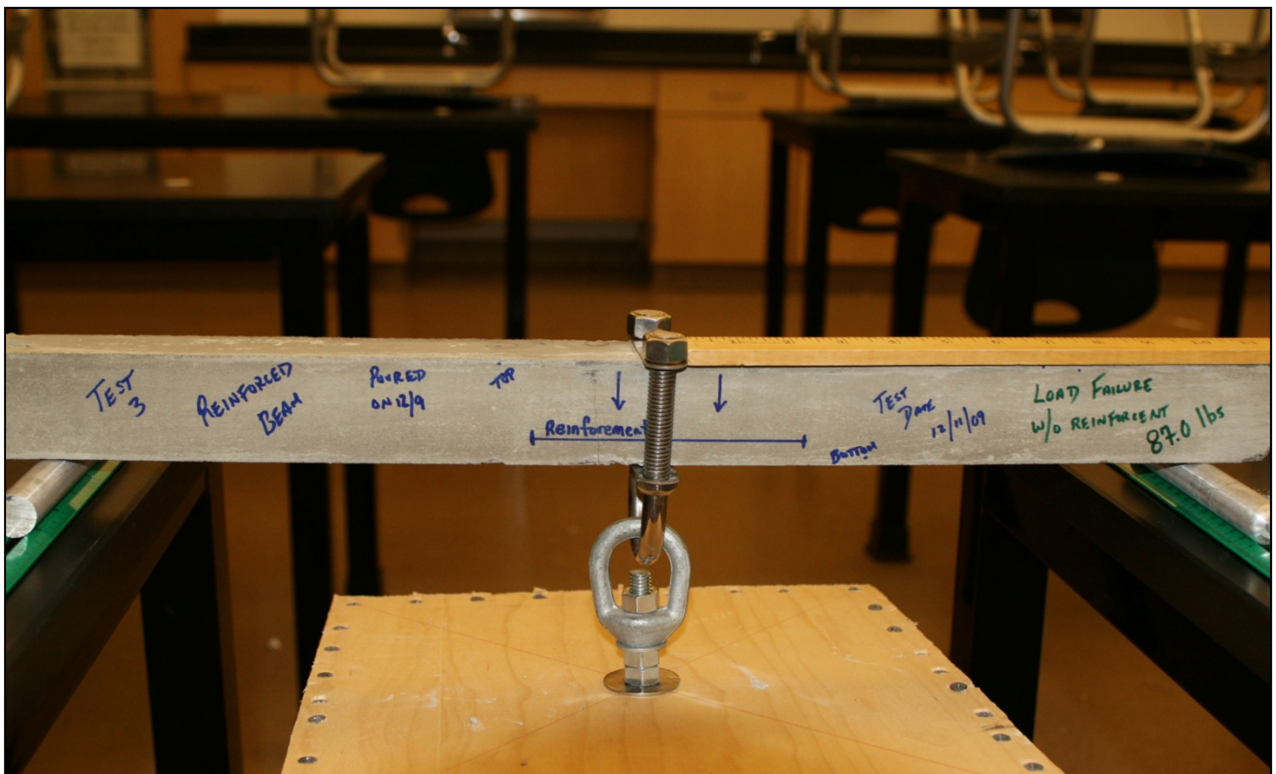
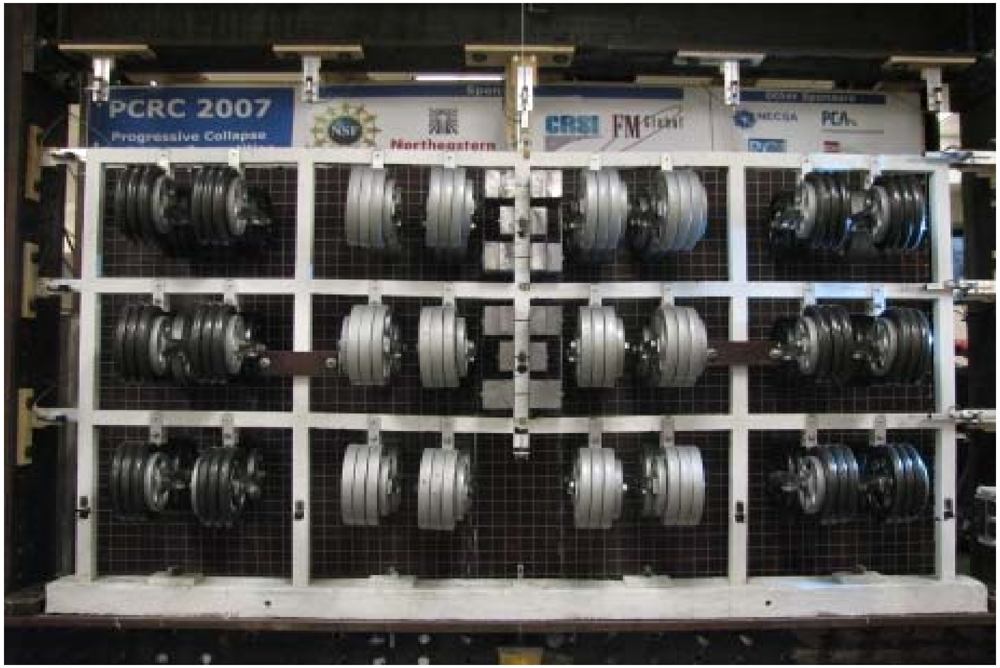
Teacher: Mark Casto
Lab Assignment: Progressive Collapse of RC Structures
Principal Investigator: Mehrdad Sasani
Lesson: CONCRETE ENGINEERING: ***BENEFITS OF REINFORCEMENT AND CATENARY ACTION***

