Introducing Civil Engineering Measurements through Bridges

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ABSTRACT

Freshman engineering students at Rowan University are introduced to engineering measurements through a series of hands-on laboratories emphasizing teamwork, computer utilization, oral and written communication skills and professional ethics. The major focus of the freshman clinic class for a full semester is engineering measurements and design. Problems are drawn from the four disciplines to introduce students to laboratory and field measurements. The civil engineering program introduces students to basic civil engineering measurements and terminology through a three week module using a simple truss bridge example. A model aluminum truss bridge was constructed to expose the students to the concepts of stress and strain. Omega bonded resistance strain gauges were mounted on certain members of the truss bridge to illustrate tension and compression in various members. This hands on experience was further complimented by a three hour module on surveying involving principles of triangulation and soil analysis. These two modules expose students to angle, distance and particle size measurements and their significance in structural engineering. The class ends with a team bridge building competition through the use of a bridge builder software developed by the United States Military Academy (USMA). This final section introduces students to innovation and creativity in engineering design while emphasizing the significance of the use of computers in structural analysis and design.

INTRODUCTION

Founded in 1923 as Glassboro State Teachers College, Rowan University has evolved into a comprehensive regional state university with six colleges including the new College of Engineering. The College of Engineering was initiated as a result of a major donation in 1992 from the Rowan Foundation [1]. The engineering faculty is taking a leadership role by using innovative methods of teaching and learning, as envisioned by ASEE (1994) [2], to better

prepare students for entry into a rapidly changing and highly competitive marketplace. Key program features include: (i) creating inter- and multi-disciplinary experiences through collaborative laboratories and coursework; (ii) stressing total quality management (TQM) as the necessary framework for solving complex problems; (iii) incorporating of state-of-the-art technologies throughout the curricula; (iv) and creating continuous opportunities for technical writing and communication. To best meet these objectives, the four engineering programs of Chemical, Civil, Electrical, and Mechanical Engineering have common engineering *clinic* classes throughout their programs of study.

All freshmen engineering students at Rowan University are introduced to engineering experiments and calculations through a series of modules in measurements. The primary goal of this course is to expose freshmen engineering students to multidisciplinary projects that teach engineering principles using the theme of engineering measurements in both laboratory and real-world settings. This concept is an inversion of the traditional laboratory curriculum paradigm. The current situation is that freshman programs focus either on a design project or discipline-specific experiments that may not be cohesively integrated. In real-world settings engineers work in multidisciplinary teams on a variety of complex problems. The fundamental principles of measurement and their application are crucial to the solution of these problems.

The Civil and Environmental Engineering department introduces freshmen students to structural measurements using a bridge module. Bridges serve as aesthetic icons, engineering achievements and defining structures for their communities. They tend to leave a lasting impression on the human mind. They are also reminders of historic battles and patriots honored. A recent article in Civil Engineering (1997), [3] reported the new ISTEA (Intermodal Surface Transportation Efficiency Act) provisions for historic preservation and restoration of old bridges in this country. Elementary, junior and high school students in recent years are being exposed to various hands-on bridge projects [4,5]. Thus bridges are a powerful tool for exciting and exposing students to the world of structural engineering.

A three week module introduces students at Rowan to basic structural measurements associated with the design and construction of a truss bridge through a series of field and laboratory experiments. The students learn common structural terminology, field measurements, material

properties and the importance of computers in the design of a truss bridge. Three important areas of measurements are explored:

- Land measurement through surveying
- Soil Particle Size Measurement through sieve analysis
- Stress and Strain Measurements through an instrumented truss bridge

The module is ended by focusing on computer aided design of truss bridges. Students also are required to make a technical presentation on one of the bridges in the Delaware Valley area. While the overall objective of this module is to teach structural measurements, students are expected to be able to

- *Measure* distance and angles using basic land surveying equipment,
- *Calculate* distances using basic trigonometric functions,
- *Characterize* soil properties,
- *Describe* the physical concepts of stress and strain, tension and compression in axially loaded members,
- *Calculate* stress and strain in members of a truss bridge,
- *Explain* the significance of material properties, and
- *Appreciate* the use of computers in structural design.

Details of the module are presented below.

Surveying

Students first survey an existing bridge on campus and are challenged with a project that involves the use of basic surveying equipment and triangulation techniques. This module challenges students to determine the span of a bridge on campus assuming that it has been washed away by high floodwaters. Students are not allowed to measure the length of the bridge directly. Each team is provided with a Sokkia™ digital theodolite, a leveling rod and a measuring tape. Bearing in mind that their knowledge of trigonometry is their only analytical tool for this problem, students in teams of four apply the principles of triangulation to measure angles and distances. This three hour outdoor class not only generates excitement but helps them reinforce their trigonometric knowledge and gives them a first-hand opportunity to understand the significance of surveying in engineering. They also plot their triangulation solution to a given

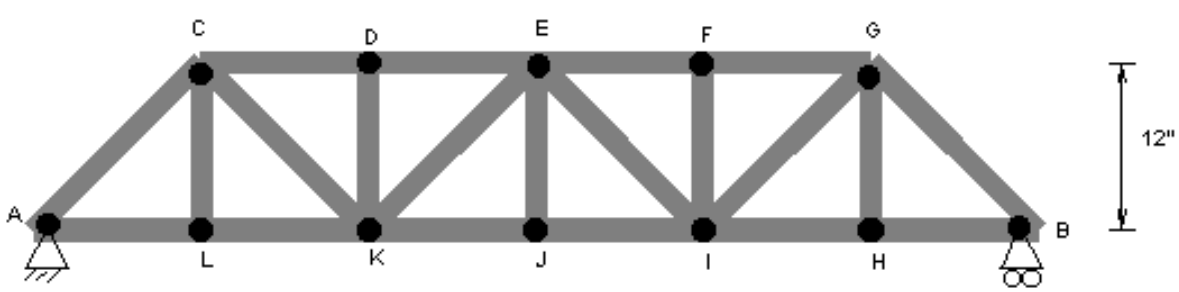
scale using AUTOCAD™ Release 14. This exercise exposes them to the importance of engineering drawings.

