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REU Site in Advanced Engineered Wood Composites

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Organization: University of Maine

Title:

REU Site in Advanced Engineered Wood Composites

Project Participants

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Worked for more than 160 Hours: No
Contribution to Project:
Research Mentor

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Worked for more than 160 Hours: No
Contribution to Project:
Research Mentor

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Worked for more than 160 Hours: No
Contribution to Project:
Research Mentor

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Contribution to Project:
Research Mentor

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Worked for more than 160 Hours: No
Contribution to Project:
Research Mentor

Name: Peterson, Michael
Worked for more than 160 Hours: No
Contribution to Project:
Research Mentor

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Worked for more than 160 Hours: No
Contribution to Project:
Research Mentor

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Contribution to Project:
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Post-doc

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Undergraduate Student

Technician, Programmer

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Contribution to Project:
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Worked for more than 160 Hours: No
Contribution to Project:
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Contribution to Project:

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Fiscal year(s) REU Participant supported: 2001
REU Funding: REU site award

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Fiscal year(s) REU Participant supported: 2001
REU Funding: REU site award

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Fiscal year(s) REU Participant supported: 2001
REU Funding: REU site award

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Contribution to Project:

Years of schooling completed: Junior
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Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2001
REU Funding: REU site award

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Fiscal year(s) REU Participant supported: 2001
REU Funding: REU site award

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Contribution to Project:

Years of schooling completed: Sophomore
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Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2001
REU Funding: REU supplement

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Fiscal year(s) REU Participant supported: 2001
REU Funding: REU supplement

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Years of schooling completed: Junior
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Fiscal year(s) REU Participant supported: 2001

REU Funding: REU supplement
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Fiscal year(s) REU Participant supported: 2001
REU Funding: REU site award
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REU Funding: REU site award
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Years of schooling completed: Junior
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Fiscal year(s) REU Participant supported: 2002
REU Funding: REU supplement
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Fiscal year(s) REU Participant supported: 2002
REU Funding: REU supplement
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REU Funding: REU supplement

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Fiscal year(s) REU Participant supported: 2002
REU Funding: REU supplement

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Fiscal year(s) REU Participant supported: 2002
REU Funding: REU supplement

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Fiscal year(s) REU Participant supported: 2002
REU Funding: REU supplement

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Years of schooling completed: Sophomore
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Fiscal year(s) REU Participant supported: 2002
REU Funding: REU supplement

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Fiscal year(s) REU Participant supported: 2002
REU Funding: REU supplement

Name: Donald, Waller
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Contribution to Project:

Years of schooling completed: Junior
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Fiscal year(s) REU Participant supported: 2002
REU Funding: REU supplement

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Contribution to Project:

Years of schooling completed: Junior
Home Institution: Other than Research Site
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Fiscal year(s) REU Participant supported: 2002
REU Funding: REU site award

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Contribution to Project:

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REU Funding: REU site award

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Contribution to Project:

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Home Institution: Other than Research Site
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Fiscal year(s) REU Participant supported: 2003
REU Funding: REU site award

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Contribution to Project:

Years of schooling completed: Junior
Home Institution: Other than Research Site
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Fiscal year(s) REU Participant supported: 2003
REU Funding: REU site award

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Fiscal year(s) REU Participant supported: 2003
REU Funding: REU site award

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Fiscal year(s) REU Participant supported: 2003
REU Funding: REU site award

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Contribution to Project:

Years of schooling completed: Junior
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Fiscal year(s) REU Participant supported: 2003
REU Funding: REU site award

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Contribution to Project:

Years of schooling completed: Junior
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Fiscal year(s) REU Participant supported: 2003
REU Funding: REU site award

Name: Robinson, Jonathan

Worked for more than 160 Hours: Yes
Contribution to Project:

Years of schooling completed: Sophomore
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Home Institution Highest Degree Granted(in fields supported by NSF): Master's Degree
Fiscal year(s) REU Participant supported: 2003
REU Funding: REU site award

Name: James, Upshaw
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Fiscal year(s) REU Participant supported: 2003
REU Funding: REU site award

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Fiscal year(s) REU Participant supported: 2003
REU Funding: REU site award

Name: Turner, Adam
Worked for more than 160 Hours: Yes
Contribution to Project:

Years of schooling completed: Sophomore
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Fiscal year(s) REU Participant supported: 2004
REU Funding: REU site award

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Contribution to Project:

Years of schooling completed: Freshman
Home Institution: Same as Research Site
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Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2004

REU Funding: REU site award

Organizational Partners

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

Findings:

Training and Development:

Outreach Activities:

Journal Publications

Books or Other One-time Publications

Sarah Blake, William Davids, and Eric Landis, "Towards Bridging Length Scales in Wood", (2003). Conference Presentation, Published
Bibliography: Presented at the Society for Experimental Mechanics Conference on the Mechanics of Biological and Bioinspired Materials

William Davids, Christine Riker, Justin Desjarlais, and Eric Landis, "Mixed Mode Fracture of Wood-FRP Bonds", (2004). Conference Presentation, Published
Bibliography: Presented at the Annual Meeting of the Forest Products Society

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Categories for which nothing is reported:

Organizational Partners

Activities and Findings: Any Findings
Activities and Findings: Any Training and Development
Activities and Findings: Any Outreach Activities
Any Journal
Any Web/Internet Site
Any Product
Contributions: To Any within Discipline
Contributions: To Any Other Disciplines
Contributions: To Any Human Resource Development
Contributions: To Any Resources for Research and Education
Contributions: To Any Beyond Science and Engineering

Activities and Findings – Training and Development

Research Projects

Below are abstracts for the projects conducted by the 10 NSF supported REU students. Included with each abstract are the project supervisor and associated graduate students. The abstracts were written by the students.

Structural Durability of FRP Drains in Bridge Decks

Micah Florea, Tulane University
Advisor: Roberto Lopez Anido

Fiber Reinforced Polymers (FRP) are quickly becoming the material of choice to solve civil engineering challenges in corrosive environments. In the state of Maine, where deicing salts are generously applied to roadways every winter, conventional steel down spouts used to drain concrete bridge decks are quickly corroded and need constant replacing. Looking to lower maintenance costs, the Maine Department of Transportation has joined efforts with the University of Maine to design an FRP down spout to replace the degraded steel ones. Three identical prototypes were fabricated, embedded in a simulated concrete decking, and were submitted to a series of laboratory tests to ensure structural integrity and to optimize the design for long-term durability. The tests included an ice formation study, dual-ramp compression loading tests based on the AASHTO HS25 loading specification, 100,000 cycle fatigue tests, ultimate compression tests, and reverse push out tests. The prototype proved to be acceptable, but not optimal. The prototype design was slightly modified and the new design described in this report is approved as a safe, functional, and durable drain system to be fabricated and installed in bridge decks throughout the state of Maine.

Timber Guardrail Splice Connection Design

Chad Gibson, University of Evansville
Advisor: William Davids
Participating Grad Student: Josh Botting

Research into designing an aesthetically pleasing and structurally sound timber reinforced guardrail system at the University of Maine is being sponsored by the New England Transportation Consortium. The project specifies the use of glulam beams, as opposed to the use of solid sawn timbers. The composite design will feature a strip of pultruded E-glass epoxy bonded to the tension side of the guardrail and bonded steel splice connections that will attach the railings to posts. Through modeling with the BARRIER VII program, it is apparent that large tensile forces must be transferred between rail sections. The splice connection design will remain as the central focus of this paper as a result of a tendency for structural failure at these critical locations. From BARRIER VII the projected critical axial load is 40 kips. A splice connection must be designed to transfer the loading across the rail system and be appropriately evaluated in a tension test. The connection, which has been tested, is a steel plate bonded to the FRP and bolted to the splice plate. The critical component of the splice is the steel to FRP bond. In order to assess this bond a test setup has been designed. The results of the test proved comparable to the capacity of standard W-beam guardrails.

Extrusion of Wood-Plastic Composites

Elizabeth Jordan, University of Connecticut
Advisor: Douglas Gardner

As an REU student the focus of my project was supposed to be the extrusion of wood-plastic composites involving nylon and pine wood flour. Unfortunately due to several miss haps with the equipment and machinery this project was not carried out. Sue to the fact that my original project did not pull through I have done a variety of things this summer and I have learned a great deal too. Although it may not sound like a lot I have also been able to gain an understanding of lab work and graduate school though the program this summer.

This summer I have seen polypropylene and wood flour extrusion as well as masonite and polypropylene extrusion. Our most recent extrusion involving mixtures of polypropylene and wood flour actually came out very well. after successfully making the wood-four polypropylene wood composite we did a four point bending test on our samples. For this we used the Instron 8801 universal testing machine. With these tests we found the maximum loading strength of our boards and then plotted our results. we also used the instron machine to test some commercial boards. We did water soak tests for these. Our results from these boards were also plotted and recorded. By doing these tests I learned how to use the instron 8801 and how to plot and record data in excel.