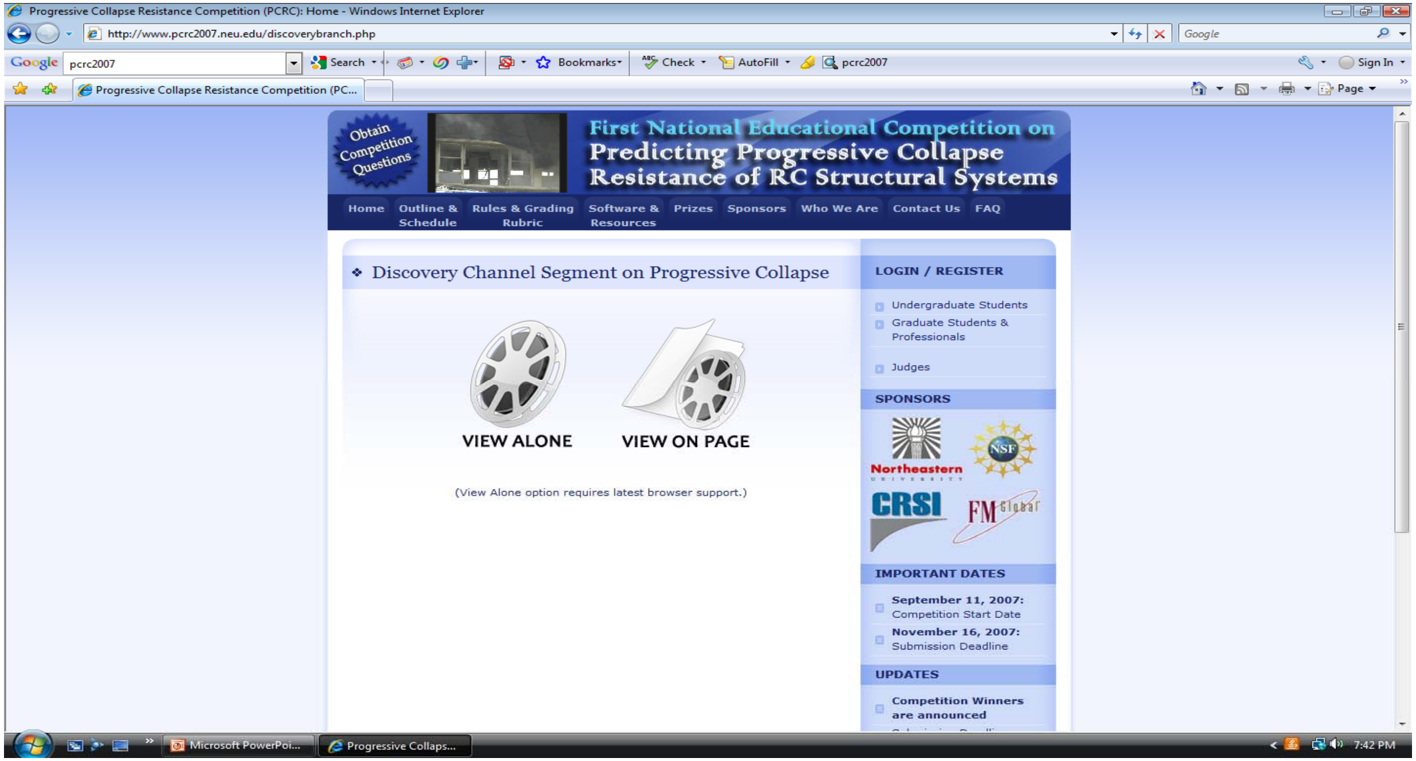


ABSTRACT

The extent of initial damage to the World Trade Center Towers and the Pentagon during the September 11, 2001 terrorist attacks was beyond what was perhaps practical to be considered for progressive collapse resistant design. The extreme assaults and the tragic outcomes have initiated wide spread interest and research in progressive collapse of structures under more moderate initial damage scenarios. As part of an on-going research on progressive collapse of structures at Northeastern University, experimental and analytical studies will be conducted on potential collapse of reinforced concrete structures due to loss of columns. Following loss of columns, the beams bridging over these columns will need to dynamically redistribute the gravity loads to other parts of the structures. In order to reliably model the behavior of these critical beams and its effect on the response of the buildings, small scaled models of RC buildings will be tested. (Sasani, 2009)

Initial Research Competition





http://www.pcrc2007.neu.edu/discoverybranch.php

Research: Can this be done in a 9-12 classroom setting? Yes.

<u>Need to</u>: choose, test, and evaluate materials that could be used to model a real-world scenario in regards to; 1) the typical loading of a simple beam through gravitational loading, and 2) to provide a lab set-up to demonstrate catenary action. :

- *select materials that could be easily obtained by a classroom teacher*
- *select materials that are minimal in cost*
- *select materials that would provide as close to a scale model as scientifically possible*

Variables that needed to be tested and researched in order for the product to model a reality

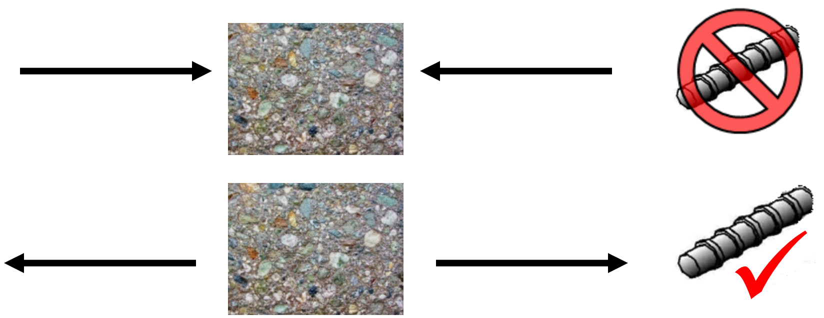
- **means of supporting beams (fixed and unfixed)**
- **means of loading the beam**
- **properties of concrete**
- **properties of rebar**
- **beam dimensions**
- **catenary action lab set-up**

What is reinforced concrete?

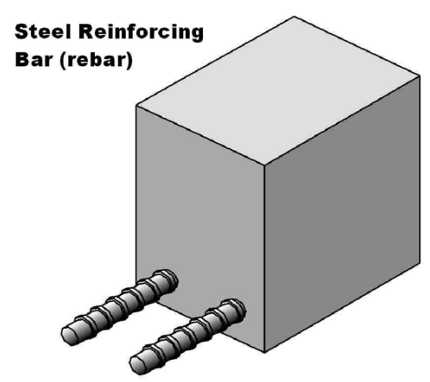
Reinforced concrete structures are built by combining concrete and steel.

** Concrete **

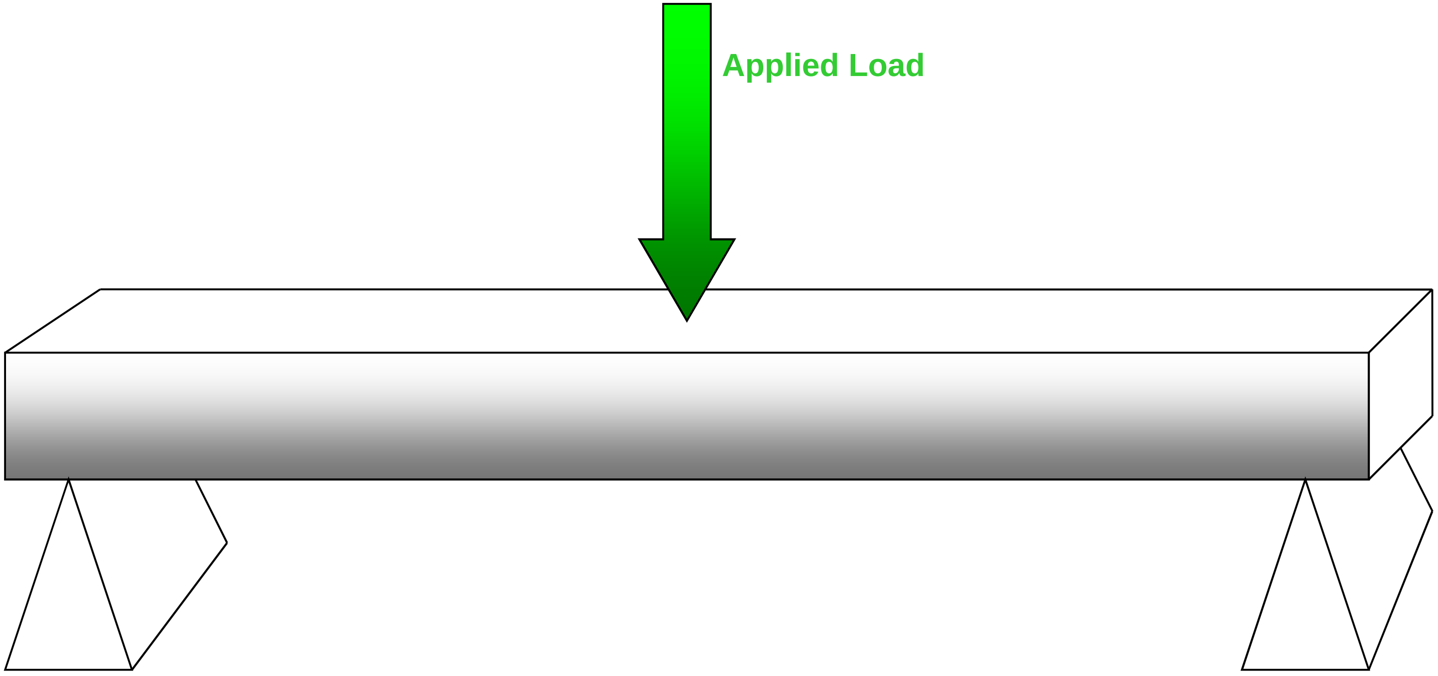
- strong in compression
- weak in tension



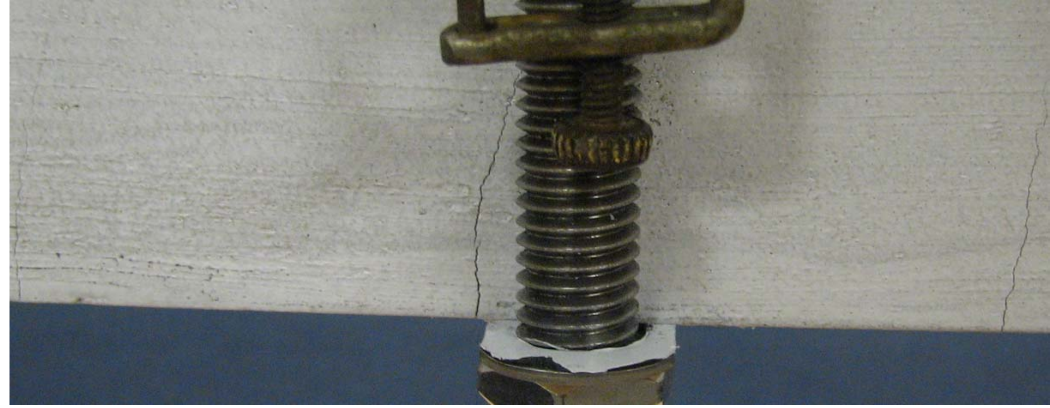
Steel reinforcement (rebars) is placed to carry the tensile forces that develop in the structural elements.

