PERFORMANCE OF A STRUCTURE

Materials

- Performance Of A Structure - BLM 7.4.1
- Bridge Structure - BLM 7.4.2
- Spreadsheet Example - BLM 7.4.3
- Testing the Strength of 2-D Shapes – BLM 7.4.4
- Struts and Ties - BLM 7.4.5
- Testing the Strength of 3-D Shapes – BLM 7.4.6
- popsicle sticks
- white glue
- strong cord or wire
- sand
- Jinks wood
- Straws

Overall Expectations: 2. Design and construct a variety of structures, and investigate the relationship between the design and function of these structures and the forces that act on them (7s21); 3. Demonstrate an understanding of the relationship between structural forms and the forces that act on and within them (7s

Structures and Mechanisms – Forms and Function -
– Performance of a Structure –

Description: Students will measure the structure's ability to support a load. They will construct a bridge and determine the ratio of mass (of the structure itself) to load (mass that it supports). They will compile and display data using a spreadsheet and graphs.

Part A (60 mins) - Struts and Ties

1. Using pictures of some the structures from subtask one examine the different shapes found in structures. Discuss what shapes are most common. Examine pictures of frame structures and review the terms struts and ties. Struts are the supports that resist compression (they are usually the vertical supports). Ties are the supports that resist tension (they are usually the horizontal supports).
2. Divide the class so that the students are working in pairs. Set out stations with hot glue guns. Distribute materials (fettuccini noodles, straws, or art straws) to the students and instruct them to create the following two-dimensional shapes:
   - a) an equilateral triangle
   - b) a square
   - c) a rectangle
   - d) a regular pentagon
   - e) a regular hexagon
3. Have students predict which shape will be the strongest. Students test the shapes by having one partner hold the bottom corners of the shape while the other partner places one finger against a top corner, and pushes down toward the centre of the shape. Students check to see if the shape is rigid or if the shape collapses. Students complete BLM 7.4.4 while working on this activity.
4. Which shapes are strong? What factors may have contributed to the weakness of certain shapes?
5. Which shape is the strongest? Why is the triangle such a strong shape? Structures are made stronger by using the principle of triangulation, because triangles give strength to both the struts (the part of a structure that resists pushing forces (compression)) and the ties (the part of a structure that resists pulling forces (tension)). Ask the question, "If you were a builder, how could you improve the strength and stability of a frame structure that contained only struts and ties?" Teachers may refer to BLM 7.4.5 as a reference.

Part B (60 mins) - Strength and Three Dimensional Shapes

1. Ask the question: Do engineers use the principle of triangulation when building? Examine various pictures to demonstrate where it is used.
2. Divide the class so that the students are working in small groups. Set out stations with hot glue guns. Distribute materials (fettuccini noodles, straws, or art straws) to the students and instruct them to create the following three-dimensional shapes:
   a) four rectangular prisms b) four triangular prisms c) four square based pyramids.
3. Have the students construct three structures consisting of four corner supports and a platform. Use a different three dimensional shape for the corner supports of each structure. Test the ability of each structure by placing weights on the platform and gradually increasing the weight. Watch for signs of tension and compression. Students should use the Strength of Three-Dimensional Shapes BLM 7.4.6 chart to record their findings. Have the groups share their findings.
4. With the class examine pictures of various types of truss bridges. Try to determine which truss designs might be stronger than others. Discuss the fact that the strength and stability of a structure are determined by its characteristics (shape, size, types of materials, and construction techniques). For example, the strength and stability of an arch bridge is dependent on the arch and how the arch is created. Refer to pictures of structures to support the point you are making. Have the students find pictures of as many tower type structures as possible and have them describe the different methods used to create structural strength and stability.

Part C (40 mins) - Load

1. Any structure that is built must be strong and stable. There are so many forces acting on structures they have to be built to withstand these forces. It must be constructed to withstand the many forces acting upon it. In order to prevent or reduce the risk of structural failure or collapse, engineers need to know what factors contribute to the strength and stability of a structure. To do so they examine the load.
2. Discuss with the students the concepts of the load and why engineers examine the load. (see Notes To Teacher)