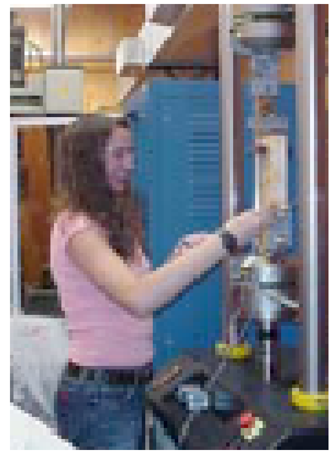
As stated earlier the woodtruder or Wt 94 was out of order for a good portion of the summer. While the machine was down I used the time to write work instructions and to begin a thermal expansion testing project. For the thermal expansion testing project I prepared samples and obtained a set up to test for the thermal expansion of wood-composites in relationship to time.

Before I started my thermal expansion project and during the time that the extruder was still broken I wrote work instructions and helped other students with their projects. After all of this I have no real results to show other than the few tests that we just completed but I did gain a great deal of experience. Even though I did not get to finish my project I learned how research can be unpredictable and how problem solving a key aspect of it all.

Multifunctional Reinforcements for Conventional Wood Composites: Lateral Nail Test

Katherine Jordan, University of Connecticut/Materials and Metallurgy Engineering
Advisor: Ciprian Pirvu

Conventional oriented strand board(OSB) is commonly used in construction. In certain areas that are prone to hurricanes, high winds, and high humidity, such as coastal areas, traditional OSB structures become weakened where they are connected to the wall studs. By desiging an effective edge protection system, moisture can be prevented from entering the wood compostie and causing deterioration. Also, the reinforcment should increase the dimensional stability and connector durability of the compostie. During this project, eight different types of reinforcement were tested for lateral nail holding strengh. These reinforcements were designed to prevent moisture from entering the wood composite at the connection joints and to increase the nail holding strength of the composite. In order to determine which reinforcements performed the best under both wet and dry conditions, a lateral nail test was performed on each type of sample under both wet and dry conditions. The samples were composed of Polyester Resin or Vinyl Ester Resin, Regular OSB and either, Glass Fabric, Aramid Fabric, Chopped Strand Fiberglass, or Fiberglass particles. Advanced OSB, 3/8 inch and 1/2 inch plywood as well as Regular OSB were used as control samples with no reinforcement added. Half of all the samples were soaked in a water bath for twenty-four hours. Each sample was then nialed to a stud and tested on a 22 Kip Instron machine. Together with the results of a nail pullthough test and the moisture content test, the most effective reinforcement can be chosen. From lookinag at the results of the Lateral Nail Test I noticed that Aramid Fabric tended to act well and the _ inch Plywood and Advanced OSB also performed well under wet and dry conditions. Further analysis is necessary in order to determine which method of reinforcement provides the greatest amount of reinforcement at the most reasonable price and with the most efficient application process.



Simulating the Failure and Load Deformation Response of Nailed and Bolted Connections

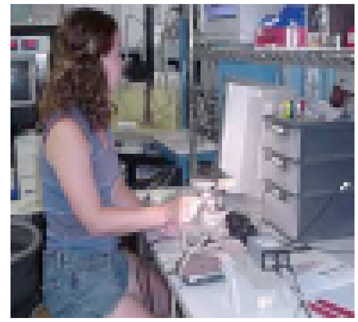
Melissa Kahl, Syracuse University, Civil Engineering
Advisor: Eric Landis

The prospective applications of computer simulations have a tremendous potential for deciphering of real world situations. One such application would be to the failure of wood that is joined together with either a bolt or nail. If the details of this failure of the two dominate fasteners in wood construction were to be correctly predicted, then it would be possible to begin to take necessary steps to prevent this failure. This purpose of this project was to compare the load deformation curve and the aesthetic distortions of the wood produced by the computer simulation, to those produced by the data collected from a simple tension test of these joints. The computer simulation works by first creating a lattice of the wood specimen through the definition of several variables including the thickness of the wood, its width and height, and the number of nodes. The beams and verticals connecting the nodes where the bolt or nail is located are removed to represent the damage caused by these penetrations, creating a notch in the middle of the mesh. The bolted mesh is represented as a square hole in the mesh, as opposed to the nailed mesh that is represented with the beams around the hole curved to simulate the distorted grain surrounding the notch. Each node is then assigned the appropriate restraints.   The nodes on the left border of the notch are given displacements to represent the force from the nail or bolt. The nodes on the right border of the specimen are all treated as fixed connections, excluding the end one which is treated as a pin. All of the other nodes are free to move. The experimental tension test was performed by inserting a bolt through a drilled hole in the wood and then through a piece of steel with a comparable predrilled hole. Steel was used to ensure that the wood failed on the side of the connection that was being recorded. Strain gauges were then attached to measure the extension of the wood. For the nailed connections, a concrete nail was used to hold the wood and the steel together and prevent slippage. All of the 20 tests for each connection were recorded with digital microscopy. The comparative results of the computer simulation and the tension tests were very similar. The typical computer simulation of the nailed and bolted connection predicted a generally linear extension vs. load curves that was very similar to the curves created from the tension test data. The visual deformations of the meshes when compared to the wood specimens were also alike with both models showing the portion of the specimen between the applied load and the wood border ‘pushed out’ of the wood.

Acquisition of the Elastic Constants of Small Diameter Timber Using Non-Destructive Ultra-Sonic Testing

Katherine Kwasnik, Boston College/Physics
Advisor: Michael Peterson

The elastic constants of wood are an important factor in how the wood can be used. The constants that correspond to large diameter wood are well known, making it more desirable than small diameter wood, which has constants that are significantly different from those of mature wood and are not as well understood. Small diameter timber causes a fire hazard in National Forests, and must be thinned out in order for a healthy forest to thrive. However the small diameter trees that are thinned are not often used because the properties are not well understood, and thus it is difficult and costly to thin these forests. The purpose of this project was to use ultra-sonic testing to find the elastic constants of small diameter timber to facilitate the use of these trees. Twenty spherical wooden balls were made out of sitka spruce on a wood lathe and conditioned in an environmental chamber so that the results can later be repeated and confirmed. An apparatus was constructed that allows an ultra-sonic wave to be passed through the ball, and the ball to be turned so that the wave can pass through at different angles and in different incident planes. The transducers were connected to an oscilloscope, and a computer recorded the data. Each ball was turned through 25 angles in each of 4 incident planes. A lens was connected to a television to allow the angles to be accurately measured. This data was processed in a MatLab program to calculate the velocity of the wave in each of the angles. The velocities calculated are then used to calculate the elastic constants of the balls that were tested. The wave was expected to travel at different speeds different planes of symmetry, since wood is an aniostropic material. The velocity curves that were acquired with the data showed that, with a few inconsistencies due to the fact that wood is not a consistent material subject to environmental conditions, the velocities fell into three levels, confirming the fact that there are three planes of symmetry in the samples. This data indicates that the data collected will allow the elastic constants to be found using the method developed. The elastic constants could not be calculated due to an optimization problem in the MatLab program designed to calculate the constants, but the velocity curves support the expectation the elastic constants can be found from this data.



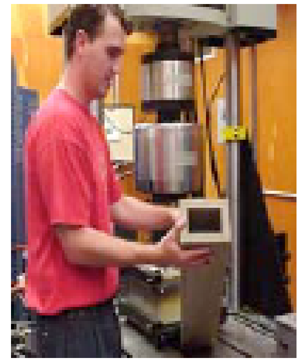
Improved Fluid Penetration in Permeable, Impermeable Woods and Composites: Analysis of the Role of Compressed Air in Pressure Processes

Seth McDonald, King College/ Physics
Advisor: Barry Goodell
Participating Graduate Student: Ben Herzog

Previous work has shown that compressed air pockets form in impermeable timber species during pressure treatments. We have hypothesized that venting to atmospheric pressure will allow the compressed air to be released from wood resulting in increased apparent permeability. Our initial work to test this hypothesis has been done with both aqueous dyes in wood, and with a model system using liquid resin to penetrate highly permeable E-glass fabric sandwiched, or bound, between layers of impermeable plastic wood. Aqueous experiments included those with non-vented and single vent samples of 2” x 6” x 2’ long southern yellow pine where venting was to the atmosphere. Samples were submersed in containers of aqueous dye prior to the application of pressure. The applied pressures were 60 and 120 psi for periods of 30, 45, 60 minutes. This round of experiments included full cell processes. For the liquid resin experiments with E-glass, billets of 1” x 6”-2’ plastic lumber were ported with one vent, two vent, and five vents, or were left unvented. The samples were immersed in resin, and the pressures again were 60 and 120 psi for a period of 2 hours. Venting did not appear to increase the dye weight retention in the southern pine. However it did improve penetration of resin in the glass fabric samples. The largest increase in resin infusion appeared to occur when only a single-vent was applied. Increasing additional vents marginally increased resin infusion but this limited increase may have been due to the small size of the samples. Clamping number, pressure, and position all affected the infusion of resin. Although venting did not improve weight retention in the southern pine wood, the penetration data were not examined in this work. Future work should therefore explore how fluid penetration in wood is affected by venting to relieve air compression. A study of the effects of clamping pressure on infusion is also recommended.