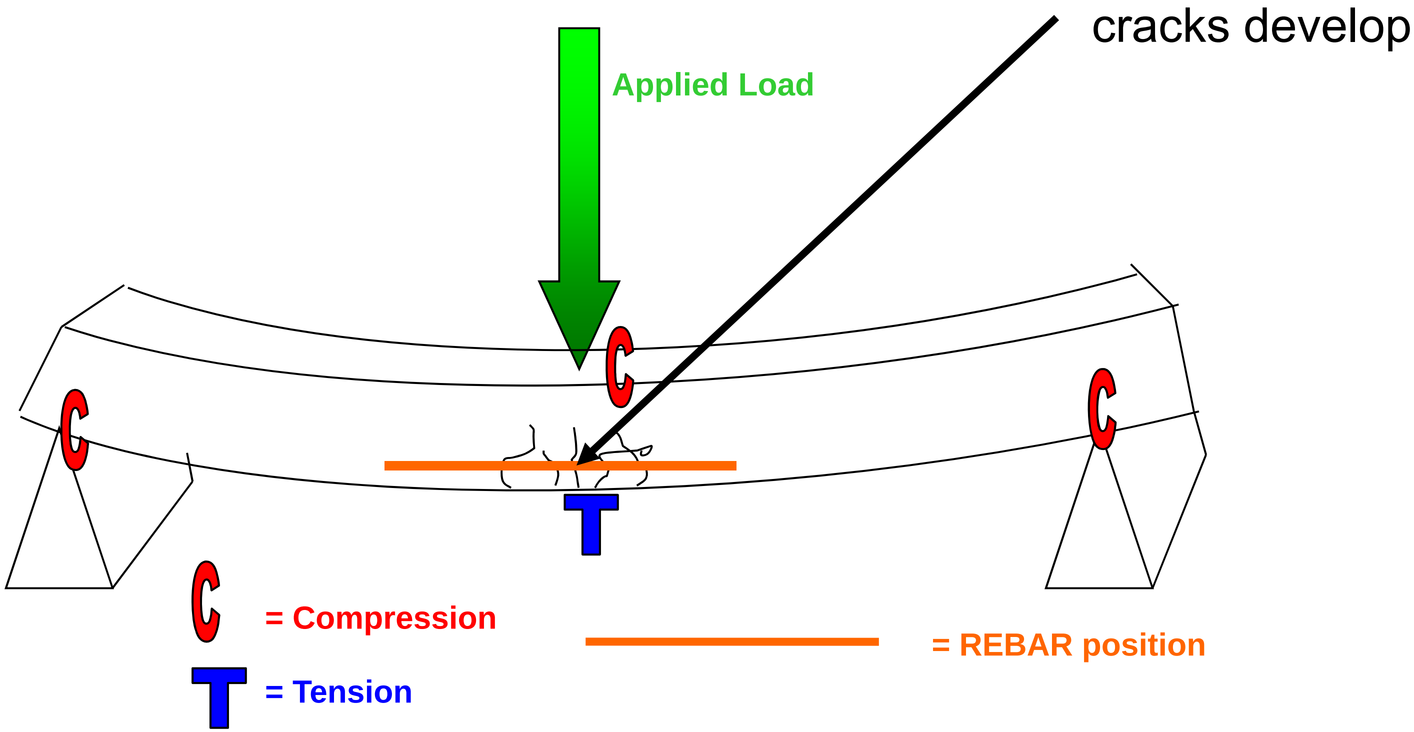


Simple Structural Beam (unfixed)

