TECHBRIEF

Strengthening Historic Covered Bridges to Carry Modern Traffic

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Objective

This TechBrief describes research on the use of glass fiber reinforced polymer (GFRP) composites to strengthen wooden superstructure components of historic covered bridges. The research was conducted during the years 2000 to 2004.

Introduction

At one time, the United States reportedly had as many as 14,000 covered bridges. Fewer than 900 now survive.[1] Under the National Historic Covered Bridge Preservation Program, the Federal Highway Administration provides funds for the rehabilitation, restoration, and preservation of covered bridges. If the goal for a particular bridge is to strengthen it sufficiently to support today's vehicular traffic, a major engineering challenge arises. The research described in this TechBrief could help meet that challenge.

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Figure 1. GFRP rebars embedded in a wood beam.

Research

Laboratory experiments were conducted on the use of GFRP composite materials—plates and rebars—to reinforce timber components of covered bridges. The use of adhesive to affix the GFRP materials in place also was included in the experiments. The GFRP plates were designed to increase the bending and shear capacities of flexural floor members. Tension and bending tests were conducted to establish the bond strength of GFRP rebars embedded in wood (figure 1), and to establish the bending strength and stiffness of floor beams reinforced with GFRP plates and rebars. In addition, increasing the shear capacity of floor beams by bonding GFRP plates on edge in narrow slots in the beams was investigated using large-scale, floor-beam specimens. GFRP rebars were tested as axial reinforcement for truss members.

Because maintaining the historic appearance of covered bridges is very important to preservationists, several methods of concealing the reinforcements also were examined. In one of the more successful methods, a GFRP plate was bonded inside a wide, shallow slot on the bottom face of a wooden member and hidden with an integrated veil matching the grain and color of the wood.

The major experiments conducted are summarized in table 1. Other experiments were conducted to determine the best combination of adhesives and the methods, such as pressure injection, to apply that combination.

Table 1. Summary of experiments.

Type of Test	Number of Experiments	Comments
Tension—small scale	9	Bonded in GFRP rebars; strength of tension splice and development length tested.
Bending—small scale	3	GFRP plates flat; strength and stiffness tested.
Bending—large scale	6	GFRP plates flat; strength and stiffness tested.
Bending—large scale	2	GFRP rebars; strength and stiffness tested.
Shear—large scale	3	GFRP plates on edge; strength and stiffness tested.
Total	**23**	

Results and Conclusions

Results of and conclusions from the research include the following points.

The adhesive used in the research performed very well in bonding the GFRP materials to the wooden structural members. It required less stringent preparation than epoxy.

In the tension tests, sand-coated GFRP rebars embedded in the wooden members performed well in terms of pullout force and bond strength. The rebars were 1.27 centimeters (cm) in diameter and approximately 10.16 cm in length.

In small-scale bending tests, the strength and stiffness of wooden members was improved by bonding a GFRP plate to the tension face of the members; however, this method had limitations. To provide a suitable bonding area, the wood needed to be prepared so that the surface was plane. If the bond was not adequate, the GFRP plate would peel away from the member. Also, the surface had to be degreased and freed of loose material.

The results from the large scale bending tests indicated that the strength and stiffness of wooden members can be improved significantly.

Bending tests with GFRP rebars at the top and bottom of the test specimens did not achieve the desired levels of performance; however, this method should be very useful with compression members in a truss.

A transformed section analysis based on strain compatibility and internal moment equilibrium accurately predicted the moment capacity of full-scale members and could be used for design purposes.

Moisture content and temperature of the test specimens were held as constants for the research project. All specimens were tested at an indoor ambient temperature that had very little variance. The question of degradation of the adhesive in a moist environment should be studied in the future.

Shear tests were performed on two GFRP flitch beams, which are created by inserting a GFRP plate on edge in a deep slot. Although the shear capacity was expected to improve significantly, it actually decreased slightly. The flitch beams tested were severely checked, which degraded their shear strength as compared to the solid control specimen. Also, the modular ratio of GFRP to wood was not very high.

Recommendations

Future research or actions should:

- Examine the feasibility of reinforcing wood at jointed connections with GFRP composite materials.
- Conduct full-scale tests on trusses, beams, and tension members to eliminate or reduce the effects of the reduced scale.
- Evaluate the long-term performance under varying environmental conditions of GFRP rebars bonded in wood members that are subjected to tension.
- Conduct the tests in this research study under field conditions on existing structures.

- Evaluate the long-term performance of GFRP reinforced bridge members exposed to wood preservative chemicals and pressures.
- Develop a stand-alone manual, or a separate chapter in a broader-scope manual, on step-by-step procedures for the preservation and strengthening of historic covered bridges using GFRP composite materials.

Additional Information

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References

Federal Highway Administration. *Covered Bridge Manual*. Report No. FHWA-HRT-04-098. April 2005. McLean, VA: Federal Highway Administration.

Researchers—This study was performed by the Constructed Facilities Center and the Institute for the History of Technology and Industrial Archaeology, both of West Virginia University, Morgantown, WV.

Distribution—The unpublished report covered in this TechBrief is being distributed through the National Technical Information Service, www.ntis.gov.

Availability—The report will be available May 2007, and may be obtained from the National Technical Information Service, www.ntis.gov.

Key Words—Glass fiber reinforced polymer, GFRP, composites, wooden superstructure components, historic covered bridges.

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