Buckling of Wood-Plastic Composite Columns

Ryan Vignes, University of Iowa/Mechanical Engineering
Advisor: M. Asif Iqbal



Due to the navy's extensive ownership of wooden marine structures, it is extremely interested in enhancing docks and piers to better withstand the hazards of their aqueous environment. Wood-plastic composites as possible replacements for conventional wood in structurally demanding applications have recently become an area for extensive research. Along with wood-plastic composites' increased ability to endure an aqueous environment by resisting fungal decay and marine borers, the composite is also a practical solution to help improve environmental concerns such as rapid deforestation. Since the composite is composed mostly of wood fibers embedded in a plastic matrix, less wood is required for a structural member, resulting in a diminishing demand for logging. Additionally, wood-plastic composites do not require the application of the dangerous and hazardous chemicals used when treating conventional wood. In addition to these attributes, the composite material can be handled and assembled in the same manner as conventional wood; no modification of current construction equipment is necessary [Dagher 01]. Before wood-plastic composite columns can be used in a structural capacity, their reactions and ability to support loads must be evaluated. To perform this evaluation, the material properties must be determined. Column reactions will then be analyzed both experimentally and analytically with ANSYS, a finite element analysis package.

Post Peak Deformation of Wood Loaded Parallel to the Grain

Donald Waller, University of Central Florida/Civil Engineering
Advisors: Eric Landis

Fracture mechanics is based on the study of the stress and displacement at the fracture process zone. This zone is the region around the tip of the crack. For many years wood has been an interesting subject to study in the category of fracture mechanics. Brittle fracture (unstable crack growth) has been known to commonly occur in wood specimens. This projects goal was to determine the complete tensile response of a notched wood specimen. There were no ASTM specifications for this type of experiment so they were determined by pre-testing. A dog-boned spruce specimen was determined from the pre-testing and was loaded until fracture at two different rates using the Instron 8801. The control mechanism for our experiment was the crack mouth opening displacement (CMOD). Strain gauges were attached to each side of the specimen and used as the output of the CMOD. The larger of the two was used as the control of the closed loop. The purpose of the closed loop is to keep the CMOD at the rate desired. Eighteen specimens were tested at a rate of 0.05 mm/min. Two data points were collected every second and were used to formulate the load vs. strain graphs. For the most part each the graphs showed unstable crack growth and nothing new was discovered to differentiate the results from earlier experiments done by other researchers. Modifications were made and fifteen more specimens were tested. The rate was changed to 0.02 mm/min and the machine was manually tuned. Automatic tuning was used in the earlier testing and showed a deviation of 1mm in some parts. The first five specimens were tested at the new rate and during the test the strain gauges were unable to find the desired signal and started vibrating. It was too slow for the machine so the final 11 specimens were tested at the original rate of 0.05 mm/min. The same unstable crack growth occurred for the remainder of the tests. The suggestion I have for future study of this subject is to use a different strain gauge setup. Strain still needs to be the control but the extensometers didn't perform the way we needed them to for us to achieve our desired goal of stable crack growth. Future study, with some modifications and the right tools, has the potential for determining the complete tensile response of a wood specimen.

Active Vibration Control of a Carbon Composite Beam, Using Piezoelectric Actuators and Sensors

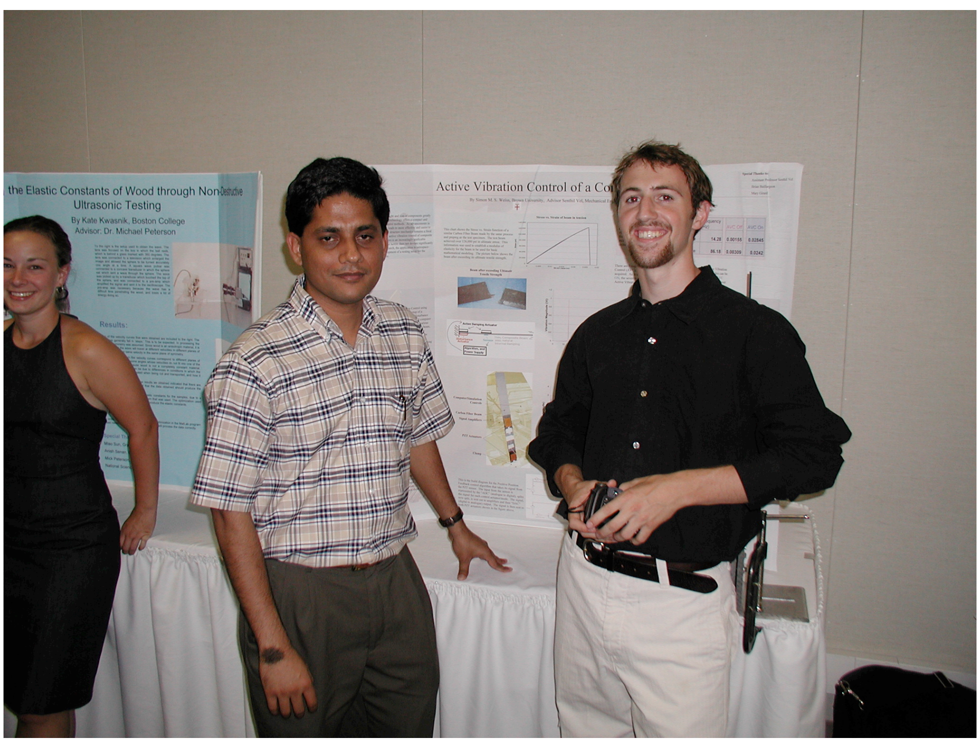
Simon Weiss, Brown University/Mechanical Engineering
Advisor: Senthil Vel

“Smart Structures” are mechanical systems that utilize lightweight, energy efficient electronics to actively dampen out mechanical vibrations, where passive damping units are not suitably effective or too cumbersome for the design application. Active Vibration Control (AVC) using piezoelectric actuators (PZT) has applications where weight is a factor, and thus lightweight, stiff composite structures are in use. Space and Aeronautic systems can benefit from PZT AVC because both applications rely on the accuracy and precision of lightweight structures.

To determine the relative effectiveness of Active Vibration Control using Piezoelectric (PZT) actuators and sensors, an experimental setup of a cantilevered, thin carbon fiber beam, three PZT actuators (one disturbance actuator, and two active damping actuators) and a PZT sensor, and computer interface and control algorithms was created. The effectiveness of various simple active control algorithms was compared to free vibration of the beam, and a simple PZT-resistor damping system by measuring the frequency response of the system, time-response after excitation, and comparing the calculated damping coefficients.

Two methods were used to show the effectiveness of the AVC. The time response functions of the beam show decrease in vibration magnitude with respect to time after momentary disturbance (manually tapped). Because of the method used to begin vibrations in the beams, the initial magnitudes from test to test are not necessarily consistent, but the data still provides useful qualitative and quantitative information. As can be seen from the graphs, it takes the model without damping 8 seconds to reach 10% its initial vibration magnitude, while the AVC damped version takes less than 1 second. The frequency response functions (FRF) of the beam *with* and *without* Active Vibration Control (AVC) shows how the AVC affects the first and second vibration modes. As is apparent from the slopes of the mode peaks from AVC OFF vs. AVC ON, the severity of slope and magnitude of the vibration is *substantially* greater without Active Vibration Control.

The test results and other information acquired this summer show the effectiveness of active vibration control using PZT material relative to passively and free-damped systems.



Recruitment and Selection Process

Approach

As with 1998-2001, we focused our recruiting efforts on an internet-based strategy. We prepared electronic versions of our promotional information and our student application. We then conducted a "shotgun" e-mailing to both selected faculty and student organizations throughout the country. Specifically, we identified about 200 faculty contacts that we knew would distribute our informational material to interested students. These faculty were primarily in fields of civil and mechanical engineering, wood science, and wood technology programs at national universities, including several minority institutions. In addition we identified approximately 20 New England liberal arts colleges, (including all women's colleges). At these schools we contacted science (physics, chemistry, biology, math and computer science) faculty to whom we sent our materials.

In addition to the faculty contacts we combed the web for contacts in student chapters of professional societies. These societies included the American Society of Civil Engineers, American Society of Mechanical Engineers, Society of Women Engineers, Society of Black Engineers, and the Forest Products Society. We sent our materials to as many student contacts as we could find published on the web. Our thinking was that if possible it is best to get the information directly into the hands of those who can most benefit. About half of our applicants came in as a result of this "direct mail" approach. The second leading source of applicants was the NSF REU website.

Applicant Pool

A total of 24 students formally applied to our program, which is down from previous years. At this point we'll assume it a statistical variation, and not a trend. The overall quality of applicants, however, was excellent (average GPA of 3.44). By college major we had twelve in civil engineering, two in chemical engineering, three in mechanical engineering, two in materials science, two in physics, and the remainder in a variety of science and engineering disciplines.