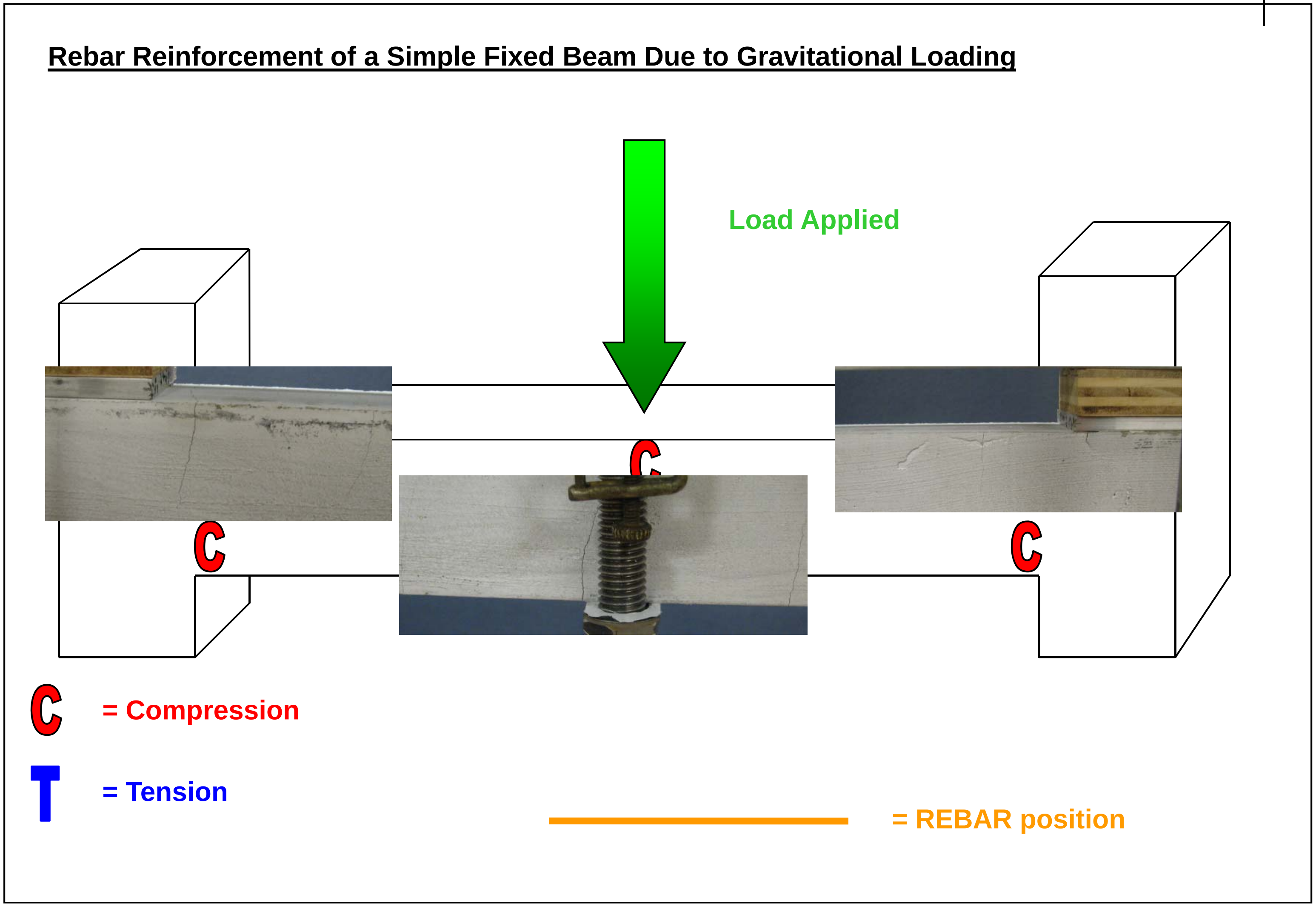


After Loading

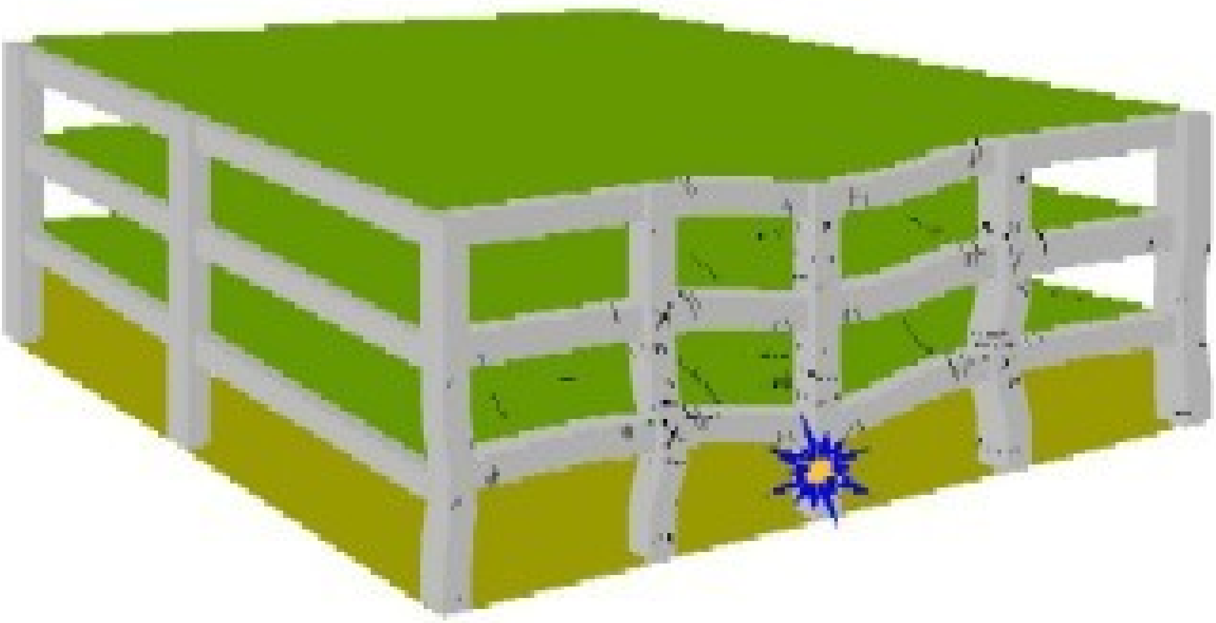




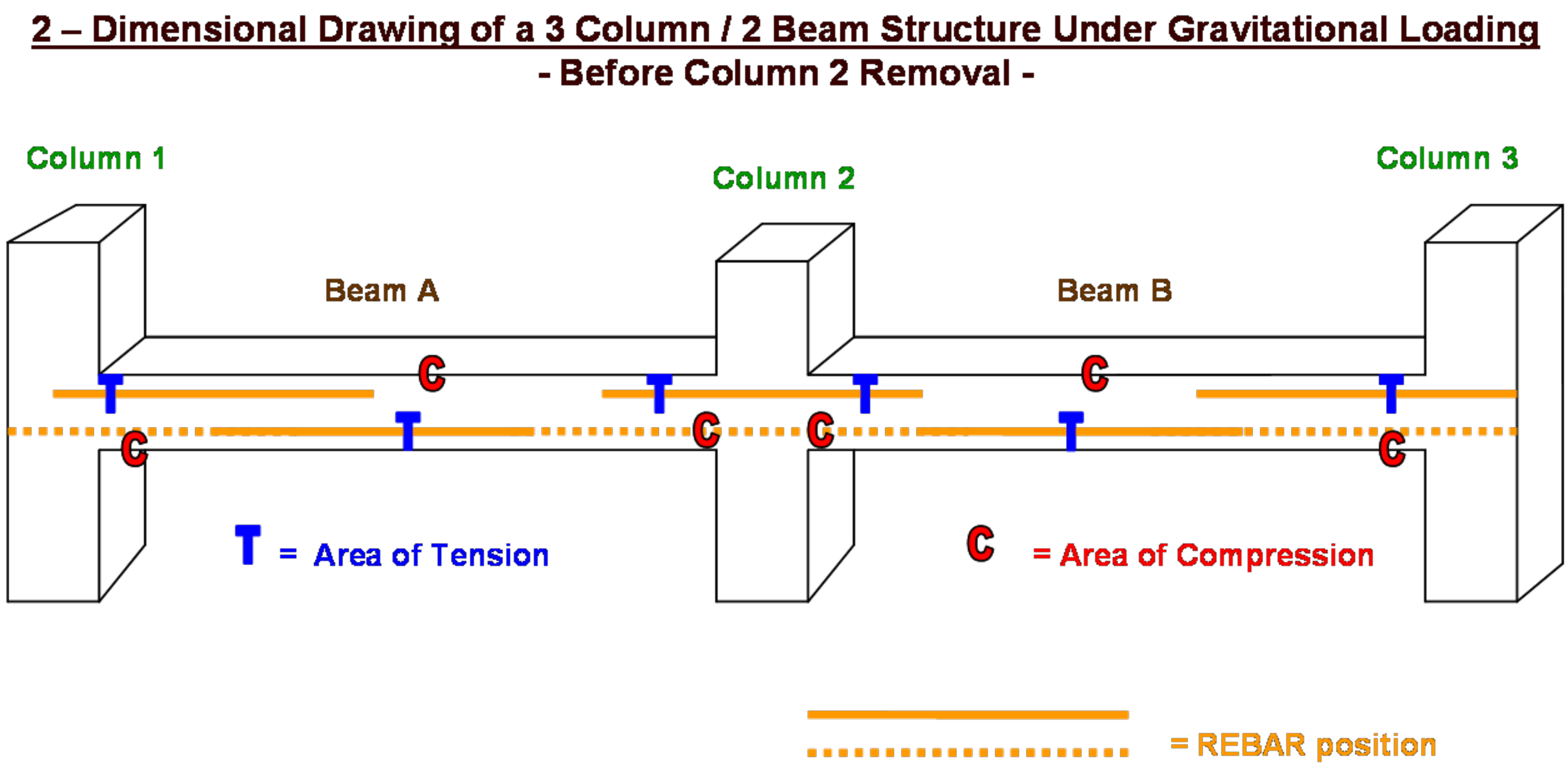
Simple Structural Beam (fixed)



