (March 22, 2018).

Ritter, M. (1990). *Timber bridges design, construction, inspection, and maintenance.* USDA Forest Service, Washington, DC, 944 p.

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