Structural Truss Elements and Forces

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Introduction:

Within the field of construction, the majority of structures are supported by several groups of truss systems working together synergistically. A truss is a group of centered and balanced elements combined to carry a common load (Warner, 2003). The most common place trusses are identified lie within the roof of a structure, but they can also be found in floors, walls, bridges, and in other areas. Trusses are used because they provide strength against loads and forces within a structure.

Structural truss making is a complex field of study, but can often be simplified by identifying three major relational elements within it: primary, secondary, and tertiary. The terms primary, secondary, and tertiary serve as a language used to describe the roles that different elements play within a truss system. This terminology also serves as a relational link in comprehending how elements interact between themselves and the forces and loads applied to them. Being aware of the relational roles that these three elements play will lead toward a better understanding of trusses and their construction.

The ability to comprehend primary, secondary, and tertiary element relationships within structures leads to a greater understanding of how constructed structures and elements distribute the forces and loads applied to them. Common forces that structures experience include: compression, tension, torsion, bending, and shear. Being able to grasp and understand how these forces act on trusses and their elements will lead toward improved and informed truss design.

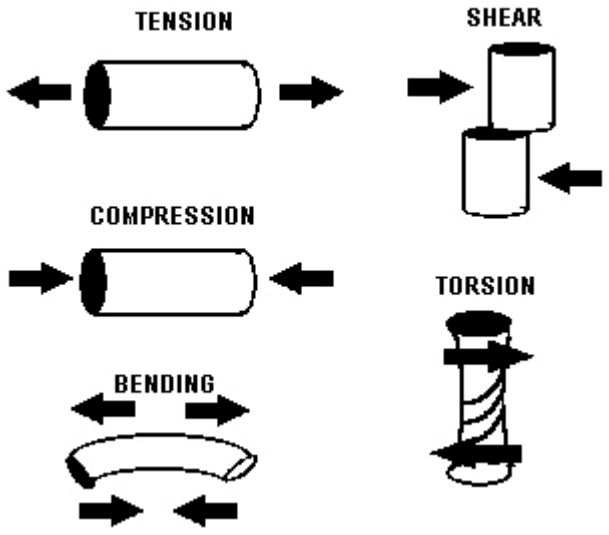
Key Definitions:

Element Relationships

Primary Element	element(s) that carries the greatest load and force that is in direct contact with that load and force (Warner 2003)
Secondary Element	element(s) that carries the second greatest load or force (Warner 2003)
Tertiary Element	element(s) that carries the least amount of load or force (Warner 2003)

Forces

Compression	a force that tends to push a material together (Hutchinson 2003)
Tension	a force that tends to pull material apart (Hutchinson 2003)
Bending	a force that tends to distort a structural element (Hutchinson 2003)
Shear	a force that tends to push material in two opposite directions (Hutchinson 2003)
Torsion	a force that tends to twist material apart (Hutchinson 2003)



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Live Load	the total of all moving and variable loads that may be placed on or in a building (Olin, 1995)
Dead Load	the weight of all permanent and stationary construction or equipment included in a building (Olin, 1995).

Truss and Components

Truss	a group of beams formed into a rigid frame (Polette, 2001) a group of centered and balanced synergistic elements combined to carry a common load (Warner, 2003).
Chords	the top and bottom members of a roof or floor truss (Koel, 1997).
Web	truss member that runs between and ties together the top and bottom chords (Koel, 1997).
Gusset Plates	plates of galvanized iron or plywood that are placed on each side of a joint in the truss to hold pieces together (Hop, 1988).

The Challenge:

In teams of two, you will design and build a truss containing at least eight total elements utilizing at least one of each element, primary, secondary, and tertiary. The truss will be made out of a corrugated cardboard material that will be supplied by the instructor. After building the truss, you will identify and test the forces acting upon those elements.

Objectives:

1. Students will effectively work within groups of two, to complete the design challenge.

2. Students will use materials and tools to construct a truss system.

3. Students will identify and explain the three structural elements within their truss system.

4. Students will identify and explain the structural forces acting on their truss system.

5. Students will define what a truss is and identify the different components of a truss.

6. Students will test their truss system to determine and conclude the relational roles between the elements within the truss, and the forces acting upon it.

Resources:

World Wide Web

Spence, W. (1985). *Architectural design, engineering, and drawing*. Bennett & McKnight Publishing Company. Encino, CA. P. 200-201

Polette, D., Landers, J. (2001). *Construction Systems*. The Goodheart Willcox Company, Inc. Tinley Park, IL. P. 246-250.

Weaver, G. (1974). *Structural Detailing for Technicians*. McGraw-Hill, Inc. P. 126.

Hutchinson, J., Karsnitz, J. (1994). *Design and Problem Solving in Technology.* Glencoe / McGraw-Hill. Peoria, IL. P. 120.

Koel, L. (1997). *Carpentry (3rd Ed).* American Technical Publishers, Inc. P. 390-391.

Hop, F. (1988). *Residential Construction and Design: Techniques for the modern builder.* Prentice Hall. Englewood Cliffs, NJ. P. 206 –326.

