Composites in Construction: A Research Experience for Teachers

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Abstract
A grant to the University of South Carolina from the National Science Foundation's Research Experiences for Teachers (RET) program supported five high school science teachers to conduct engineering research on the university campus during the summer of 2002. The goal was to increase the teacher's knowledge of engineering materials and to enhance their inquiry skills. The teachers also developed several laboratory modules that were derived from their research to take back and use in their classroom.

The teachers conducted research on the use of fiber reinforced composite materials to strengthen and stiffen the components of bridges. For the past two decades, composites have been introduced to the construction industry as a practical way to improve the load carrying capacity of existing concrete, steel and wooden structures. Wood was chosen for the RET research due to the availability of wood beams, the limited duration of their summer research experience, and the ease in creating easily transportable in-class laboratory modules. Specifically, the teachers investigated the factors affecting the strength of the bond between epoxy-glass composites and southern yellow pine.

During the six-week program, the teachers learned to conduct literature research in the library, to design experiments, to fabricate composite material overlays on wood beams, to test the beams to determine strength and stiffness improvements and to test the bond strength after various environmental exposures. Through these experiences, the teachers gained increased content knowledge, design of experiments skills, and useful instructional materials.

Introduction
This project was made possible by a Research Experience for Teachers (RET) Supplement[1] to the University of South Carolina's Graduate Teaching Fellows in K-12 Education (GK-12) grant from the National Science Foundation. The objective of the RET was to enhance the ability of selected high school teachers to teach ENGR 101 - Introduction to Engineering in their schools for college credit. This project was designed to increase the teacher's content knowledge and inquiry skills through a complete engineering research experience, from experimental design to final reporting. The participating teachers also developed several laboratory modules that were derived from their research and could easily be taken back and used in their classroom.

The participants were recruited from a pool of 14 high school science teachers who had passed the University of South Carolina's course ENGR 701 - Introduction to Engineering for Teachers. This course qualifies them to teach ENGR 101 in their schools. The demographics of the five teachers were 1 white female, 1 black male and 3 white males. Each teacher had earned an undergraduate degree in Wood Science and Technology, Mathematics, Biology, Chemical Engineering, or Chemistry before receiving teacher certification. They were highly qualified to contribute intellectually to the research.

The RET principal investigator from Mechanical Engineering has taught the ENGR 101 course on the USC campus. He and the RET co-PI from Civil Engineering work together on an NSF-funded research program "Durability of the Bond between Concrete and Fiber-Reinforced Polymer Composites" (NSF Award Number 9908293) that was the basis of the teachers' research. The broad objective of that research program is to develop the appropriate methodology for predicting the long-term durability of the composite-to-concrete bond from short-term accelerated aging test methods. A multi-disciplinary team of civil, mechanical and chemical engineering faculty and students is involved in research that includes: natural weathering and testing of large and full-scale concrete-composite overlay specimens; fracture mechanics and small-scale beam testing of concrete specimens with FRP overlays subjected to accelerated environmental exposure; phenomenological modeling of the bond degradation at the concrete-FRP interface; and development of an engineering life prediction methods. The experience and infrastructure developed by of the faculty and students while participating in this and related extramurally funded projects formed the basis for the teacher's research experience.

Specifically, the participating teachers researched the use of fiber reinforced polymeric composites to strengthen wood structures. Despite the focus of the NSF project on concrete, wood was chosen for the RET project due to the availability of wood beams, the limited duration of their summer research experience, and the ease in creating easily transportable in-class laboratory modules. The University of Maine's Advanced Engineered Wood Composites Center, and other research groups, are generating some information on the structural behavior of full-scale wood members reinforced with polymer composites. However, more experimental results on the behavior of composite repaired wood are needed to support its use by the construction industry. This RET research program therefore had the added benefit of being a pilot project at the University of South Carolina that takes advantage of existing expertise and infrastructure.