Geographically our applicants came from all parts of the country. Applicants came from the following universities:

- Arizona State University
- Boston College
- Brown University
- Columbia University
- Cooper Union
- Eastern Kentucky University
- King College
- Santa Monica College
- Seattle University
- Swarthmore College
- Syracuse University
- Tulane University
- University of Central Florida
- University of California-Davis
- University of Connecticut (2)
- University of Delaware
- University of Detroit Mercy
- University of Evansville
- University of Houston
- University of Iowa
- University of Oklahoma
- West Virginia University
- Worcester Polytechnic Institute

While the list represents a relatively broad spectrum of institution types, the majority of applicants came from large research universities. This is likely due to the engineering focus of the program, and engineering programs tend to exist at larger universities. For 2003 we will modify the promotional materials to better emphasize the wide range of disciplines that are supported by this program.

The diversity of the applicant pool was not as good as previous years, but still respectable. We seem to do reasonably well recruiting women applicants (42% of pool), however declared racial minorities represented only 20% of the pool. (17% did not respond to the optional question of racial background.) In total, 50% of the applicants were from under represented groups.

In selecting the students for our program we look at a combination of academic achievement (evaluated through grades, activities, and recommendations) and mutual interests with participating faculty (evaluated through their required statement of interest). We had little trouble matching students to faculty. The ten positions were filled after making offers to fifteen applicants.

Table 1 presents a list of the student participants. The demographic characteristics of the students participating in the program are shown in Table 2.

Table 1. 2001 UMaine AEWC-REU Participants

Name	Home University	Major	Yr
Micah Florea	Tulane University (D)	Civil Engineering	Sr
Chad Gibson	University of Evansville (M)	Civil Engineering	Jr
Elizabeth Jordan	University of Connecticut (D)	Materials Engineering	So
Katherine Jordan	University of Connecticut (D)	Mechanical Engineering	So
Melissa Kahl	Syracuse University (D)	Civil Engineering	Jr
Katherine Kwasnik	Boston College (D)	Physics	So
Seth McDonald	King College (B)	Physics	Jr
Ryan Vignes	University of Iowa (D)	Mechanical Engineering	Jr
Donald Waller	University of Central Florida (D)	Civil Engineering	Jr
Simon Weiss	Brown University (D)	Mechanical Engineering	So

Highest degree in NSF discipline: B = Bachelor, M = Master, D = Doctorate

Table 2. Demographic Characteristics of Students in Program

Principal Investigator: ***Eric N. Landis***

Award Number: ***EEC-0097500***

Students:	***Female***	***Male***	***Total***
Race:			
American Indian or Alaska Native			
Asian			
Black or African American			
Native Hawaiian or Other Pacific Islander			
White	*4*	*6*	*10*
Ethnicity:			
Hispanic or Latino			
Not Hispanic or Latino	*4*	*6*	*10*
Disability Status:			
Hearing Impairment			
Visual Impairment			
Mobility/Orthopedic Impairment			
Other			
None	*4*	*6*	*10*
Classification:			
Senior		*1*	*1*
Junior	*1*	*5*	*6*
Sophomore	*3*		*3*
Freshman			
Citizenship:			
U.S. Citizen	*4*	*6*	*10*
Permanent Resident			
Other non-U.S. Citizen			
Choice:			
From own institution			
From other schools	*5*	*5*	*10*

Student Activities

We tried in all our activities to strike a balance between structure and independence, group and individual learning, and educational and social activities. A summary of the various activities is shown in Table 3. The program was structured so that all ten students would be part of a single team working toward a common goal. Although individual research projects were quite different, at the end of the nine weeks, there could be no doubt about their shared goal.

Table 3. Scheduled Activities: 2002 UMaine AEWC REU Program.

Week	***Research Activities***	***Seminars/ Group Meetings***	***Field Trips and Special Events***
1	• Tour of campus and departmental research facilities • Advisors to introduce each student to their research topic • Develop Research Plan.	"Introduction to Advanced Engineered Wood Composites" Dr. Habib Dagher Short course on Research Methods – Dr. Eric Landis, Dr. Mick Peterson	• Monday morning coffee and bagel get –acquainted/orientation meeting • Friday afternoon hike at Acadia National Park
2		Monday Meeting Student presentations of Research Plans	
3		Monday Meeting	Maine Composites Conference – Portland
4	• Students work on their research project	Monday Meeting Marketing Issues in Product Research and Development	
5	• Submit weekly progress report to advisor	Monday Meeting Student presentations: "Research in Progress"	Group field trip to Louisiana Pacific Oriented Strand Board Plant
6		Monday Meeting Intellectual Property Issues in Science and Engineering	Ascent of Mount Katahdin
7		Monday Meeting Graduate School: How do I get in, how do I pay, and how do I choose?	
8		Monday Meeting	
9	Each student writes research report and prepares final poster presentation	Monday Meeting	Thursday night banquet and presentation of research posters

The topics listed are self-explanatory with the exception of the Monday Meetings. The group met every Monday morning of the program period in an informal setting. The topics of discussions varied, but in most cases the meetings were led by a faculty who discussed their work and how it related to the overall R&D effort of the AEWC center. The informal setting was intended to encourage interaction between the students and the faculty.

Stipend and Other Expenses Paid

The students were paid a stipend of $3600 for participation in the nine-week program. In addition, housing was covered for those who chose to live on campus. The on campus housing was a fraternity house where the students lived together among other UMaine students. Living together reinforced the sense of community established in the laboratory, while living with other students gave them insight into life at UMaine and the surrounding community. All ten students chose the on-campus living.

Travel expenses were covered for all students to and from Orono at the beginning and end of the summer.

Contributions to Human Resource Development

Project Assessment

As with last year, our project assessment consisted of two parts: A quantitative measure of certain benchmarks, and student questionnaire for more qualitative measures of program effectiveness.

Quantitative Measures

We made quantitative measures of our 2002 class in the following areas:

Publicity and Recruitment:

- number on inquiries – 32 (phone or email)
- number of applicants – 24
- number of under represented applied – 12
- number of under represented offers – 4
- number of offers turned down – four

Student interest in research (includes 2001 class):

- number of students who continue research project beyond nine week program – 2
- number of students who apply to graduate science or engineering programs – 2 to date
- number of students who enroll in graduate science or engineering programs – 2 to date

Scientific quality (includes 2001 class):

- number of refereed journal publications: 0
- number of conference and other publications resulting from program (in order to qualify, student must be co-author) – 1
- external research support that results from pilot studies conducted under REU program – 4 pending.

As indicated above, the diversity of the applicants was acceptable, but not as good as in the past. The areas where we need to improve are the number of applicants from smaller colleges, particularly minority institutions. In addition we would like to widen the range of academic disciplines represented. Efforts are being made to improve in these two areas for 2003.

It is too soon to fully gage the impact of student interest in research. Most of the participants are still completing their undergraduate studies. A brief questionnaire will be sent out to program "alumni" as a follow-up to their summer experience. We are cautiously optimistic that most of the participants will pursue advanced degrees in science or engineering.

As with previous years, the scientific quality has been quite mixed, ranging from outstanding (likely publishable in refereed journal) to fair. Again, the key seems to be to match the students up with a project that excites them and motivates them to do good work. (Also there is a bit of luck required – no student lab blunders, no equipment malfunctions, no materials backorders, etc…) While we design each project to produce publishable results in the nine week period, to date only three projects have produced publishable results. One has been published, one is in review, and one is in preparation.

Participant Survey

A 29-question survey was given to the students at the end of the summer to give us feedback on students' opinions of the program. A copy of the survey is included at the end of this section.

We found the students to be overall very happy with the program. (mean response to question 28 – "Your overall evaluation of the program" – was 8.33 on a 10 point scale). The survey gave us lots of feedback on housing (most want as cheap as possible), the most valuable activities (field trips), biggest problems (faculty travel), and general administration.

The survey results indicate we are doing the following things well:

> A strong commitment of the mentors to providing an enriching research experience.
>
> An enthusiastic program director.
>
> Providing a living and working environment that leads to an enriching and rewarding intellectual experience.

The survey results indicate we need to improve in the following areas:

> Better pre-arrival communications between the mentor and the student, so the student could "hit the ground running."
>
> Provide alternate research advisor when the regular mentor is traveling.

Below are some sample student comments:

> "Before this I wasn't sure what 'research' really entailed. Now I feel I understand."
>
> "The program was structured well with a good balance of work related issues and exciting and engaging outside activities."
>
> "It was a great way to spend the summer – working/learning, finding out what research is all about, clinging to cliffs for dear life… what could be better?"

Individual program elements were evaluated. The faculty research discussions continue to get better reviews, indicating a better understanding of the audience by the presenters.

Summary

We are quite confident of our ability to provide a polished program for our students based a combination of our growing research facilities and our experienced faculty. The devil is always in the details however, and additional refinements will continue to be made to improve the student the experience.

