# Introducing General Civil Engineering Concepts to Freshman Engineering Students

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**Abstract** – "Introduction to Engineering" (EGN-1002) is a freshman course developed by Hoit (1) under a grant from the National Science Foundation. The purpose of this course is to familiarize students with the curriculum of eleven different departments within the College of Engineering. The College of Engineering includes departments in Biomedical Engineering, Chemical Engineering, Civil and Coastal Engineering, among others. This course is directed at familiarizing students with different branches of engineering and is geared toward assisting students in deciding their future careers. This paper is focused on only the Civil and Coastal Engineering portion of the course. It is a three-hour class that includes a lecture, lab work and lab presentations. The presentation is divided into four parts. The first part of the session is a lecture introducing students to general civil engineering principles and concepts. The second part involves building a truss bridge. Students are divided into teams. The teams follow given criteria such as cost, efficiency, and strength. Each team is provided with the same quantity of materials, and all materials are assigned a certain cost. Teams are given a time limit of 45 minutes to complete the task of building a truss bridge. Each team's truss bridge is tested under load, and the team with the highest score wins. The third part of this session includes a demonstration of hurricane forces simulated with an air pressure cannon. The final part demonstrates the compressive strength of a concrete cylinder and the tensile strength of a steel rod. This exercise introduces students to civil engineering concepts and creates a better understanding of compressive strength, stress, strain, neutral axis, tension, compression, and project management. At the end of the presentations, the students also learn about the American Society of Civil Engineers Student Chapter and its activities including canoe building, steel bridge building and technical paper writing for local and national competitions.

*Keywords: truss bridges, freshmen, Concrete, Steel, Strength, Compression*

## INTRODUCTION

Under a National Science Foundation grant, Hoit (1) developed a one semester- hour course, "Introduction to Engineering" (EGN 1002). The purpose of the class is to create an understanding of engineering field majors (Electrical and Computer, Industrial and Systems, Chemical, Civil and Coastal, Mechanical and Aerospace, Environmental, Agricultural, Materials, Biomedical, Nuclear and Radiological) among freshman engineering students within the College of Engineering at the University of Florida (2). This is a one-credit hour class in which a group of students visits each department once a week for three hours. Each visit includes presentations and student participation. Each department presents its curriculum with examples so that students can gain an overall understanding of each department before choosing their specific majors (3).

This paper focuses only on the Department of Civil and Coastal Engineering presentation for this course. Each week, a new group of freshman engineering students attends the EGN 1002 class. Attendance is mandatory and the instructor calls roll; the attendance record is mailed to the Associate Dean for Academic Affairs of the College of Engineering, who is in charge of administering the course. As soon as the class roll is called and the introduction formality is completed, the instructor gives an overview of what civil engineering is all about. The instructor goes over the various sub-fields within civil and coastal engineering and the curriculum, such as structures, water resources, geotechnical engineering, geo-sensing systems, transportation, public works, materials, and construction

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engineering and management. Students become familiar with the total construction process, from inception of the idea through startup. Furthermore, the students learn about educational requirements and courses required in the field of civil engineering. They also learn about advancements in the profession and requirements for master's and Ph.D. degrees, as well as salary expectations for graduates within the civil engineering field (3).

Part of the lecture for the class introduces students to the second part, a lab for building a truss bridge. Students are divided into teams to build truss bridges. This laboratory creates the spirit of teamwork among students. The third part of the presentation uses an air-pressure cannon to shoot a 2-in. by 4-in, 9-ft. long piece of wood into a 2-ft by 2-ft, ¾ inch wooden frame attached to a steel frame 16 ft away from the cannon. This part of the lab work provides students with an understanding of the effect of a Category 1 hurricane's strength (a force of 74 to 95 mph winds). The fourth part of the presentation includes another lab test, one involving load testing a 6-in. × 12-in. concrete cylinder in a compression-testing machine until it is crushed, which offers an understanding of compressive strength to these future engineers. The last part of the lab presentation includes a tensile strength test on steel, which demonstrates the elasticity or stiffness of the steel sample. These exercises and laboratory presentations introduce students to civil engineering concepts such as compression, tension, stress, strain, strength, modulus of elasticity, elastic range, moment, neutral axis and moment of inertia (3). A further description of the lab work is discussed below.