Soil Analyses

The second week focuses on the importance of soil properties for constructing any structure. Students perform the standard sieve analysis test on a Gilson Shaker from material obtained from the bridge site. Results are plotted on an Excel Spreadsheet to obtain the particle gradation curve. Values of D_{60} and the uniformity coefficient C_u are obtained from the curve. This exercise helps them understand the significance of particle size and the significance of well-graded soils.

Instrumented Truss Bridge

A large number of freshman students typically have had some prior experience with the design of bridges and beams during their high school years [5]. Therefore repetitive experiments are avoided and a state-of-the-art instrumented aluminum truss bridge as shown in figure below was constructed to introduce students to basic concepts of stress, strain and material properties. The bridge has a pair of plane trusses with a pin and roller support at its two ends. ¾ x 1/8 and ½ x 1/8 flatstock aluminum was used to construct the bridge. Steel nuts and bolts, washers and lock washers were used to connect the members. Omega bonded resistance strain gauges were mounted on certain members of the truss bridge to illustrate tension and compression in various members. These gages consist of a grid of very fine wire or foil bonded to a backing or carrier matrix. The electrical resistance of the grid varies linearly with strain. In use, the carrier matrix is bonded to the surface, force is applied, and the strain is found by measuring the change in

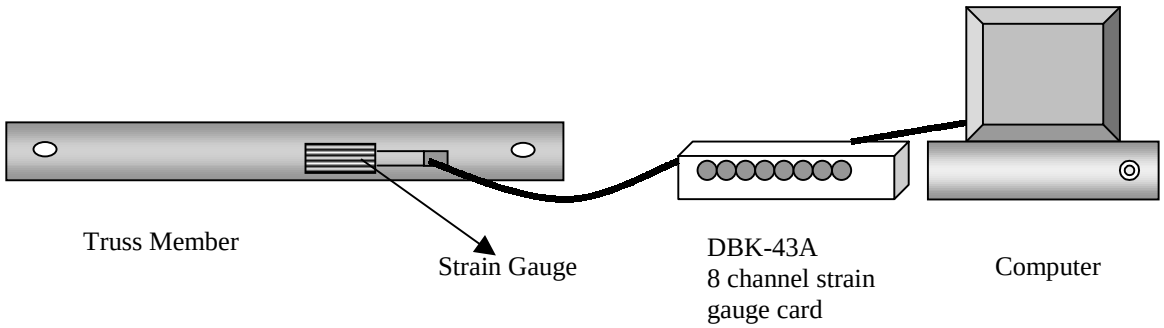


6 members @ 12" = 72"

resistance. The bonded resistance strain gage is low in cost, can be made with a short gage length, is only moderately affected by temperature changes, has small physical size and low mass, and has fairly high sensitivity to strain. A data acquisition system comprising of IoTech's DaqBoard/100A internal PC card, an external DBK 43A strain gauge card and DaqView and DaqViewXL

software. The strain gauges were hooked to a DBK43-A 8 channel strain gauge card which was connected to a computer for instant strain data acquisition when a load was applied to the bridge. Strain gauges mounted on various truss members were calibrated to determine the relationship between voltage and force in pounds in the members. Loads ranging from 25 to 75 pounds were place at the center of the bridge at the midpoint of the cross-beam. Forces in various members due to the addition of the dead weight on the bridge could be read off directly from the computer screen. The negative or positive values indicated whether the member was in tension or compression. Students then performed calculations on Excel to determine the strain and stresses in each member of the truss.

The Daqview XL software runs Daqview as a macro from an Excel spreadsheet. The cost of the system is approximately $1500. A schematic of a truss member connected to the strain gauge card for data acquisition on a PC is presented below.



Computer-Aided Design

The class ends with a competitive truss bridge design competition using a CAD software the *West Point Bridge Designer* developed by the Department of Civil and Mechanical Engineering at the USMA. USMA uses this software package as a vehicle for outreach to high school students. The program allows the user to design a simply supported truss bridge within certain design restrictions. Materials and cross-section of the truss members can be varied and the user

has complete freedom of defining the truss structure. The design objective is to minimize cost. This software is extremely user friendly. The final load test animation feature makes students extremely happy as it gives them a sense of completing a successful design-specifically their very own first truss bridge design! This software helps students develop an appreciation of the aesthetics, innovation and creativity involved in engineering design and also the importance of computer simulations to reduce efforts spent on repetitive calculations.

Conclusions and Future Recommendations

In real-world settings engineers work in multidisciplinary teams on a variety of complex problems. The fundamental principles of measurement and their application are crucial to the solution of these problems. This three week module effectively introduces students to common structural measurements through conventional and innovative computer-integrated experiments. Students are also encouraged to build up their communication skills through extensive use of technical, writing, spreadsheets and presentations. Spreadsheets are employed for engineering calculations, plots and regressions. Presentations using PowerPoint are given by the students at the end of each module.

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