Advanced Engineered Wood Composites
2002 Research Experience for Undergraduates Program
Participant Evaluation

How did you learn about the program?

1. NSF Web Site
2. Received information from faculty. (who? __________________)
3. Received direct e-mail message
4. Other (please list: __________________________________)

Did you apply to other similar summer programs? If so, how many?

Was the information you received on travel, housing, and program prior to your trip to Maine adequate? What could be improved?

Why did you choose this program over other opportunities you may have had?

How much did the stipend amount ($3,600) weigh into your decision to accept this position?

1	2	3	4	5
not at all				a lot

Was the fraternity housing acceptable? If not what would you suggest we do in future years? Would you pay more money (or receive a smaller stipend) in exchange for a nicer apartment?

Did you like living with the other REU students, or would you have preferred to be on your own?

One of the objectives of the program was to put you into a multi-disciplinary research environment. How well do you think this goal was achieved?

1	2	3	4	5
I spent the summer in a cocoon				I was aware of the wide range of activities

Do you feel the research you were engaged in was of importance?

1	2	3	4	5
not important				very important

Do you think you will continue to correspond with your research group?
Other REUs? (y/n)
Your advisor (y/n)
Other UMaine students, staff, faculty (y/n)

Is it likely you will apply to graduate school in science or engineering?

11. How do you think this REU program will affect your decision?

1	2	3	4	5
not at all				very much

How might this REU program experience affect your education? (check any that apply).

- ❒ By integrating your research results into course material
- ❒ By choosing different courses
- ❒ By sharing research experiences
- ❒ By revealing opportunities for future career options
- ❒ By deepening your enthusiasm and understanding
- ❒ Will have little or no impact

Do you think prospective employers (or graduate admissions officials) will think highly of your participation in this program?

1	2	3	4	5
not at all				very much

Did you develop new areas of interest as a result of your interaction with the REU program and/or research colleagues?

1	2	3	4	5
none				many

comments?

Did you feel you were adequately challenged by your research project?

1	2	3	4	5
not at all				very challenged

If not what would improve it?

Do you think the program gave you a taste of graduate research? (y/n)

comments?

Please rate the following on a scale of 1 to 10. (1 being lowest/worst, 10 being highest/best)

Program administration. (e.g. application process, communication, etc…)

1 2 3 4 5 6 7 8 9 10

comments?

Organized social activities.

1 2 3 4 5 6 7 8 9 10

comments?

Landis "Research Methods" presentations

1 2 3 4 5 6 7 8 9 10

comments?

Goodell Seminar on Wood.

1 2 3 4 5 6 7 8 9 10

comments?

Gardner Seminar on Wood Plastics.

1 2 3 4 5 6 7 8 9 10

comments?

Lopez Anido Seminar on Composites.

1 2 3 4 5 6 7 8 9 10

comments?

Landis "discussion" on Graduate School.

1 2 3 4 5 6 7 8 9 10

comments?

Watt Seminar on "Commercialization Issues."

1 2 3 4 5 6 7 8 9 10

comments?

What programs would you have liked to see but did not?

Rate your advisor on the following (1 to 10):
Explained project objectives and relevance ____
Approachability ____
Helpfulness ____
Enthusiasm ____
Knowledge ____
Ability to explain ____
Ability to advise ____

Comments:

Your overall evaluation of the program.

1	2	3	4	5	6	7	8	9	10
Sucked									Totally Cool

comments?

Your overall impression of the AEWC and the University of Maine.

1	2	3	4	5	6	7	8	9	10
Sucked									Totally Cool

comments?

Please list three changes you would make to improve the experience for future students?

Activities and Findings – Training and Development

Research Projects

Below are abstracts for the projects conducted by the 10 NSF supported REU students during the summer of 2003. Included with each abstract are the project supervisor and associated graduate students. The abstracts were written by the students.

Bridging Length Scales in Wood with Lattice Models
Sarah Blake, University of Maine, Mechanical Engineering
Advisors: William Davids and Eric Landis

The lattice model being used to predict the fracture and failure of wood is based on experimental data for small pieces of clear wood. The element properties are determined to fit these macroscopic properties. The goal of this project is to use known properties of individual wood fibers to determine more realistic properties for the elements parallel to the grain, which represent bundles of wood fibers. A Matlab program is used to create virtual fibers with random strengths and stiffnesses based on the experimental average and coefficient of variation of each of these properties. The program simulates applying a tensile force to a bundle of fibers, yielding the strength and stiffness of this bundle. The properties are calculated for bundles of earlywood and latewood fibers from various growth rings and heights. The lattice model is adapted to have rows of earlywood and latewood elements, with the number of fibers in each element found so that the average element strength is equal to the strength used previously in the model.

Experimental-Analytical Approach to Characterize Core Failures in Carbon Composite Sandwich Panels Based on a Modified Hydromat Test Method

Andrew Brinks, Michigan State University, Civil Engineering
Advisor: Roberto Lopez-Anido
Participating Grad Student: Paul Melrose

Composite sandwich panels, made of high stiffness face sheets and low-density core materials are becoming increasingly implemented in transportation and marine structures due to their high strength to weight ratio and their corrosion resistance. The Hydromat standard plate bending test, ASTM D6416, is a recent experimental approach to characterize composite sandwich panels. A uniformly distributed load is applied on a plane by means of pressing the sandwich panel onto a water-filled bladder. However, using the standard pressure bladder and a flexible panel it is often difficult to create large enough deflections to induce panel failure without interferences with the edge supports. Furthermore, the standard bladder tends to induce core shear failure relatively close to the edge supports at the boundary. Composite sandwich plate theory was implemented with a Navier's double Fourier series solution to predict deflections and strains. Carbon composite sandwich panels were fabricated with two different core materials: end-grain balsa wood and closed-cell polyetherimide foam. The panels were fabricated by the VARTM/SCRIMP process using vinyl ester resin for infusion molding.

The objective of this study was to characterize core shear failures using a smaller pressure bladder. The smaller pressure bladder induced core shear failures away from the edge supports, and therefore avoided boundary effects. Composite sandwich plate analysis was conducted to model the smaller bladder and predict deflections, surface strains and core shear failure locations. To analyze core shear failures, the shear properties of the core must be characterized. The standard core shear test, ASTM C273, was considered with two different loading schemes. In the core shear test, the compression loading scheme successfully induced shear failure in the specimens, while the tension loading scheme resulted in localized peeling failure. Both in the core shear tests and the panel bending tests, balsa wood panels exhibited a linear response with brittle failure, while foam panels showed a non-linear response with considerable plastic deformation prior to failure. Using the smaller bladder, panels exhibited core shear failure away from the supports. The composite sandwich plate model was capable of computing deflections and surface strains of the balsa wood panels and predicting the location of core shear failure.

Economizing the Temporary Bridge

Mack Conachen, University of Minnesota, Civil Engineering
Advisors: Robert Lindyberg, Olivia Sanchez

The Maine department of transportation along with the Innovative bridge Research and Construction committee, commissioned a design for an economically efficient, high life cycle, temporary bridge. Temporary bridges are used to allow traffic to flow around work being done on more permanent structures. The objective of my research was to test and refine a design of such a bridge.

Description of Proposed design

The intent of the proposed design is to reduce the overall cost involved with temporary bridges by minimizing construction time and maximizing life of materials. The proposed design to achieve these goals, calls for a continuous bridge deck heavy enough to eliminate the need to fasten the deck to the girders below.

Making the deck thicker both minimizes the installation time (by removing bottom clips) and potentially lengthens the life cycle of the deck (possibly being used in several projects instead of the current single use.) Currently the standard bridge is composed of 5" thick wooden decks clipped individually to the girder below. The proposed design will take two of these decks and laminate them together so that a lap joint will occur when sections are placed side by side. This lap joint will be mechanically fastened.

Strategy for testing design

The ability for the bridge deck to act as a continuous diaphragm will be dependent on the strength of the materials and the points where the materials are joined. In order to refine the design of the deck it was necessary to test the capacities of the lamination joints and the mechanical joints. The decks were laminated together using FPL-1, (an adhesive developed by Forest Products Laboratories.) The strength of this lamination is dependent on the penetration of the adhesive into the wood. Penetration is achieved by balancing the viscosity of the adhesive with the clamping pressure. A higher viscosity helps to keep the adhesive in place while under clamping pressure; however it also makes it more difficult to push into the pours of the wood. To test this relationship, samples were produced with varying degrees of viscosity and clamping pressure. The samples were then subjected to the standard method of accelerated weathering. The test uses alternating vacuum and pressure to saturate the wood. After the wood is dried overnight the percentage of de-lamination is measured. All of the samples had 100% de-lamination.

Recommendation for Further Study

This leads to the conclusion that alternate methods of lamination should be explored. A few possibilities include; using the organic compound hydroxyl-methylated resorcinol to assist FPL-1 bonding, using a polyurethane adhesive, or using a PRF adhesive. The wood beams that were salvaged to make the samples were laminated using the PRF. Those lamination joints were considerably more successful under accelerated weather testing.