## TRUSS BRIDGE DESIGN AND CONSTRUCTION LAB

Students are introduced to civil engineering concepts pertinent to design and construction of bridges (compression, tension, moment, moment of inertia, neutral axis) in the lecture portion of the class. To illustrate these concepts in the lab, the instructor presents a simple bridge of cubical shape made up of solid foam. The instructor applies force to the bridge until it bends. This illustrates information about compression and tension. When the bridge has been subjected to compressive and tensile forces, it bends.

To give students a hands-on engineering experience, they are divided into teams of four or five and given the assignment of building a truss bridge. Materials and equipment are given to each team with a set of instructions on how to build a strong and cost-effective truss bridge. Each team is provided with 29 short craft sticks, 27 long craft sticks and 20 bolts with matching nuts. The craft sticks are drilled with holes on both ends. A cost is associated with each of these materials for the purpose of developing an understanding in the students about cost effective alternatives and cost analysis. The cost that is assigned to the materials is:

| | |
|---|---|
| Short craft sticks | $0.75 |
| Long craft sticks | $1.00 |
| Each bolt and matching nut | $2.00 |

The teams are given 45 minutes to complete the project. This time limit initiates an understanding of project management and timely delivery of projects, an essential tool of civil engineering practice (4). Each team's truss bridge is then tested under load. Figures 1 and 2 present sample trusses built by students.

## Load Testing of Truss Bridges

Each team's truss bridge is tested for strength by placing it in a frame as shown in Figure 3. An empty bucket is then attached to the truss bridge. The bucket is gradually filled with gravel, sand, rocks or other heavy weight until the truss bridge collapses (see Figure 4). Once the truss is broken, the bucket is removed and weighed for the failure load. The failure load and cost ratio are then scored.