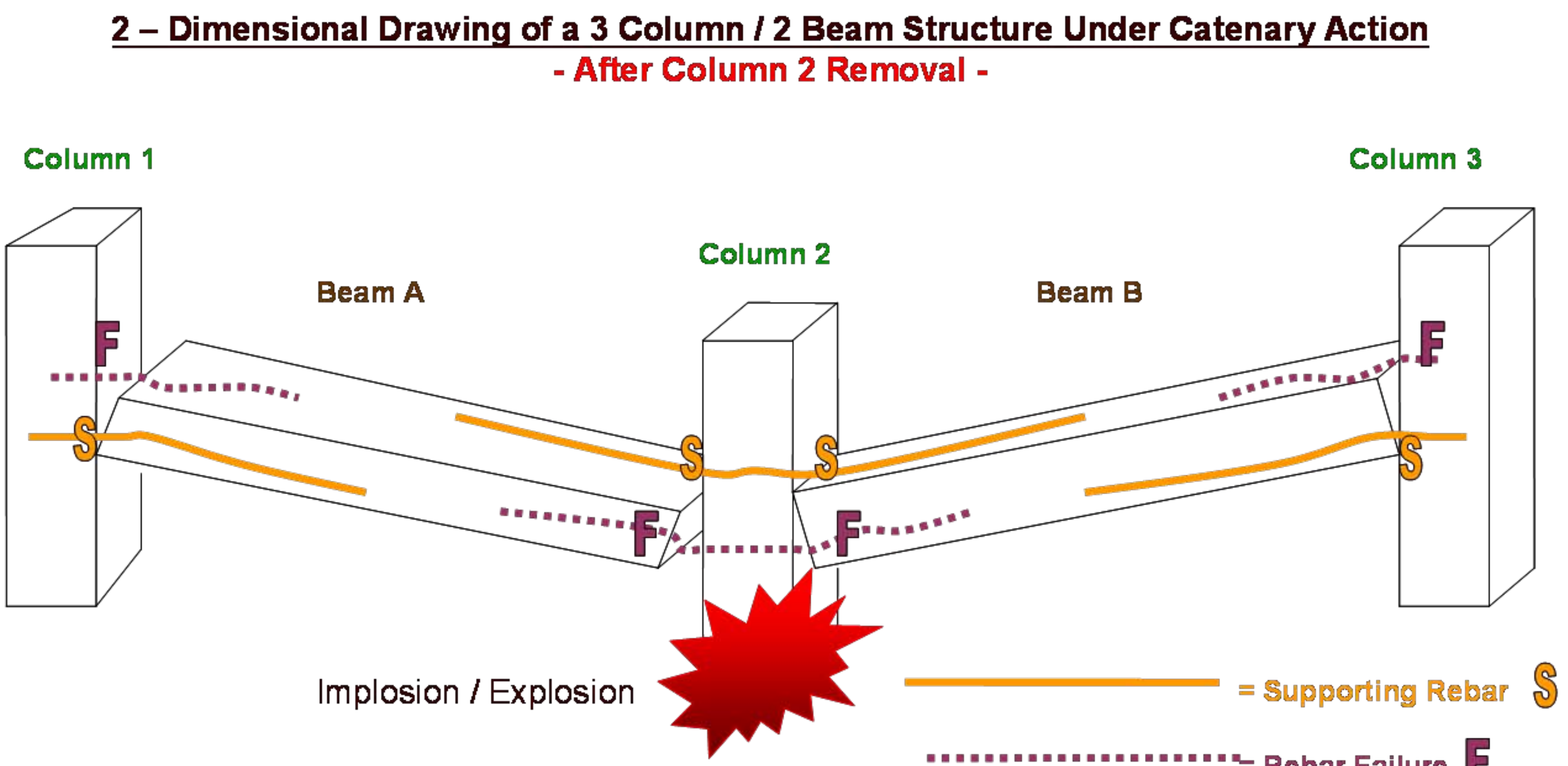
In the competition a 2-D model was constructed and contestants had to model the outcome after a column was removed from a multiple beam / column structure.



3 Column – 2 Beam Section

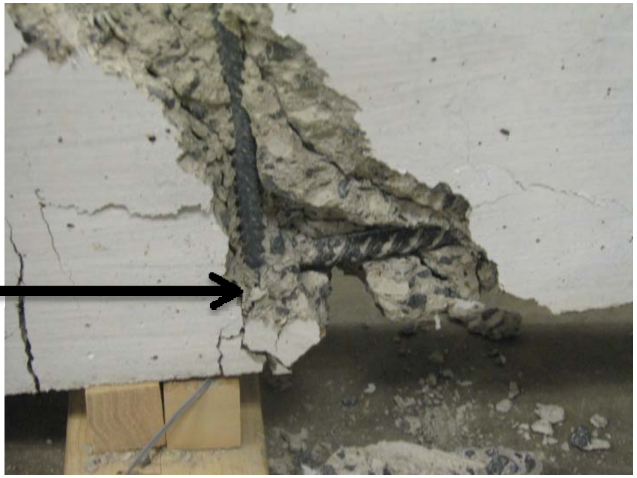


Catenary Action (after collapse)



Simple Beam Test / Lab

Compression



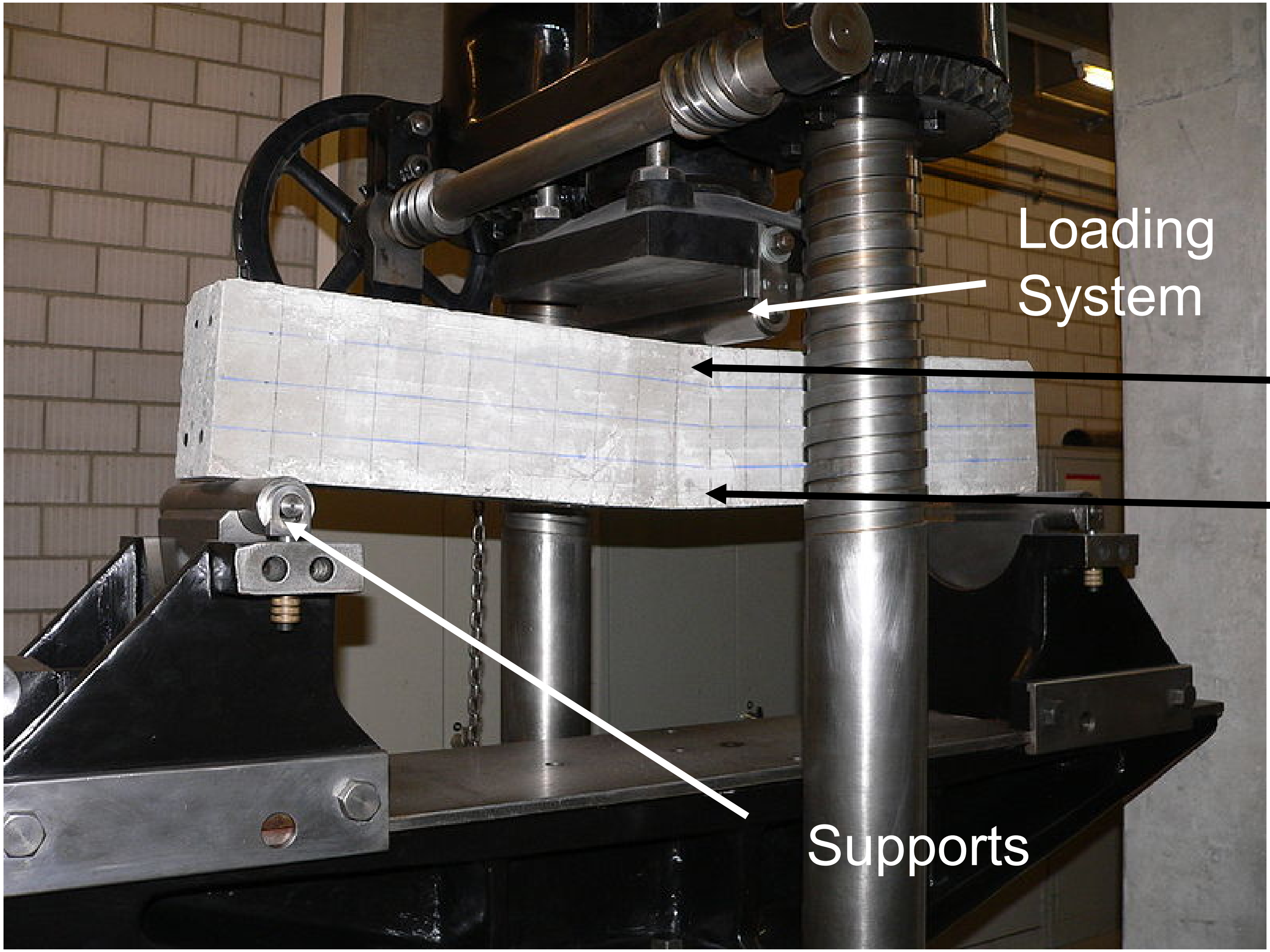
Tension

Lesson Objective:

Distinguish among tension, compression, shear, and torsion, and explain how they relate to the selection of materials in structures.