A Comparison of Different FRP Fabrication Techniques by Void Content Characterization

Michael W. Crowell, Virginia Tech, Engineering Science and Mechanics
Advisor: Barry Goodell
Participating Graduate Student: Benjamin Herzog

Fundamental to the polymeric composites industry is the actual process of infusing structural fabrics with resins to create fiber reinforced polymers (FRPs). Previous work has suggested that VARTM/SCRIMP based processes generate microvoids in the resin during fabrication due to the vacuum used in processing 'boiling' the solvents from the resin. The Composites Pressure Resin Infusion System (ComPRIS) is a newly developed process for FRP composite fabrication, whereby resin is infused through fiber reinforcement via external pressure applied in an autoclave or pressure unit, as opposed to a vacuum. We therefore wished to specifically explore whether SCRIMP-fabricated FRP material had a greater percentage of voids compared to ComPRIS-fabricated FRP, and if location within an FRP panel (near the final resin front vs. near the resin delivery point) reflected differences in void content. We also wished to determine the effect of voids on certain

mechanical properties of the FRP panels, so sample testing to determine apparent interlaminar shear strength (AILSS) was also performed. Three FRP panels composed of E-glass unidirectional woven fabric and an epoxy vinyl ester resin were fabricated using both the ComPRIS and SCRIMP processes. Specimens from each panel were tested to determine apparent void content (AVC) and AILSS. Panels made using the ComPRIS process demonstrated both better and more homogenous properties than panels made using the SCRIMP process in terms of both methods of void content characterization: AVC and AILSS. SCRIMP panels demonstrated clear relationships between panel location and both AVC and AILSS while there appeared to be no significant variations in the ComPRIS panel data with respect to panel location. Finally there did appear to be a logarithmic relationship between AILSS and AVC across both processes, especially when only AVC data from the panel mid-depths, theoretically the plane of maximum shear stress, was considered.

Mimosa Pudica: Understanding Seismonastic Movement and Turgor Release

Lydia Deere-MacLeod, Smith College, Geology
Advisor: Michael Peterson and Eric Landis
Participating Graduate Student: Edwin Nagy

Biomimetics and biomimicry have existed for a very long time as a means by which humans can fashion practical devices from ideas based in the natural world. My project this summer was to gather the information needed about the Mimosa plant so that a computer model could be created to combine the cell movement and load capacities of the plant with the physical construction of supersonic jet wing panels. The goal at the beginning of the summer was to find/create the properties of a material that could be applied to jet engineering. The focus of our research changed in the middle of the summer with more specific attention being placed on understanding the plant cell construction and nastic movement capabilities of the Mimosa plant. The majority of my time was spent on text research covering the very basics of botany and eventually more specific molecular structures specialized for mechanical stimulus induced movement in the Mimosa. From this research I have been able to put together a guide for understanding the movement of ions and water concentrations in motor cells of the pulvinus, stationed at the base of the leaf petiole. This movement of fluid is responsible for changes in turgor pressure, which ultimately controls the elongation and collapse of individual plant cells. The information gathered must be compared with properties of jet wing construction and a relationship will need to be developed so that pertinent knowledge can be applied in the long-term project of developing a new jet wing material prototype.

Determination of Strain Energy Release Rate in Wood-FRP Bonds Due to Mixed Mode Bending

Justin Desjarlais, Alma College, Physics and Mathematics
Advisor: Eric Landis
Participating Graduate Student: Matthew Richie

Glue laminated beams have been used in construction for some time but they have recently begun to be strengthened with the help of fiber reinforced polymers, or FRPs. These FRP glu-lam beams are particularly useful in bridge applications but due to the relatively new nature of these products their longevity is still to be determined. Therefore this research project was undertaken to examine one aspect of the beams construction that is questionable. Over time cracks are expected to develop in the bond between the wooden beam and the FRP. The goal of this research was determine the strain energy release rate of a crack propagating in the bond line due to a combination of Mode I and Mode II bending. In order to do this an apparatus was designed and machined that allowed multiple ratios of mixed mode bending. The test specimens were constructed of Douglas fir and FRP with an initial delamination to simulate a crack. They were loaded in the mixed mode bending apparatus under displacement control and the compliance of the system was computed experimentally using

flexure load and flexure extension. Measurements of crack growth were taken and used to compute the strain energy release rate using first principles from fracture mechanics. Four different ratios of Mode I to Mode II were used which allowed a curve to be drawn that described the interaction of these bending modes in mixed mode testing.

Determination of Critical Strain Energy Release Rate for Mode II Fracture in FRP-Wood Bonds

Christine Riker, Albion College, Mathematics
Advisor: Eric Landis
Participating Graduate Student: Matthew Richie

Wood glulam beams are large beams made up of smaller boards glued together. The locations of the beam that experience the most stress are the top and bottom boards. A more recent method to make stronger glulam beams is to use FRP (Fiber-Reinforced-Polymer) as the bottom piece of the beam. FRP is approximately twice as strong as wood. Thus instead of high quality wood on the bottom of the beam to take the large stress, FRP is bonded to the bottom of the glulam beam using an epoxy. While the bond between the wood and FRP is very strong, delamination still occurs between the two through normal weathering and fatigue. The most common location is at each end of the beam. Small cracks in the bond do not cause the beam to decrease in strength but large cracks do.

The problem to be solved is that in order to build with these new stronger glulam beams specifications need to be created to ensure safety. One of the needed pieces to the specifications is how much energy the beam can withstand before a small crack will propagate into a large crack. The energy at which the crack propagates is called critical strain energy release rate (G_c). Cracks normally grow due to Mode I, Mode II, Mode III or a mixture of the three crack propagation modes. The objective of this summer's research was to find the critical strain energy release rate for a specimen made of wood bonded to FRP with crack propagation due to Mode II fracturing.

The method used to find G_c was to create small specimens made of wood bonded to FRP. An initial crack was created in the specimen by not bonding a small section of one end of the specimen. Then the specimens were tested with a three point bending test in an Instron to simulate Mode II fracture. After testing 63 specimens the mean value of G_c was found to be 1230 N/m.

Structural Bonding of Wood Plastic Composites

Jonathan Robinson, Milwaukee School of Engineering, Architectural Engineering
Advisor: Douglas Gardner

The basis for this research was to expand the economic feasibility of producing large profiles out of wood plastic composites. The cooling process that takes place after the extrusion process greatly limits the shapes and sizes wood plastic composites can be formed into. The ability to structurally bond wood plastics with an adhesive system would make it simple and economic to produce a large array of structural shapes and solid profiles. The objectives of this experiment were to structurally bond wood plastic composites with an adhesive system and to look into surface preparations and treatments to note effects on adhesion. There was a natural, planed, and sanded surface preparation on polypropylene wood plastic boards used for all the adhesion systems. Both wood and plastic adhesive systems were examined and eight systems were devised to test in the ASTM D905 shear test. Due to the superb results of one particular adhesive system, this system was tried on other available wood plastic composites (polyethylene, polystyrene, and PVC). The results of this adhesive system that included a special surface treatment and FLP-1 epoxy, on the four types of wood plastics tested conclude that wood plastics can be structurally bonded in this manner. Another test was also conducted to observe how the system stood up to exterior conditions. The test used was ASTM D2559; this test included pressure soaking, steaming, and oven drying of cut samples. The results of this test were 0% delamination of the adhesive and material, showing that this system can withstand exterior use. Final conclusions from these tests are that this special surface treatment alters the bonding properties of wood plastic composites making it possible to structurally bond them with an adhesive system that can stand up to exterior abuse. Due to the novelty, simplicity, economic feasibility, and results of this adhesive system on wood plastics, it is being looked into as a patentable process. This process could potentially be used in wood plastic composite fabrication to economically produce solid profiles, complex forms, and structural shapes.

Evaluation of Non-Destructive Testing for Elastic Constants in Carbon-Carbon Composites

J. Michael Upshaw, University of Oklahoma, Industrial Engineering
Advisor: Michael Peterson
Participating Graduate Student: Anish Senan

Carbon-carbon composites are widely used in aerospace applications for components that experience a severe aero-thermal environment. To date, a full set of elastic constants for the material is not available in the open literature. Currently there is an ongoing effort by the research team at the University of Maine to use ultrasonic testing methods to measure the elastic properties of carbon-carbon composites. My project was to evaluate the robustness of the optimization algorithms used in the elastic constant recovery used in the ultrasonic testing method.

In order to evaluate the procedure's integrity, data was collected as a part of the project. To calculate the elastic constants of the material, ultrasonic measurements were used. Three different samples from a single block of material were used. Data from each sample was collected in the same manner. Ultrasonic signals were recorded from the sample at four different orientations of the sample and from 25 different angles at each

orientation. The next step in determining the elastic constants is to find the velocity of the ultrasonic wave through the material. This was accomplished using a series of algorithms involving cross correlation in Matlab. The elastic constants were then calculated in Matlab using the optimization toolkit and applying Christoffel's equation. This entire process was repeated three times for each sample.