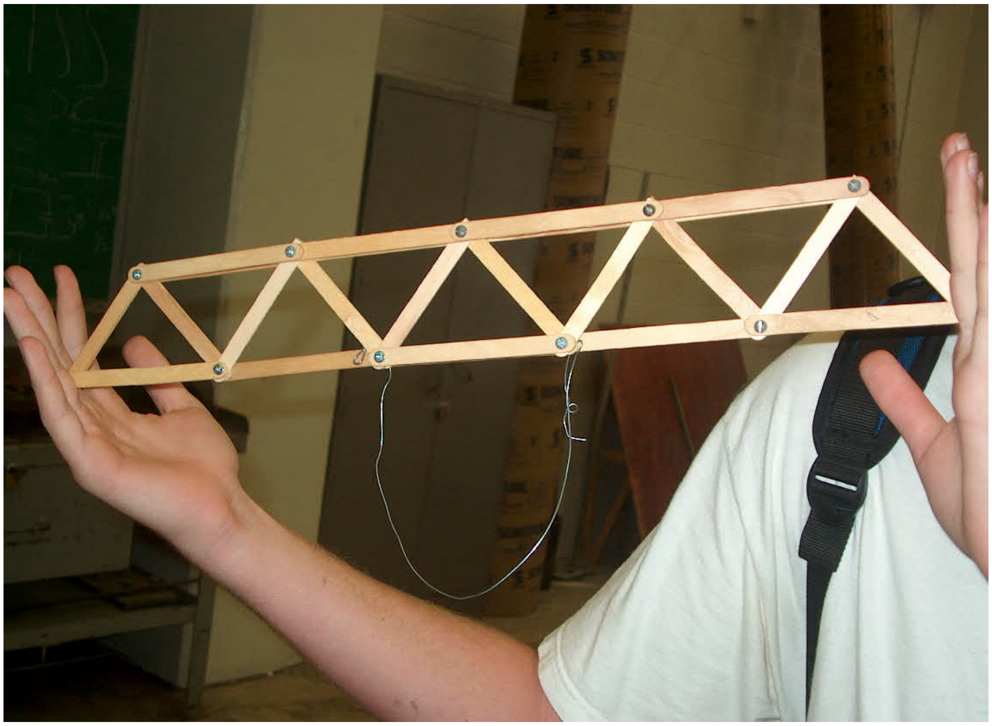

Figure 1. A typical truss bridge made by a team of students

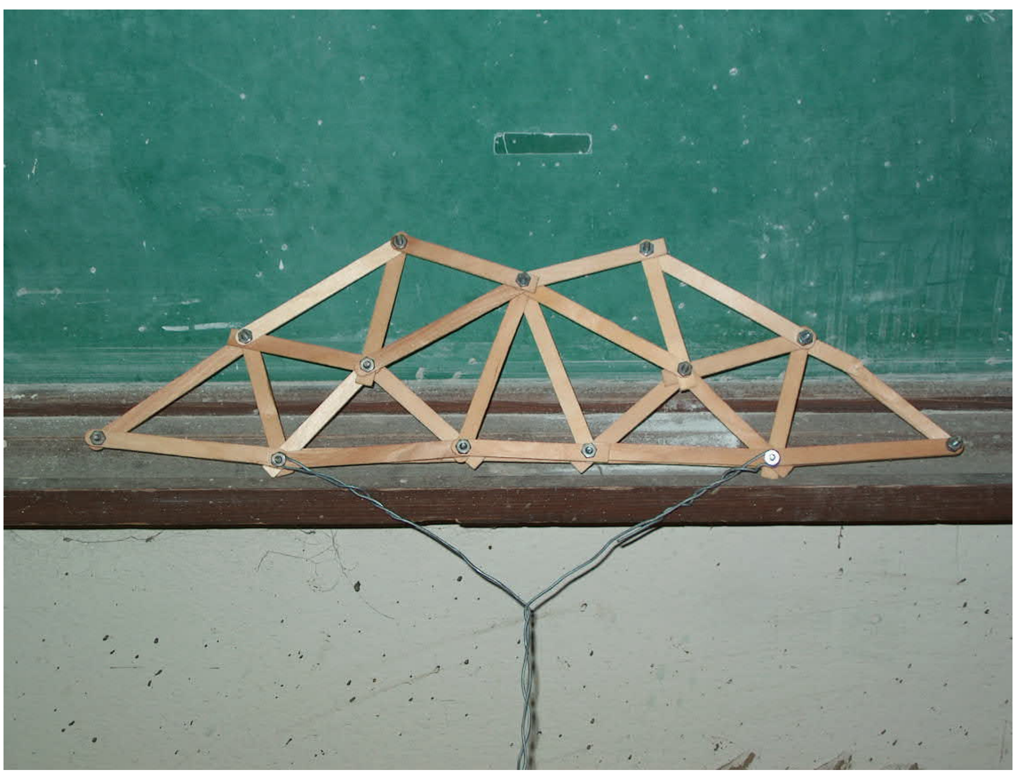

Figure 2. Truss bridge prior to load testing


Figure 3. Frame holding a truss bridge about to be load tested

Figure 4. Broken truss bridge in bucket following load testing

## Score Calculations

In scoring the failure load and cost ratio for determining the winning truss bridge team, the following formula is used to assess performance:

$$\text{Score} = (\text{failure load} / \text{cost of the truss bridge}) \times 100 \qquad (1)$$

The formula in Equation 1 helps students to understand the civil engineering concepts of cost and benefit. Table 1 shows examples of cost, failure loads, and scores obtained by several student teams. A team is also given a bonus if it completes its project earlier than the time limit of 45 minutes. The bonus is $1 off the final cost for every five minutes saved. This practice also teaches project management and underscores the importance of completing a project on time (4).

Table 1. Typical examples of student team truss bridge project scoring

| Total Cost ($) | Failure Load (lbs) | Score |
|---|---|---|
| 38.75 | 22.2 | 63.88 |
| 44.00 | 20.8 | 40.27 |
| 49.75 | 30.8 | 61.90 |
| 41.00 | 46.0 | 112.2 |
| 36.50 | 21.8 | 59.72 |
| 48.75 | 35.8 | 73.44 |
| 47.75 | 39.0 | 81.68 |

Table 2 presents final scores of truss bridges competition between each team of four students. It can be seen from column two of this table that all the teams had different failure loads (Table 2 column three). Column three of Table 2 presents score earned by each team. It can be seen from this table that team four earned the highest score of 91.93 with cost of $52. It is obvious that team four was the winner team. At the end, each member of the winner team was rewarded with a Pen.