Research Activities

The teachers' research experience was six weeks in duration. The 1st day included a tour of the facilities and an interactive lecture about the use of composites in construction and the objectives of the RET program. The research objective given to the teachers was to determine what factors affect the strength of the bond between glass-epoxy composites and wood. A number of variables to investigate were suggested to the teachers, but they were charged with choosing which ones to investigate.

After three days of self-directed literature- and internet-research, each teacher selected two material conditions to compare (e.g. with primer vs. without primer) thereby taking ownership of the project from the onset. A summary of the materials they selected is shown in Tables 1. Epoxy 1 is a commercial resin marketed for infrastructure repair with composite materials. Epoxy 2 is also marketed for infrastructure repair but is formulated to cure under wet or humid conditions. Each material system was tested after the environmental exposures shown in Table 2.

The teachers procured the HMR primer components and the wood from local suppliers. They rounded the edges of the boards with a router before they applied the epoxy-glass composite. They measured and cut the glass, mixed the epoxy resin and hardener together, primed the boards, impregnated the glass fiber with the epoxy and wrapped the uncured composite around the wood, as shown in Figure 1. They were very careful to keep the fibers straight.

Composite fabrication and mechanical testing were performed concurrently over the next 4 weeks of the RET experience. The teachers used a portable pull-off tester to measure the adhesion between the composite overlay and the wood beam, as shown in Figure 2.

Table 1. Materials systems.

Code	Description
1D	Epoxy 1 on Dry Wood
1W	Epoxy 1 on Wet Wood
1H	Epoxy 1 on Wet Wood with HMR Primer
1R	Epoxy 1 on Rough Wet Wood
2D	Epoxy 2 on Dry Wood
2W	Epoxy 2 on Wet Wood
2H	Epoxy 2 on Wet Wood with HMR Primer

Table 2. Environmental exposures.

Code	Description
AF	As fabricated
Dry	Oven dried at 110°F for 2 weeks
Wet	Submerged in water for 2 weeks
Tidal	Suspended at the mid-tide mark of the Atlantic Ocean off the coast of South Carolina for 1 week.

Preparing constituent materials. Impregnating cloth. Fabricating composite-wood beam.

Figure 1. RET participants reinforced wooden beams with glass-epoxy composites.

Portable pull-off tester used to measure the bond strength. Samples after adhesion testing

Figure 2. RET participants measured the bond strength of their materials before and after various environmental exposures.

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Depending on the material system and environmental exposure evaluated, results varied from clean separation of the overlay from the wood, to partial or complete wood pullout. The teachers learned how to apply Student's t-test to assess the significance of their results so that they could formulate conclusions and identify major dominant factors that affect bond strength. However, the presentation and discussion of the experimental results is beyond the scope of this paper. During their research, the teachers worked with faculty and students in Mechanical and Civil Engineering and participated in the team meetings of the NSF-supported researchers. In this way, they were kept cognizant of the relationships of their research to the NSF project.

Educational Modules Developed

During the last week of the RET experience, the teachers focused on developing new instructional modules for their high school students. Module topics included composite fabrication, curing of thermosets, composite mechanics and biological structure of wood. For example, one module was titled "Measuring the Bending of Long White Pine Boards in the Classroom." Here, a student applies a static load to simply supported beams by standing on it, while others measure the beam's deflections with a ruler. The students measure and compare the deflections experienced by a long bare white pine board to the deflections of a long white pine board wrapped with a fiber reinforced polymer (FRP). This module can familiarize potential engineering students with basic concepts from statics and solid mechanics, motivate them to learn spreadsheet data analysis methods, and help develop their ability and understanding of how to do scientific inquiry, part of the national science education standards.

Concluding Remarks

This project involved issues that are very broad-based and interdisciplinary in nature. The five participating teachers worked together as a team in planning their experiments. The faculty investigator advised these teachers and met with them as a group as well as individually. The teachers gained increased content knowledge, design of experiments skills, and useful instructional materials.

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Reference

1. Esin Gulari, "Research Experiences for Teachers (RET) Supplements and Sites," 1 Jan. 2002, http://www.nsf.gov/pubs/2002/nsf02078/nsf02078.pdf (accessed 2/19/03).

Biographical Information

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