The phase velocities and the elastic constants were then analyzed with ANOVA and paired T-tests using SAS and Minitab respectively. Tests were conducted to examine differences in the samples and trial runs. In every case, the results from the ANOVA agreed with the results given by the paired T-tests. For both the velocity and the elastic constant data, the ANOVA showed that the different trial runs had no effect on the data but that the different samples did affect the data. The paired T-tests confirmed the ANOVA results and gave further insight to the differences in the samples: it was clear that samples A and C yielded similar data while sample B yielded data that differed from the other two. After analyzing the results, it was clear that the procedure is repeatable and that the different samples produce differences in the velocity and elastic constant values. Upon further inspection, we determined that the difference in samples was consistent with the variation in the samples due to the resin infusion process and that points to the need to use advanced techniques in the characterization of these materials for design and reliability.

Research Experience for Teachers Supplement

Ms. Lauree Gott, a math and science teacher from Veazie Community School in nearby Veazie, Maine was selected from a variety of nominations. She worked with Prof. Eric Landis on a project aimed at quantifying microstructural parameters of extruded wood-plastic composites. She applied a technique called x-ray microtomography to make 3D scans of material samples. She was then able to use an array of 3D image processing tools to make measurements of phase distributions for different materials and processing parameters. Some of the experimental variables, in addition to processing parameters, included load-deformation response and the corresponding changes in microstructure associated with damage.

In addition to the research work, we spent considerable time discussing ways to incorporate and teach science in the classroom. This included age-appropriate and content-appropriate topics.

Our work with Ms. Gott is ongoing, and our experiences will be integrated with an existing Research Experience for Teachers Site here at UMaine.

Recruitment and Selection Process

<u>Approach</u>

As with previous years, we focused our recruiting efforts on an internet-based strategy. We prepared electronic versions of our promotional information and our student application. We then conducted a “shotgun” e-mailing to both selected faculty and student organizations throughout the country. Specifically, we identified about 200 faculty contacts that we knew would distribute our informational material to interested students. These faculty were primarily in fields of civil, chemical, and mechanical engineering, wood science, and wood technology programs at national universities, including several minority institutions. In addition we identified approximately 20 New England liberal arts colleges, (including all women’s colleges). At these schools we contacted science (physics, chemistry, biology, math and computer science) faculty to whom we sent our materials.

In addition to the faculty contacts we combed the web for contacts in student chapters of professional societies. These societies included the American Society of Civil Engineers, American Society of Mechanical Engineers, Society of Hispanic Professional Engineers, Society of Women Engineers, Society of Black Engineers, Society for Wood Science and Technology, and the Forest Products Society. We targeted a number of minority institutions in an effort to attract more underrepresented applicants. Specifically, we emailed contacts at Florida A&M, Clark Atlanta University, and the office of minority programs at Loyola Marymont University. We sent our materials to as many student contacts as we could find published on the web. Our thinking was that if possible it is best to get the information directly into the hands of those who can most benefit. Over half of our applicants came in as a result of this “direct mail” approach. The second leading source of applicants was the NSF REU website. Word-of-mouth from former students has also led to applicants.

<u>Applicant Pool</u>

A total of 44 students formally applied to our program, which is up from 24 in the previous year. The overall quality of applicants was excellent (average GPA of 3.5). By college major we had twelve in civil engineering, eight in chemical engineering, four in mechanical engineering, two in materials science, four in physics, and the remainder in a variety of science and engineering disciplines.

Geographically our applicants came from all parts of the country. Applicants came from the following colleges and universities:

- Albion College
- Alma College
- Arizona State University (2)
- Binghamton University
- Carnegie Mellon University
- Cooper Union (2)
- Cornell University
- Florida State University
- Johns Hopkins University
- Loyola Marymount University
- Michigan State University
- Michigan Technological University
- Milwaukee School of Engineering
- Massachusetts Institute of Technology
- Pennsylvania State University
- Pomona College
- Purdue University
- Rowan University
- Smith College
- South Orange Community College
- Swarthmore College
- Syracuse University

Tulane University
University of California Los Angeles
University of Central Florida
University of Delaware
University of Detroit Mercy
University of Idaho
University of Maine
University of New York at Geneseo
University of Notre Dame (2)
University of Oklahoma (2)
University of Puerto Rico
University of Massachusetts (3)
University of Wisconsin
Ventura College (2)
Virginia Tech

While the list represents a relatively broad spectrum of institution types, the majority of applicants came from large research universities. This is likely due to the engineering focus of the program, and engineering programs tend to exist at larger universities. For 2003 we will modify the promotional materials to better emphasize the wide range of disciplines that are supported by this program.

The diversity of the applicant pool was on a par with previous years. The percentage of women applicants was 34% (down from 42% in the previous year), and the declared number of ethnic or racial minorities was 28% (up from 17% in the previous year). 27% of applicants elected not to state their ethnic or racial status. Of note is that all the ethnic or racial minorities were either Hispanic (13%) or Asian (15%). We had no African American applicants despite our efforts.

In selecting the students for our program we look at a combination of academic achievement (evaluated through grades, activities, and recommendations) and mutual interests with participating faculty (evaluated through their required statement of interest). We had little trouble matching students to faculty. The ten positions were filled after making offers to nineteen applicants. It should be noted that many of the minority applicants were freshmen and sophomores with little experience. Thus we were faced with a trade-off between promoting underrepresented students with their likely ability to make meaningful contributions to the research. We specifically told these students to apply again in the future when they will be in a better position to contribute. Table 1 presents a list of the student participants. The demographic characteristics of the students participating in the program are shown in Table 2.

Table 1. 2001 UMaine AEWC-REU Participants

Name	Home University	Major	Yr
Sarah Blake	University of Maine (D)	Mechanical Engineering	Jr
Andrew Brinks	Michigan State University (D)	Civil Engineering	Sr
Mack Conachen	University of Wisconsin (D)	Civil & Environmental Engineering	Sr
Michael Crowell	Virginia Tech (D)	Engineering Science & Mechanics	Sr
Lydia Deere-MacLeod	Smith College (B)	Geology	Jr
Justin Desjarlais	Alma College (B)	Physics and Mathematics	Jr
Christine Riker	Albion College (B)	Physics and Mathematics	Jr
Jonathan Robinson	Milwaukee School of Engineering (M)	Architectural Engineering	So
J. Michael Upshaw	University of Oklahoma (D)	Industrial Engineering	Jr
Henry Wong	MIT (D)	Computer Science	So

Highest degree in NSF discipline: B = Bachelor, M = Master, D = Doctorate

Table 2. Demographic Characteristics of Students in Program

Principal Investigator: ***Eric N. Landis***

Award Number: ***EEC-0097500***

Students:	***Female***	***Male***	***Total***
Race:			
American Indian or Alaska Native			
Asian		*2*	*2*
Black or African American			
Native Hawaiian or Other Pacific Islander			
White	*3*	*5*	*8*
Ethnicity:			
Hispanic or Latino			
Not Hispanic or Latino	*3*	*7*	*10*
Disability Status:			
Hearing Impairment			
Visual Impairment			
Mobility/Orthopedic Impairment			
Other			
None	*3*	*7*	*10*
Classification:			
Senior		*3*	*3*
Junior	*3*	*2*	*5*
Sophomore		*2*	*2*
Freshman			
Citizenship:			
U.S. Citizen	*3*	*7*	*10*
Permanent Resident			
Other non-U.S. Citizen			
Choice:			
From own institution	*1*		*1*
From other schools	*2*	*7*	*9*

Student Activities

We tried in all our activities to strike a balance between structure and independence, group and individual learning, and educational and social activities. A summary of the various activities is shown in Table 3. The program was structured so that all ten students would be part of a single team working toward a common goal. Although individual research projects were quite different, at the end of the nine weeks, there could be no doubt about their shared goal.

Table 3. Scheduled Activities: 2003 UMaine AEWC REU Program.