Flexural Test – Engineering Lab

http://en.wikipedia.org/wiki/File:Trois-points-p1040189.jpg



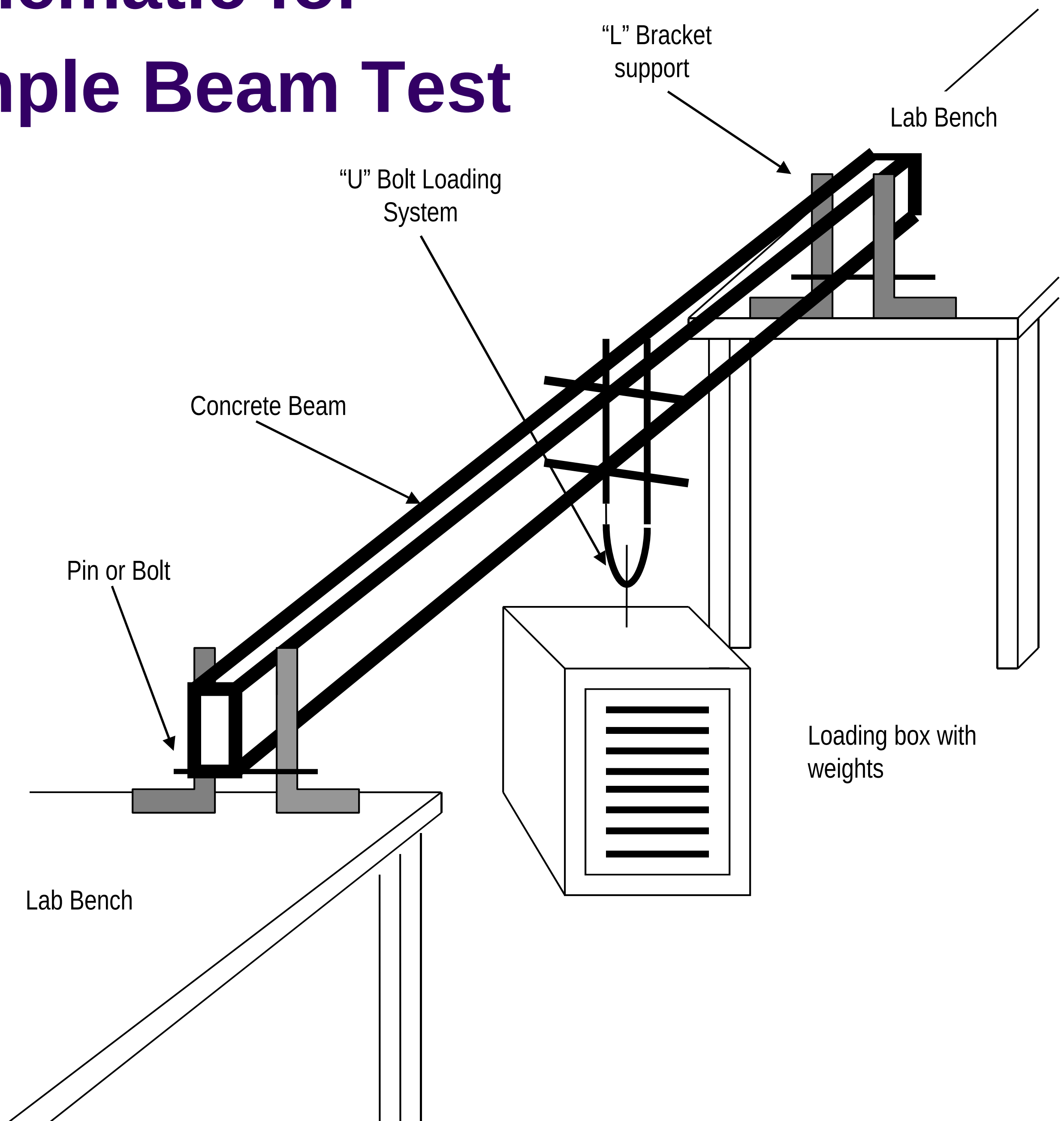
Curriculum Connection
(Engineering Technology Framework)

Construction Technologies

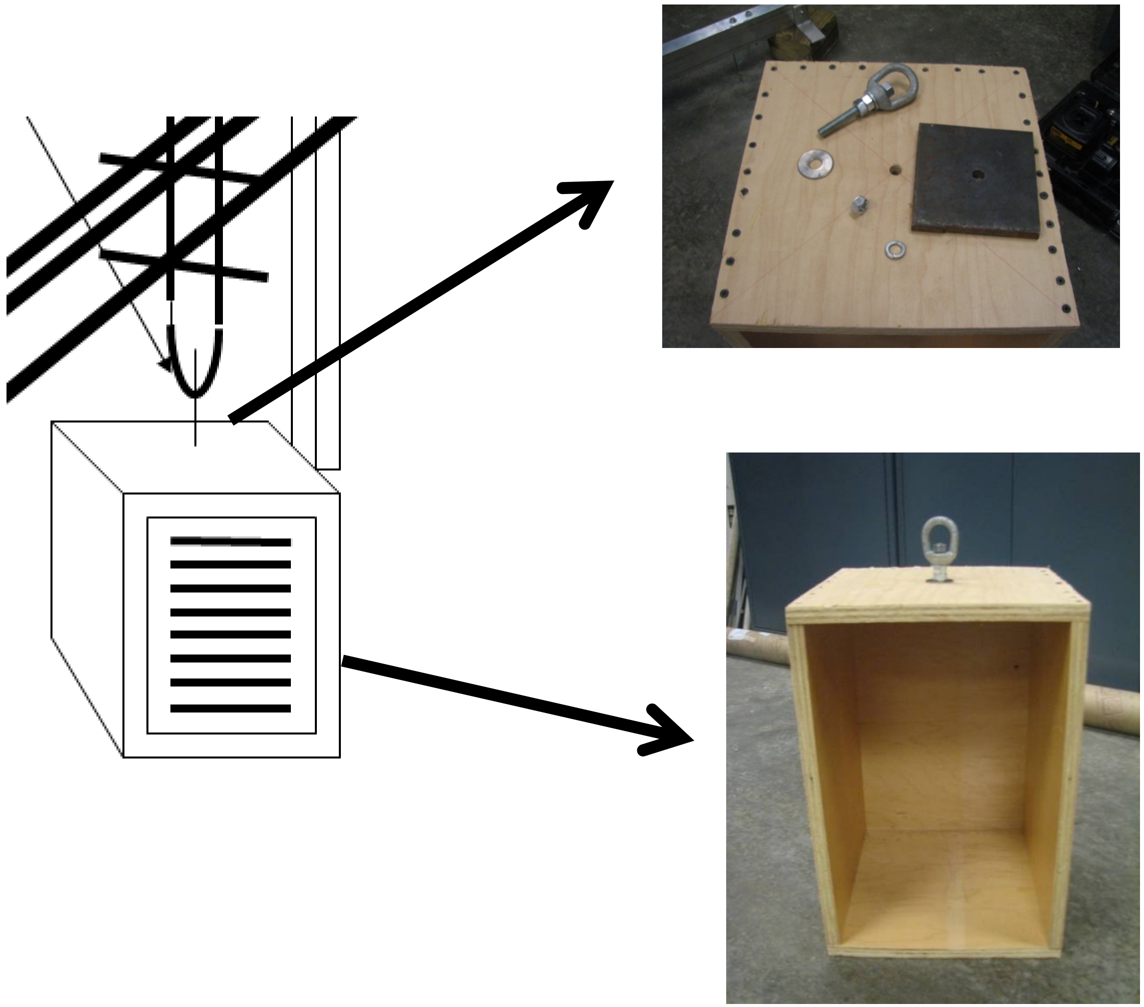
Central Concepts: The construction process is a series of actions taken to build a structure, including preparing a site, setting a foundation, erecting a structure, installing utilities, and finishing a site. Various materials, processes, and systems are used to build structures. Students should demonstrate and apply the concepts of construction technology through building and constructing either full-size models or scale models using various materials commonly used in construction. Students should demonstrate the ability to use the engineering design process to solve a problem or meet a challenge in construction technology.

- 2.1 Identify and explain the engineering properties of materials used in structures (e.g., elasticity, plasticity, R value, density, strength).
- 2.2 Distinguish among tension, compression, shear, and torsion, and explain how they relate to the selection of materials in structures.

