Nature Sunday Academy Lesson Plan – 2014-15

Title – Truss Design – The load bearing member of building structures

Description:

The objective of the lesson plan/presentation is aimed at demonstrating how trusses can be designed to carry load in different conditions. Trusses are widely used in the building structures, bridges, airplanes, electric power lines etc. Truss word is derived from Old French *trousse* which means collection of things bound together. In simple terms a truss is a single plane framework (planer truss) of individual structural members connected at their end (nodes) that forms a series of triangles sections that can span a large distance. The engineered truss structure comprises of five or more triangular units. The main parts of the truss are upper and lower chords and web in between, the nodes have either metal gussets or are glued. Two common types of trusses are pitched truss and parallel chord truss. Newton's Laws apply to the structure as a whole, as well as to each node or joint. In order for any node that may be subject to an external load or force to remain static in space, the following conditions must hold: the sums of all (horizontal and vertical) forces, as well as all moments acting about the node equal zero. Compression and tension are two dominant forces in trusses.

Truss in truly engineering marvel that provides means of spanning an opening much wider than the length of the truss's longest member without large bending stress. During the lesson plan students will be exposed to different truss design strategies, and fabrication techniques. Students will participate in hands on exercise where they will design, analyze, fabricate and test the trusses.

There are two hands on activities planned for this lesson plan. The first activity is focused on designing a truss with a given amount of chord material. They will be using hot melt glue and small nails to restrain the members. Students will first use graph paper to design the truss model and calculate the dimensions of each element of their truss as well as the angles. Once the design is selected they will cut the material and assemble two identical trusses using glue and nails. They will understand how different sections of trusses are required to bear compressive and tensile loads. They will understand how critical is ensure the angle of each element.

The second activity is designed at assembling the two trusses using a sheathing material that will act as a roof so load can be applied to test the strength of the truss system. This activity is designed for students to learn how different designs can impact the load bearing capacity of trusses. It will also help to engage students in a small competition where most efficient truss (strong and light weight) design will be identified. All these activities will also help students understand how engineering principle can be

applied to build strong, light and durable trusses comparing strength to weight ratios for various applications.

Cultural Connection:

Objectives:

Student will familiarize with fundamental properties of engineered building product.

Standards Covered: 9-10, .1.1., .1.4., .1.5., .2.2., .2.3.,.2.7., .2.8., .6.2., .6.3.

11-12, .2.5., .2.6., .6.2., .6.3., .7.4.

Session Organization:

11.00 – 11.15 AM - Cultural Connection

11.15 – 11.45 AM – Introduction/Presentation

11.45 -12.30 PM – Start Activity 1 (Design)

12.30 – 1.00 PM – Lunch

1.00 – 2.15 PM – Initiate Activity 2 (Fabrication)

2.15 – 3.00 PM – Competition

Materials List:

Markers – 4

Graph Paper Sheets – 5

Pencils/Eraser - 10

Hot Melt Glue Guns - 5

Glue Sticks – 10

Ruler – 5

Box Cutter Knife - 5

Chord Balsa wood Strip - 1”x0.125”x120”

Small Nails - 60

Weighing Scale - 5

Cardboard Sheets - 2

Plastic Slings/chord – 100 inches

Latex Gloves – 10 pairs

Coke 2 liter Bottles - 2

Bucket - 1

Testing Jig – 1

Paper Towel

Vocabulary – Definitions:

Truss

Chord and Web

Pitch

Forces (Compression and Tension

Nodes

Reaction Points

NDS Standards

ANSI Standard

MSR (Machine Stress Rated)

Modulus of Elasticity (MOE)

Load Deflection Curve

Axial and Shear Rotations

Metal Connector Plates or Gussets

Resin

Modulus of Rupture (MOR) or Flexural Strength

Creep

Activity 1 (Design)

Summary

Students will design a truss system with a span of 13 inches (overhang of 0.5 inches on each side) and maximum height of 5 inches (top to bottom chord) and minimum height of 4 inches. The maximum material to be used for designing two trusses will be 108 inch. The group will discuss and select a design that they want to fabricate for this project. A graph paper will be used to draw a full scale truss. All the elements will be carefully measured and their angles noted with a protractor in a tabular form. Students will be advised that the main objective of this activity is to come up with a design that is light and strong. They will be encouraged to come up with a design that uses least amount of glue. Each group will get a graph paper, pencil, eraser, protractor, and a ruler. General guidelines will be provided how to conduct this experiment. This activity will enable students to be creative in their truss design.