Material / Equipment:

3’ X 6’ sheet of double corrugated cardboard
Duct Tape
Utility Knife
Tape Measure / Ruler
Drawing Instrument
Straight Edge
Design Challenge Packet
Butcher Block Paper
Scissors

Limitations / Requirements:

1. Only the supplied materials can be used.
2. The design must have 8 – 12 elements.
3. Truss must be shorter than 6’ and longer than 2’ in overall length.
4. Primary elements must be 2” in width.
5. Secondary elements must be 1.5” in width.
6. Tertiary elements must be 1” in width.
7. Truss must be designed to sit on two blocks that replicate a wall or foundation block.
8. Truss must be designed to lay flat on a table for testing.
6. Truss must be a roof truss

Procedures:

1. Read through the entire design challenge packet.
2. Research potential truss designs.
3. Using the Brain Storming Sheet from this packet, sketch 4 potential truss design meeting the criteria specified in the limitations.
4. Chose a final design and complete a detailed sketch with dimensions.
5. Submit the final design to the instructor for approval.
6. Identify and label each individual element as primary, secondary, or tertiary.
7. Draw a full-scale drawing of the truss on butcher-block paper (supplied).
8. Label individual elements with numbers.
9. Cut out, with scissors, the individual elements of the truss.
10. Trace the different elements onto the cardboard, using the paper pieces as a template. Be sure to label each piece you trace with the number given.
11. Cut out truss elements from the cardboard using a utility knife and a straight edge if needed (Observe specified safety rules). See fig. 1
12. Assemble the elements of the truss using duct tape to represent gusset plates.
13. Place truss on the testing device. The testing device consists of two blocks of wood attached to a table to represent the structure that the truss will sit on.
14. The tests will be done using compressive loads applied by the tester. Plan out where the three tests will be performed, one each from the top left, the top center, and the top right.
15. On your final design sketch, identify the testing compression point by drawing an arrow to the selected point.
16. Individually cut one element in half at a designated cut point and perform a compression load test. For a web, the cut points should be approximately in the middle. For a chord, the cut point should be approximately half way in between two truss members. See fig. 1. A compression load test includes applying pressure to the truss with your hands and pushing it toward the blocks in the testing device. See fig. 2. You will perform this test from three different

areas, the top left of the truss, the top center of the truss, and finally from the top right of the truss.

17. Identify the force acting on that element, and record answers on the data sheet.
18. Repair the cut in the element with duct tape.
19. Repeat steps 16-18 for each element of the truss system.
20. Submit design packet to the instructor.

Fig. 1

Fig. 2

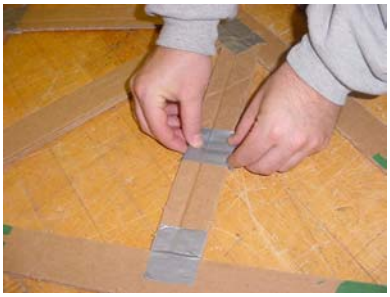

Fig. 3

References:

Hop, F. (1988). *Residential Construction and Design: Techniques for the modern builder.* Prentice Hall. Englewood Cliffs, NJ. P. 206 –326.

Hutchinson, J., Karsnitz, J. (1994). *Design and Problem Solving in Technology.* Glencoe / McGraw-Hill. Peoria, IL. P. 120.

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Spence, W. (1985). *Architectural design, engineering, and drawing*. Bennett & McKnight Publishing Company. Encino, CA. P. 200-201

Warner, J. (2003). *How Structures Perform [Worksheet].* ITEDU 306 – Construction Systems. Ball State University.

Weaver, G. (1974). *Structural Detailing for Technicians*. McGraw-Hill, Inc. P. 126.

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Brainstorming Sketches

Directions: Brainstorm 4 different truss designs and then sketch the four in the boxes provided below, and on the next page.

Names:_____ Date:_____

Brainstorming Sketches

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Names:_____ Date:_____

Final Design

Directions: In the box provided below make a final sketch of your chosen truss design. The truss should have parts labeled with dimensions. Below the sketch, in the provided area, give a brief description of your truss, and how it will function.

Design Explanation

_____

_____

_____

_____

_____

_____

Names:_____ Date:_____

Truss Testing

Directions: Below is a chart to record your data from the truss testing. The far left column is the space to list your element number. Next, identify what the element role is, either primary, secondary, or tertiary. Finally, identify whether the element is in compression or tension when a load is applied from the left side, from the middle, and from the right side.

Element #	Element Role (Primary, Secondary, Tertiary)	Load Left	Load Middle	Load Right

Truss Design Activity

Evaluation

Name(s) _____ Date: _____

_____

*All work will be evaluated as a group and not individually

Evaluation of Group Work 0-5 pts. _____

- Used time effectively
- Group worked well together
- Equal contribution by team members
- Completed design brief

Evaluation of using tools and equipment 0-5 pts. _____

- Proper use of material
- Proper use of equipment

Evaluation of truss 0-5 pts. _____

- 8 elements or more
- Labeling elements
- Truss met design limitations

Evaluation of truss testing 0-10 pts _____

- Correctly completed testing page
- Correctly identified element relationships
- Correctly identified element forces
- Demonstrate an understanding of roles and relationships between elements and forces.

Total: _____