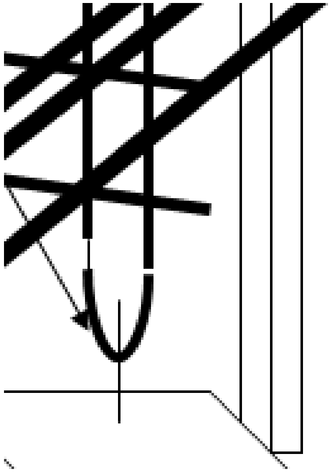
Schematic for Simple Beam Test

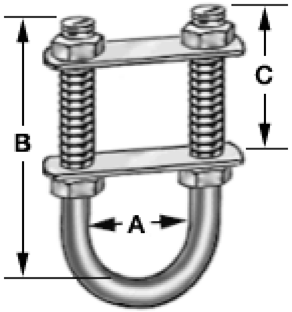


Loading Box



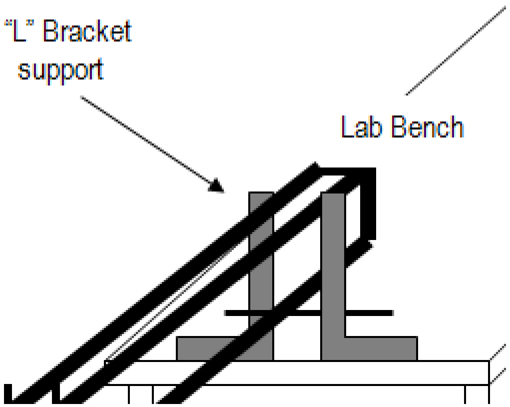
“U” Bolt Attachment

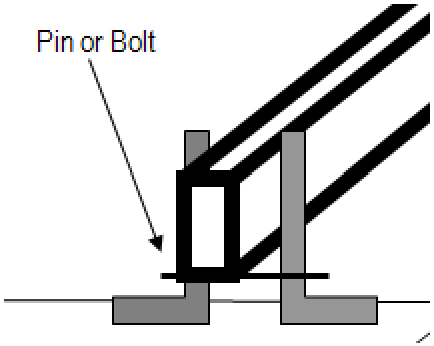


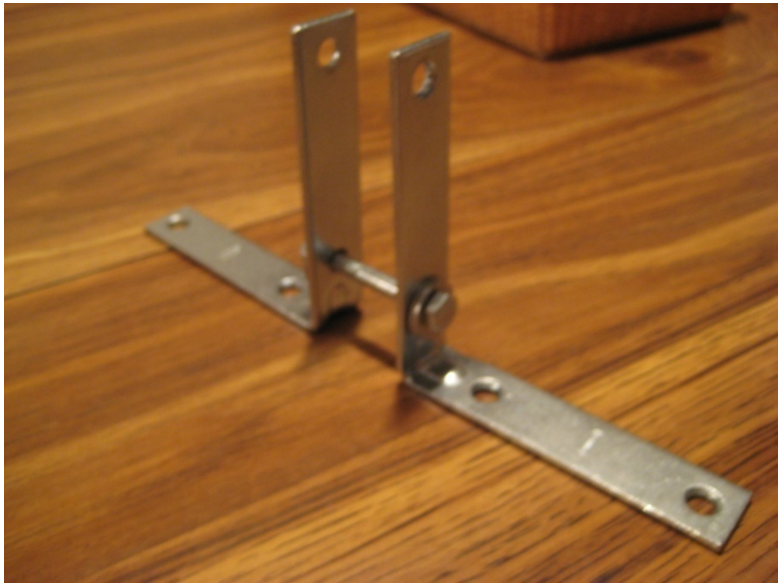


This attachment can easily be ordered online and similar attachments can be found in most hardware stores for lesser cost.

“L” Bracket and Pin System







This attachment can easily be obtained at a hardware store and is low cost. (see lesson plan)

Concrete Selection
(properties closely match those of construction grade)

Easy to obtain at most hardware stores, cost ranged from \$11.00 - \$14.00 per 20 pound bucket. A 45 pound bag averaged \$15.00.

Cost per poured beam will equal about \$2.00 to \$3.00.

Added benefit: Curing time equals 24-36 hours to achieve same compressive strength as traditional concrete (curing time 10-14 days)

Rebar Selection

(properties closely match those of construction grade)

<u>THREADED BRASS ROD</u>

Easy to obtain at most hardware stores, cost ranged less than a dollar a foot with a diameter = to 8/32.

Cost per poured beam will equal about $2.00 to $3.00.

Longer sections are readily available online which reduced the overall cost.

Activity 1 (Material Properties)

Essential Question(s):

- How does a concrete beam act under gravitational forces?
- What is reinforced concrete?
- Why is reinforcement needed?
- Where should the reinforcement be placed?

Introduction:

1) Have students describe the properties of concrete. Discuss how it relates to composite materials.

2) Discuss why concrete is used as a common building material due to its many benefits.

Activities:

- Show students a pre-poured beam on concrete.
- Have students speculate the amount of load (in lbs) that the beam could carry if it were loaded.
- Conduct load test on non-reinforced beam and record maximum load carried.

Conclusion / Extensions / Assessment:

- Have students research methods of reinforcing concrete using rebar (placement).

Activity 2 (Simple Beam Tests)

Essential Question(s):

- What are the properties of rebar?
- How is the placement of rebar determined?
- How is rebar held in place before the pouring of concrete?

Introduction:

1) Show students several images of rebar configurations.
2) Discuss areas within concrete that are under both compressive and tensile forces.

Activities:

- In groups students will work to place a limited amount of reinforcement to achieve maximum loading capacity for a simple fixed or unfixed beam.
- Students will compete for the highest loading total with the least amount of reinforcement.
- Pour / cure / test

Conclusion / Extensions / Assessment:

- Assess group results based on rubric.
- Discuss with students other factors to consider:

  **Structures are not <u>simple</u>, they are complex and fail for many reasons.

Activity 3 (Human – Induced Hazards & Catenary Action)

Essential Question(s):

- Why do RC buildings fail? (Discuss well-known examples.)
- What types of hazards are considered when building structures?
- What would happen to a structure if elements were removed?
- How does load distribution change after removing structural elements?

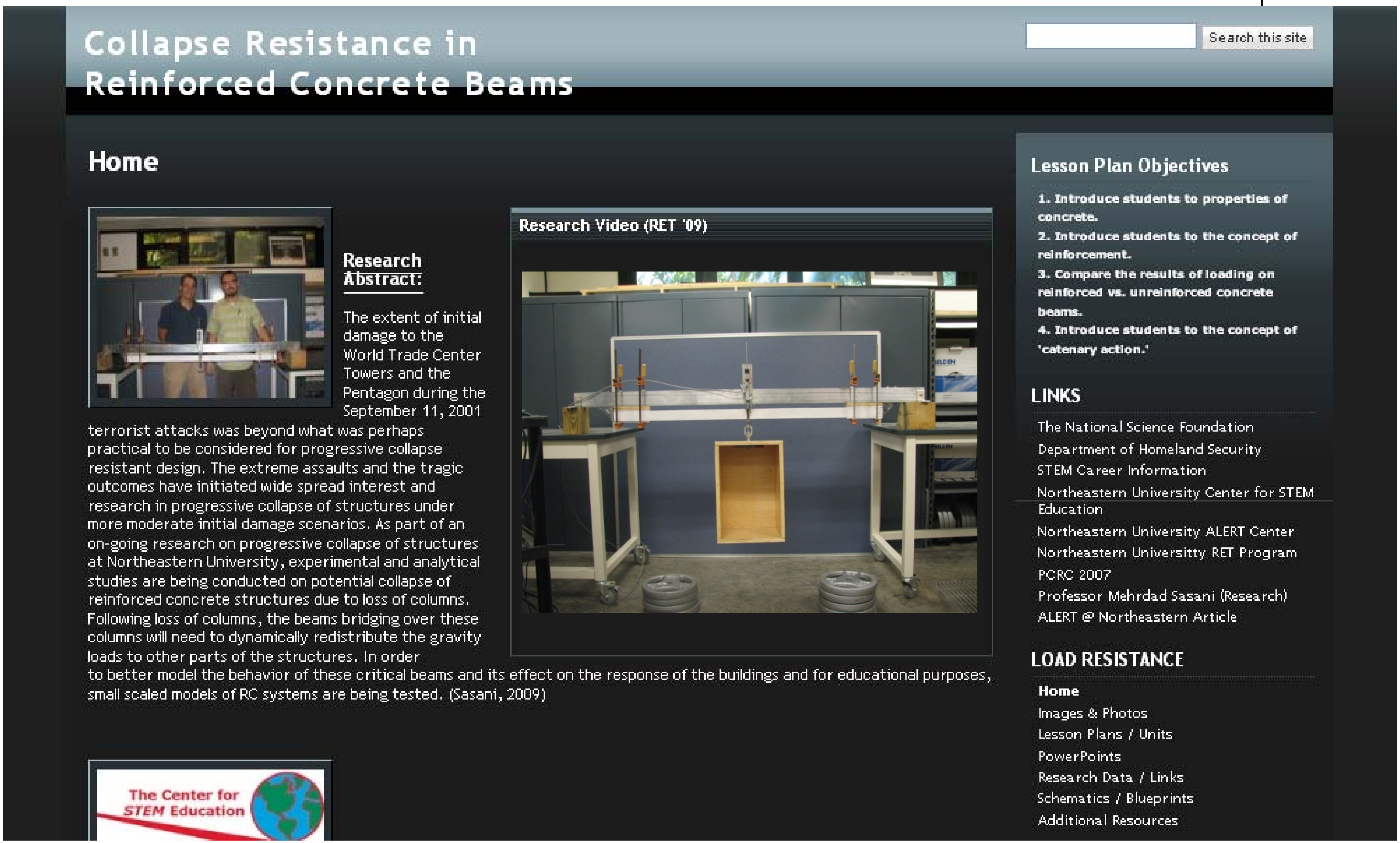
Introduction:

1) Show photos of buildings after disasters.
2) Have students speculate reasons for failures.
3) Discussion (based on research) as to why most structures still stand after significant structural failure.

Activities:

- Show Discovery School segment based on PCRC2007 challenge.
- Describe what is meant by catenary action.
- Show video (produced this summer) of their beam influenced by catenary action.

sites.google.com/site/catenary09ret/


Collapse Resistance in Reinforced Concrete Beams

Search this site

Home

Research Abstract:

The extent of initial damage to the World Trade Center Towers and the Pentagon during the September 11, 2001 terrorist attacks was beyond what was perhaps practical to be considered for progressive collapse resistant design. The extreme assaults and the tragic outcomes have initiated wide spread interest and research in progressive collapse of structures under more moderate initial damage scenarios. As part of an on-going research on progressive collapse of structures at Northeastern University, experimental and analytical studies are being conducted on potential collapse of reinforced concrete structures due to loss of columns. Following loss of columns, the beams bridging over these columns will need to dynamically redistribute the gravity loads to other parts of the structures. In order to better model the behavior of these critical beams and its effect on the response of the buildings and for educational purposes, small scaled models of RC systems are being tested. (Sasani, 2009)

Research Video (RET '09)

The Center for STEM Education

Lesson Plan Objectives

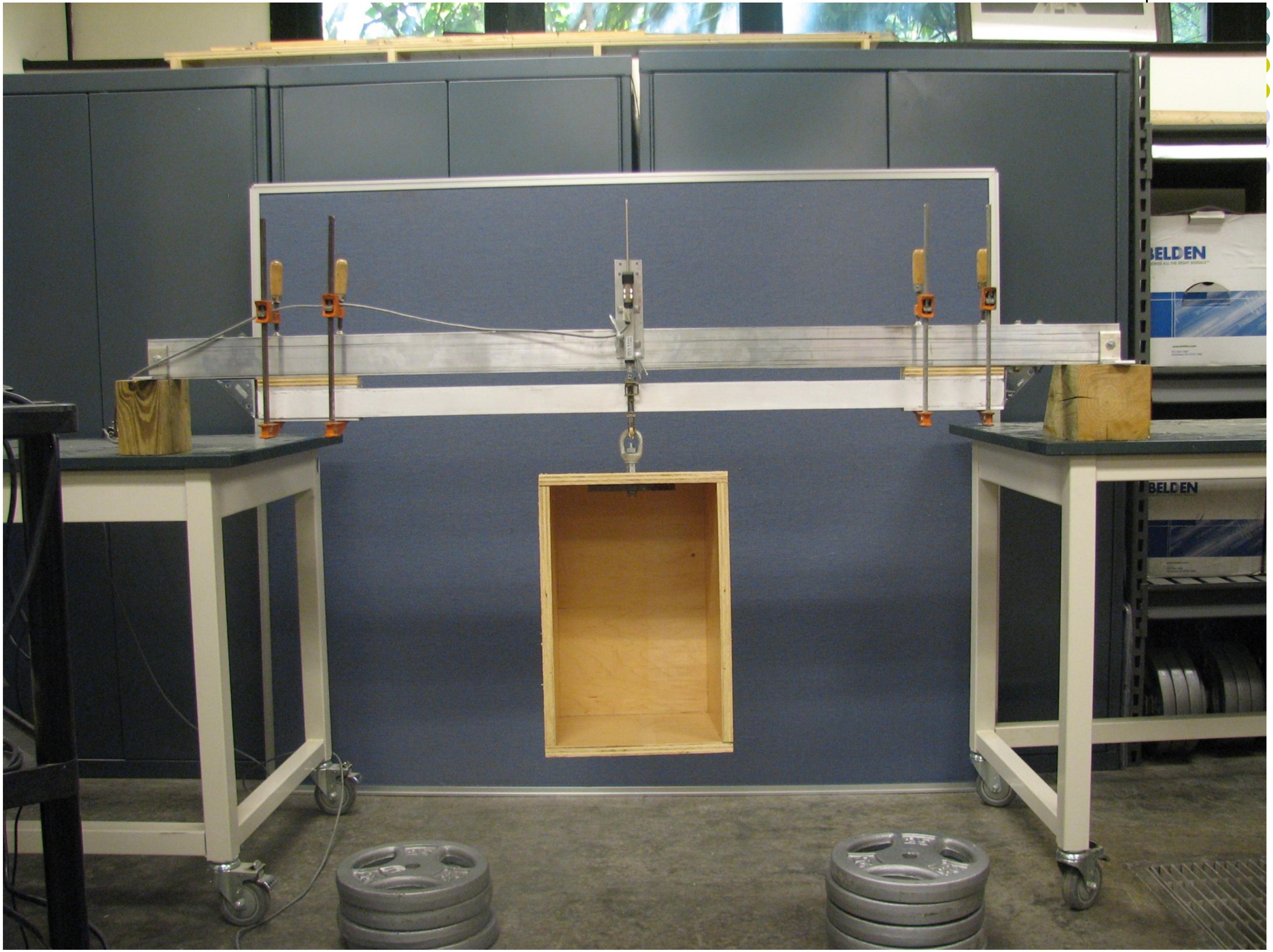
1. Introduce students to properties of concrete.
2. Introduce students to the concept of reinforcement.
3. Compare the results of loading on reinforced vs. unreinforced concrete beams.
4. Introduce students to the concept of 'catenary action.'

LINKS

- The National Science Foundation
- Department of Homeland Security
- STEM Career Information
- Northeastern University Center for STEM Education
- Northeastern University ALERT Center
- Northeastern Universitty RET Program
- PCRC 2007
- Professor Mehrdad Sasani (Research)
- ALERT @ Northeastern Article

LOAD RESISTANCE

- **Home**
- Images & Photos
- Lesson Plans / Units
- PowerPoints
- Research Data / Links
- Schematics / Blueprints
- Additional Resources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Catenary Action ??

- Catenary Action Video 8/3/09
- Set-up would be an investment of about $150.00
- Set-up could be used many times.
- How valuable is the knowledge? Does it reinforce the content? Does it create new pathways for knowledge?
- Will teachers have the expertise to fully understand and explain the concepts?

Addressing standards that are necessary, but difficult.

National Science Education Standards

- ***Natural and Human-Induced Hazards***

  Natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by humans bring benefits to society, as well as cause risks. Students should understand the costs and trade-offs of various hazards -- ranging from those with minor risk to a few people to major catastrophes with major risk to many people. The scale of events and the accuracy with which scientists and engineers can (and cannot) predict events are important considerations.

**** Students need to be aware that engineering for today's world requires thinking 'out of the box,' preparing them for scenarios that a decade or two ago might have been unimaginable.**

**** Engineers need to find new and innovative ways to design structures to provide safety and security.**