Table 1. Dimension and angle of the truss parts

Element	Length (In)	Angle	Location
Upper Chord			
Lower Chord			
Web			

Engineering Connection

Students will understand the advantages of importance of concept design and evaluation before making a prototype.

Requirements

Each group will get one graph paper, pencil, eraser, ruler, protractor and guide sheet.

Store all the measurement data on a notebook or graph paper

Procedure (Design)

1. Divide students into a group of 4-5 students.
2. Obtain a graph paper.
3. Discuss various concepts
4. Draw the concept on graph paper.
5. Measure each element of the truss.
6. Measure angle of each element.
7. Label each component and identify their position.
8. Count all the elements and fill the table.
9. Verify the design and calculate total chord material required for design.

Activity 2 (Fabrication)

Summary

The students will fabricate two identical trusses based on the design selected in activity one. The students will use the chord material to cut all the elements of the truss using the box cutter. They must measure accurately the length and angle of each element before cutting. Once all the chord elements are cut the material shall be weighed using the weighing scale and record as W1. Now assemble all the elements using a hot melt glue gun to fabricate the truss. Excessive glue should not be used as it is going to impact the weight of the truss. Critical reaction points/nodes should be selected and reinforced with nails. Once the trusses are fabricated they will be again weighed and noted at W2. This step will help to calculate how much glue was used in fabrication. The % glue used for fabrication can be calculated using formula 1.Ensure all the elements are placed on their specific locations and all the triangles are similar. This activity will also help students to understand how to fabricate the trusses based on their final design. Once the trusses are ready they will be sheathed to form a stable system that can be tested for strength. The top chords will be sheathed to the cardboard with a 3 inches span (gap). The truss system will then be subjected to variable load and deflection will be noted to identity most

This activity will help to measure the strength and deflection characteristics of different truss designs. It will also help students to understand how different member of the trusses experience different forces and relate to sagging floors and interior door that don't open in old buildings.

Engineering Connection

Students will understand impact of truss design on the deflection and strength properties.

Safety

Caution – Use box cutter knife with care.
Be watchful of any splinters.

Requirements

Each group will construct 2 trusses for designing the system and testing.
Store measurement data in a notebook or enter in the table.

Procedure

1. Divide students into a group of 4-5 students.
2. Select good quality balsa strips measuring 1inch wide, 0.125 inch thick and 120 inch long.
3. Lay the balsa strips on a hard solid surface eg. Laboratory counter tops (slate).
4. Refer to table 1 and mark the lengths and angle on the strips and label each section. First mark the top and bottom chords and then the web elements.
5. First cut the top and bottom chords using box cutter knife. Measure the length and angle before cutting the chords.
6. Label the chords as per table one to ensure they are marked and placed accurately. Take the weight of all the elements label it as W1.
7. Ensure the joints or nodes are glued carefully with hot melt glue. Avoid excessive glue.
8. Identify key reaction points or nodes and reinforce them with nails.
9. Take the weight of the assembled trusses label it as W2.
10. Calculate the percentage glue using equation 1.
11. Attach the sheathing material to the top of the trusses using hot melt glue; ensure the span between two trusses is 2 inches.
12. Cure the glue for 10 minutes.
13. Place the truss system on a jig with 12 inch span. One half inch overhangs on each side.
14. Insert two plastic chord over the truss 4 inch from each end (see figure 1).
15. Tie the chord in the middle to plastic bucket.
16. Place a rule in the middle of the truss.
17. Start adding sand the empty plastic bucket.
18. Note the deflection after every 50 gm of sand.
19. Note final deflection before truss fails.
20. Weight the amount of sand in the bucket.
21. Calculate the deflection based on the load (weight of water) and compare with the weight of truss. Use table 2 to fill the information.
22. Identify which truss design was lightest, strongest, minimal deflection and used least amount of glue.
23. Identify the failure mechanism and note the weakest links in the truss system.