<table>
<tr><th>Week</th><th>Research Activities</th><th>Seminars/ Group Meetings</th><th>Field Trips and Special Events</th></tr>
<tr><td>1</td><td>• Tour of campus and departmental research facilities
• Advisors to introduce each student to their research topic
• Develop Research Plan.</td><td>"Introduction to Advanced Engineered Wood Composites" Dr. Habib Dagher

Short course on Research Methods – Dr. Eric Landis, Dr. Mick Peterson</td><td>• Monday morning coffee and bagel get –acquainted/orientation meeting
• Friday afternoon hike at Acadia National Park</td></tr>
<tr><td>2</td><td rowspan="7">↑
• Students work on their research project

• Submit weekly progress report to advisor
↓</td><td>Monday Meeting-Dr. Barry Goodell, Wood

Student presentations of Research Plans</td><td></td></tr>
<tr><td>3</td><td>Monday Meeting-Dr. Roberto Lopez-Anido: Composites in Construction</td><td>Tour: Engineered Materials of Maine</td></tr>
<tr><td>4</td><td>Monday Meeting-Dr. Douglas Gardener, Adhesion

Seminar: Marketing Issues in Product Research and Development – Prof. Harold Daniel</td><td></td></tr>
<tr><td>5</td><td>Monday Meeting: Student presentations: "Research in Progress"</td><td>Group field trip to Louisiana Pacific Oriented Strand Board Plant</td></tr>
<tr><td>6</td><td>Monday Meeting

Seminar: Intellectual Property Issues in Science and Engineering – Mr. Chris Watt</td><td>Ascent of Mount Katahdin</td></tr>
<tr><td>7</td><td>Monday Meeting: How do I get in, how do I pay, and how do I choose?</td><td></td></tr>
<tr><td>8</td><td>Monday Meeting: Graduate Student Panel, No Faculty Allowed!</td><td></td></tr>
<tr><td>9</td><td>Each student writes research report and prepares final poster presentation</td><td>Monday Meeting: Discussion of program, and evaluation.</td><td>Thursday night banquet and presentation of research posters</td></tr>
</table>

The topics listed are self-explanatory with the exception of the Monday Meetings. The group met every Monday morning of the program period in an informal setting. The topics of discussions varied, but in most cases the meetings were led by a faculty who discussed their work and how it related to the overall R&D effort of the AEWC center. The informal setting was intended to encourage interaction between the students and the faculty.

Stipend and Other Expenses Paid

The students were paid a stipend of $4000 for participation in the nine-week program. In addition, housing was covered for those who chose to live on campus. The on campus housing was a fraternity house where the students lived together among other UMaine students. Living together reinforced the sense of community established in the laboratory, while living with other students gave them insight into life at UMaine and the surrounding community. All ten students chose the on-campus living. Travel expenses were covered for all students to and from Orono at the beginning and end of the summer.

Due to several unexpected windfalls, additional money was left at the end of the summer. This money was used to hire several UMaine undergraduates to work on research projects on an hourly basis. These civil engineering students, sophomore Amanda Birmingham and junior Adam Turner, developed a program of micromechanical testing of wood specimens that contributed to a project that included several REU students from this and previous summers.

Contributions to Human Resource Development

Project Assessment

As with last year, our project assessment consisted of two parts: A quantitative measure of certain benchmarks, and student questionnaire for more qualitative measures of program effectiveness.

Quantitative Measures

We made quantitative measures of our 2003 class in the following areas:

Publicity and Recruitment:

- number of applicants – 42
- number of under represented applied – 17
- number of under represented offers – 8
- number of offers turned down – 3

Student interest in research:

- number of students who continue research project beyond nine week program – 3
- number of students who apply to graduate science or engineering programs – 3 to date
- number of students who enroll in graduate science or engineering programs – 3 to date

Scientific quality:

- number of refereed journal publications: 2 submitted to date
- number of conference and other publications resulting from program (in order to qualify, student must be co-author) – 4
- number of patent applications – 1 in preparation.

As indicated above, the diversity of the applicants was deemed to be good, but we would like to see more racial minorities applying. The areas where we needed to improve from previous years were in the number of applicants from smaller colleges, particularly minority institutions. Some progress was made, but more needs to be done.

It is too soon to fully gage the impact of student interest in research. Most of the participants are still completing their undergraduate studies. A brief questionnaire will be sent out to program “alumni” as a follow-up to their summer experience. We are cautiously optimistic that most of the participants will pursue advanced degrees in science or engineering.

As with previous years, the scientific quality has been quite mixed, ranging from outstanding (likely publishable in refereed journal) to fair. Again, the key seems to be to match the students up with a project that excites them and motivates them to do good work. (Also there is a bit of luck required – no student lab blunders, no equipment malfunctions, no materials backorders, etc…) While we design each project to produce publishable results in the nine-week period, to date only three projects have produced publishable results. One has been published, one is in review, and one is in preparation.

Participant Survey

A 28-question survey was given to the students at the end of the summer to give us feedback on students' opinions of the program. A copy of the survey is included at the end of this section.

We found the students to be overall very happy with the program. (mean response to question 26 – "Your overall evaluation of the program" – was 8.9 on a 10 point scale). This score is the best we have seen. The survey gave us lots of feedback on housing (most want as cheap as possible), the most valuable activities (field trips), biggest problems (faculty travel), and general administration.

The survey results indicate we are doing the following things well:

- A strong commitment of the mentors to providing an enriching research experience.
- An enthusiastic program director.
- Providing a living and working environment that leads to an enriching and rewarding intellectual experience.

The survey results indicate we need to improve in the following areas:

- Better pre-arrival communications between the mentor and the student, so the student could "hit the ground running."
- Provide alternate research advisor when the regular mentor is traveling.
- More field trips

Below are some sample student comments:

- "Understand better what engineering research is like."
- "All I could have asked for."
- "I had a great time, and I guess it was better to experience the 'unsuccessful' results – which is probably more realistic."

Individual program elements were evaluated. The faculty research discussions continue to get better reviews, indicating a better understanding of the audience by the presenters.

Summary

We are quite confident of our ability to provide a polished program for our students based a combination of our growing research facilities and our experienced faculty. The devil is always in the details however, and additional refinements will continue to be made to improve the student the experience.

Advanced Engineered Wood Composites

2003 Research Experience for Undergraduates Program

Participant Evaluation

1. How did you learn about the program?
   a) NSF Web Site
   b) Received information from faculty. (who? __________________)
   c) Received direct e-mail message
   d) Other (please list: __________________________________)

2. Did you apply to other similar summer programs? If so, how many?

3. Was the information you received on travel, housing, and program prior to your trip to Maine adequate? What could be improved?

4. Why did you choose this program over other opportunities you may have had?

5. How much did the stipend amount ($4,000) weigh into your decision to accept this position?

1	2	3	4	5
not at all				a lot

6. Was the fraternity housing acceptable? If not what would you suggest we do in future years? Would you pay more money (or receive a smaller stipend) in exchange for a nicer apartment?

7. Did you like living with the other REU students, or would you have preferred to be on your own?

8. One of the objectives of the program was to put you into a multi-disciplinary research environment. How well do you think this goal was achieved?

1	2	3	4	5
I spent the summer in a cocoon				I was aware of the wide range of activities

9. Do you feel the research you were engaged in was of importance?

1	2	3	4	5
not important				very important

10. Do you think you will continue to correspond with your research group?
    (a) Other REUs? (y/n)
    (b) Your advisor (y/n)
    (c) Other UMaine students, staff, faculty (y/n)

11. Is it likely you will apply to graduate school in science or engineering?

11. How do you think this REU program will affect your decision?

1	2	3	4	5
not at all				very much

12. How might this REU program experience affect your education? (check any that apply).
    ❒ By integrating your research results into course material
    ❒ By choosing different courses
    ❒ By sharing research experiences
    ❒ By revealing opportunities for future career options
    ❒ By deepening your enthusiasm and understanding
    ❒ Will have little or no impact

13. Did you develop new areas of interest as a result of your interaction with the REU program and/or research colleagues?

1	2	3	4	5
none				many

comments?

14. Did you feel you were adequately challenged by your research project?

1	2	3	4	5
not at all				very challenged

If not what would improve it?

15. Do you think the program gave you a taste of graduate research? (y/n)

comments?

Please rate the following on a scale of 1 to 10. (1 being lowest/worst, 10 being highest/best)

16. Program administration. (e.g. application process, communication, etc…)

1 2 3 4 5 6 7 8 9 10

comments?

17. Organized social activities and field trips.

1 2 3 4 5 6 7 8 9 10

comments?

18. Landis "Research Methods" presentations

1 2 3 4 5 6 7 8 9 10

comments?

19. Gardner Seminar on Wood Plastics.

1 2 3 4 5 6 7 8 9 10

comments?

20. Lopez Anido Seminar on Composites.

1 2 3 4 5 6 7 8 9 10

comments?

21. Landis "discussion" on Graduate School.

1 2 3 4 5 6 7 8 9 10

comments?

22. Watt Seminar on "Commercialization Issues."

1 2 3 4 5 6 7 8 9 10

comments?

23. Grad Student Panel

1 2 3 4 5 6 7 8 9 10

comments?

24. What programs would you have liked to see but did not?

25. Rate your advisor on the following (1 to 10):
   (a) Explained project objectives and relevance ____
   (b) Approachability ____
   (c) Helpfulness ____
   (d) Enthusiasm ____
   (e) Knowledge ____
   (f) Ability to explain ____
   (g) Ability to advise ____

   Comments:

26. Your overall evaluation of the program.

1	2	3	4	5	6	7	8	9	10
Sucked									Totally Cool

comments?

27. Your overall impression of the AEWC and the University of Maine.

1	2	3	4	5	6	7	8	9	10
Sucked									Totally Cool

comments?

28. Please list three changes you would make to improve the experience for future students?