Table 2: Example of a recent student team competition

| Team | Cost ($) | Failure Load (lbs) | Score |
|---|---|---|---|
| Team One | 44 | 17.8 | 40.45 |
| Team Two | 39.25 | 28.4 | 72.36 |
| Team Three | 61.25 | 37.8 | 61.7 |
| Team Four | 52 | 47.8 | 91.93 |

## HURRICANE SIMULATION

Florida is one of the most hurricane prone locations in the world. In the most recent hurricane season, Florida was struck by four hurricanes. Much damage is done by flying objects which the hurricane force winds project against buildings. To demonstrate to prospective engineering students in the freshman class the damage a projectile caught in heavy winds can do, a Category 1 hurricane wind force is simulated in a lab.

The Department of Civil and Coastal Engineering at the University of Florida has a very active hurricane research center. The center has developed an air-pressure cannon which simulates a Category 1 hurricane wind force (see Figure 5). The cannon can shoot a piece of wood at speeds of 74 up to 95 mph.

The lab demonstration includes shooting a 2-in. by 4-in., 9-ft long piece of wood into a 2-ft. by 2-ft, ¾ inch wooden frame attached to a steel frame 16 ft away from the air-pressure cannon (see Figure 6). The 2-ft by 2-ft, ¾ inch wooden frame is used because it is the most widely used framing technique in the manufactured home industry. This demonstration illustrates how flying objects can hit a building by hurricane strengths of Category 1 winds, 74-95 mph (4).

Figure 5.  Air-pressure cannon

Figure 6.  A 2-in. by 4-in., 9-ft long piece of wood shot by the air-pressure cannon (to simulate category 1 hurricane or 75-mph force winds) penetrated into a 2-ft by 2-ft by ¾-in. plywood attached to a steel frame

## Strength Demonstration of Concrete and Steel in Lab

Concrete and steel are the most widely used materials in engineering design. Concrete is a very strong material when placed in compression, however, it is extremely weak in tension. Students are shown an example of the compressive strength of concrete and a demonstration of the tensile strength of steel to show the need for reinforcing concrete with steel in order to take up the slack for the weakness of concrete in tension.

The compressive strength of concrete is calculated by placing a 6-in. × 12-in. concrete cylinder in a compression-testing machine that increases load until the concrete cylinder crushes (see Figure 7). In this laboratory experiment, students learned about compressive strength of concrete and its use by engineers in engineering design.

Steel is a structural material, which consists of mostly iron and carbon. Steel has a very high tensile strength and it is used to reinforce concrete in structures. The last lab presentation demonstrates this tensile strength in a steel rod. A cylindrical "coupon" made of steel is placed in the tensile testing apparatus. A displacement indicator is attached to the coupon to take strain readings measuring the elongation of the specimen. The coupon is then pulled until it breaks. This information is used to calculate the modulus of elasticity (a measure of steel stiffness), the stress experienced by the coupon, and the strength of the steel that was used to make the coupon.

The above practices are very similar to what engineers do in real-life projects and these demonstrations induce a good understanding of the civil engineering profession to freshman engineering students (4).

Figure 7. Determination of compressive strength of concrete cylinder

## Conclusion

The civil engineering portion of the freshman engineering course, "Introduction to Engineering," is comprised of a lecture and a group of lab demonstrations. The lecture introduces students to the concepts of compressive strength, tensile strength, stress, strain, modulus of elasticity, elastic range, moment, neutral axis and moment of inertia. The truss bridge design and construction by each team created interaction among students within each team. Each student was involved and shared his or her idea with team members in building a truss bridge. The construction of each bridge by each team, developed an understanding of a project planning, quality control by examining each craft stick for quality assurance and replacing defected sticks. The entire process helped students understand to construct their bridge within cost and on time. The air-pressure cannon simulating the Category 1 hurricanes' strength provided students an understanding of hurricane power and engineer's responsibilities to design structures that must stand hurricane strengths. Students learned that concrete is strong in compression and weak in tension by observing the 6" x 12" test cylinder placed under compression test. They also learned that steel is strong in tension when a coupon was placed under tension. These demonstrations gave a general view of what civil engineers do in real life.

The recent student evaluations of this course indicate a very positive response to the Civil and Coastal Engineering presentation. Students ranked the presentation at the top compared to other department presentations. Also, several students indicated their high interest in joining the Department of Civil & Coastal Engineering following their participation in these presentations. The authors of this paper conclude that developing methods such as those described above can stimulate freshmen to become interested in the engineering field.

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