$$\% \text{ Glue} = \frac{W2 - W1}{W1} * 100 \qquad (1)$$

Table 2. Truss Testing

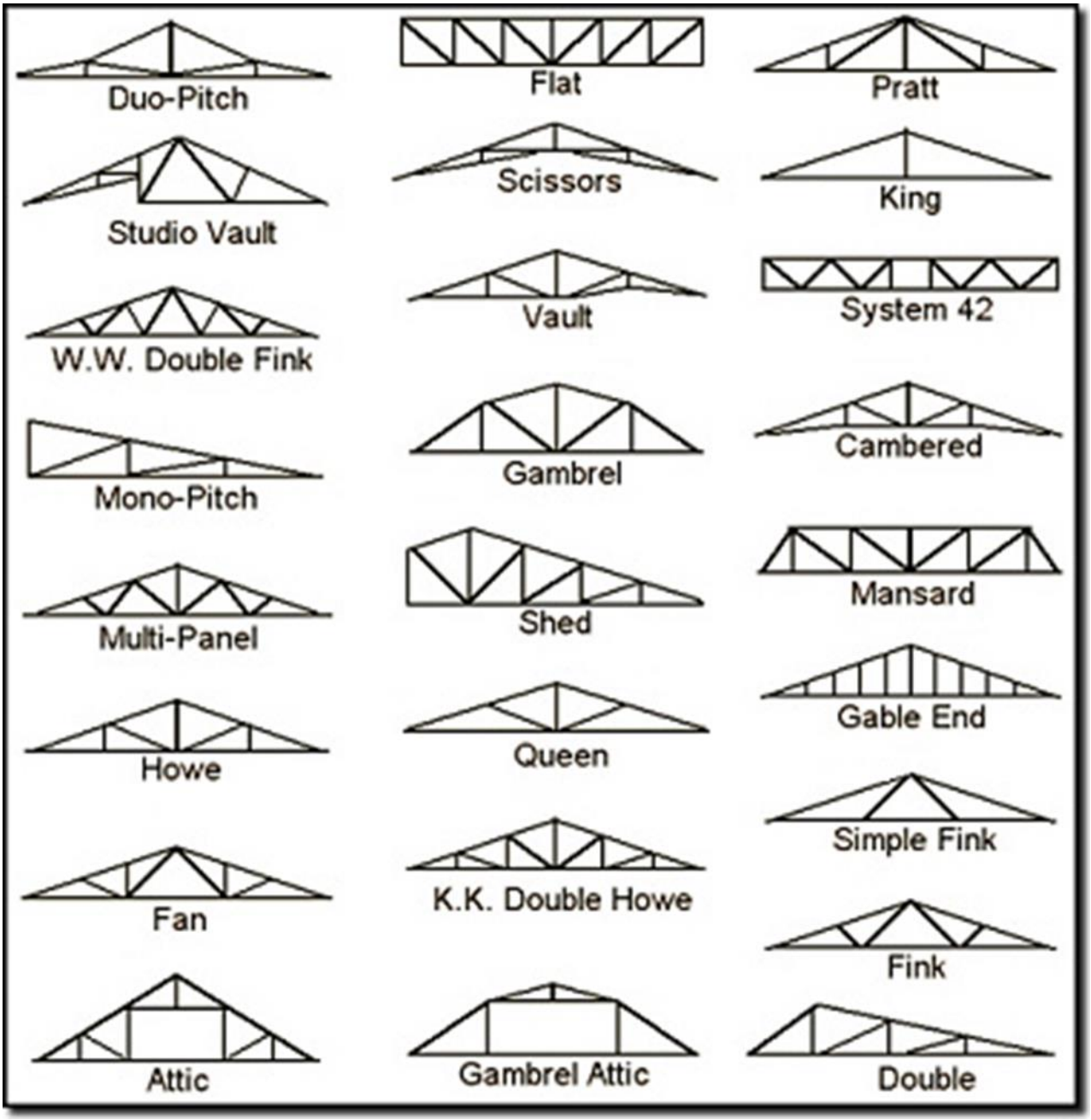
Group No.	Chord Weight	Maximum Load	Truss Weight	Glue Weight	Rating
	(gm)	(gm)	(gm)	(gm)	

Questions

1. Why are trusses used?
2. What are different kinds of trusses?
3. Name five different applications of trusses?
4. What kinds of forces are exhibited in trusses?
5. How truss design can impact the performance and strength?
6. How do you notice durability of trusses?
7. What kind of new engineered materials are being used in truss manufacturing?

Reference Sheet:

Various truss designs


Duo-Pitch
Flat
Pratt
Studio Vault
Scissors
King
W.W. Double Fink
Vault
System 42
Mono-Pitch
Gambrel
Cambered
Multi-Panel
Shed
Mansard
Howe
Queen
Gable End
Fan
K.K. Double Howe
Simple Fink
Fink
Attic
Gambrel Attic
Double