Part D (240 mins) - Performance of a Structure

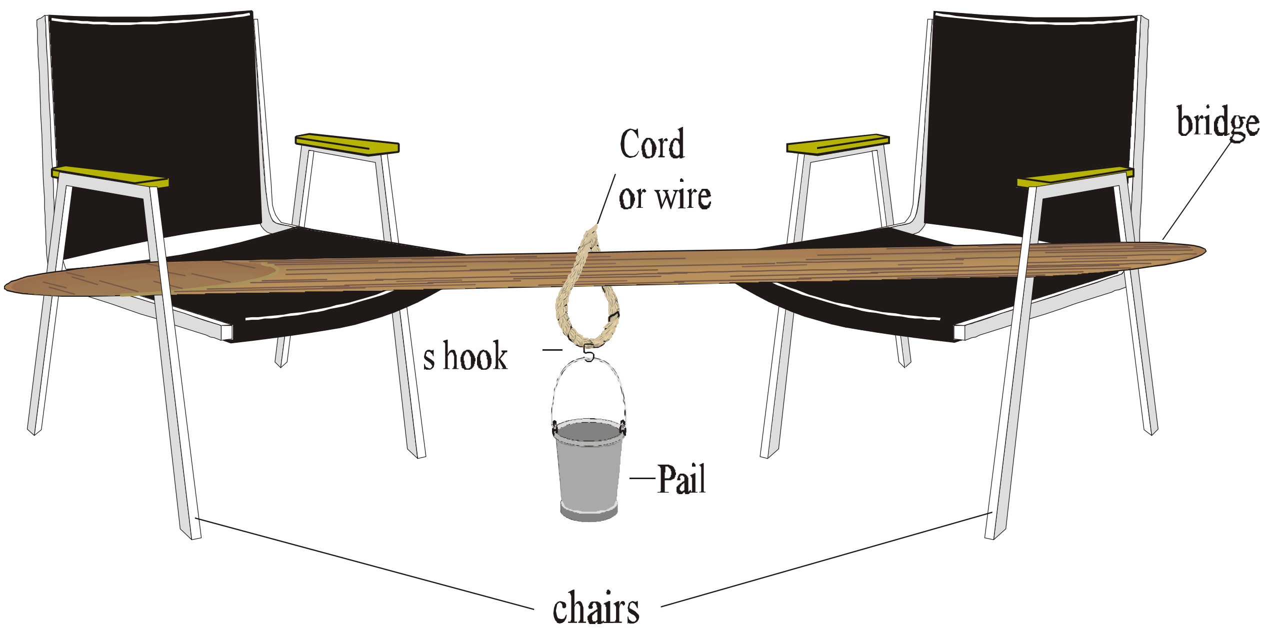
1. Each group will be given 60 popsicle sticks, five 5 cm pieces of Jinks wood (to be used as cross supports), and 125 ml of glue. Each group must create a bridge using all of the popsicle sticks but not necessarily all of the glue. All bridges must be 30 cm in length and 5 cm in width.
2. Once the bridge is constructed, the students must find the mass of the bridge and record this information on Performance Of A Structure - BLM 7.4.1. Students must also include a diagram which shows exactly how the popsicle sticks were arranged in the design and construction of the bridge.
3. Test each bridge using the following procedures. Refer to the illustration Bridge Structure - BLM 7.4.2.
    - suspend the bridge between two chairs placed 25 cm apart
    - loop a strong cord or wire over the centre of the bridge.
    - attach an "s" hook to the wire and suspend a point form the "s" hook.
    - add sand to the pain until the bridge breaks or collapses.
    - weight the pain to determine its mass record this information on Performance of a Structure BLM 7.4.1.
4. At this point, students have found the static load and the dynamic load so they can figure out the corresponding ratio and record this on Performance Of A Structure - BLM 7.4.1 too. Remember, static load is the mass of the bridge itself. Dynamic load is the mass that the bridge can support before it breaks. The total load is the addition of both of these masses.
5. Before the testing stage, the teacher should make up a class chart in order to record all information. After each group has tested its bridge, students should copy down all of the information from the class chart onto their copy of Performance Of A Structure - BLM 7.4.1 so that they can use this information to create a spreadsheet. The spreadsheet calculations can include, static load vs. dynamic load ratio, total load, etc. An example is included in the blackline masters for your reference (see Spreadsheet Example - BLM 7.4.3).
6. Follow-up: In a large group pose the following questions:
    a) Which bridge design supported the most mass? Why?
    b) Why did we have to measure the mass of the bridge itself?
    c) Why did different bridges support different masses?
    d) What were some of the problems that were encountered in the design process?
    e) If you were able to do this activity again, what would you change about the design?
    f) What was learned about the relationship between dynamic load and static load?
7. For teacher reference here are some possible answers to the above questions.
    a) Which bridge design supported the most mass? Why? Answers will vary depending on the bridge, but some of the reasons will be: overlapping of sticks, amount of glue, how sticks were piled, shape made when sticks were piled, etc.
    b) Why did we have to measure the mass of the bridge itself?
    c) The mass of the bridge was measured because the bridge must support its own weight plus whatever weight is added to it. As well, you do not want the weight of the bridge to be too much or this might lower the amount of weight that you could add to it.
    d) Why did different bridges support different masses?
    e) Different bridges supported different masses due to their design structure and the amount of material that was used in each design.
    f) What were some of the problems that were encountered in the design process? Answers will vary but might include: sticks breaking, glue not sticking, conflict between group members, design flaws, waste of materials, etc.
    g) If you were able to do this activity again, what would you change about the design? Answers will vary but should include ideas that they learned while testing the bridges as a class.
    h) What was learned about the relationship between dynamic load and static load? The higher the dynamic load compared to the static load, the better the bridge design and the use of materials to build the bridge.
8. Evaluation: Employ a variety of assessment strategies to information for the purposes of evaluation. Consider the following:
    a) How effectively each group's bridge was constructed to resist the four basic forces: shearing, compression, torsion, tension.
    b) The degree of co-operation among group members as they planned, constructed, and tested their bridge.
    c) How accurately information and data was recorded in tables, charts, etc.
    d) The ability of students to use a spreadsheet to organize information
    e) The quality of the student's written responses.

PERFORMANCE OF A STRUCTURE

Drawing of bridge design	**STATIC LOAD** Mass of bridge itself	**DYNAMIC LOAD** mass of pail and sand EXCLUDING bridge	**LOAD RATIO** dynamic/static
OUR GROUP DESIGN			
GROUP A			
GROUP B			

BLM 7.4.2

A Bridge Structure



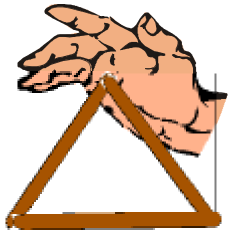
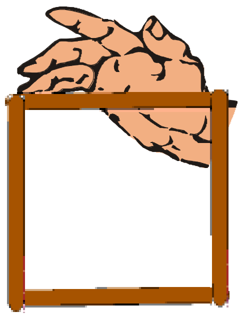
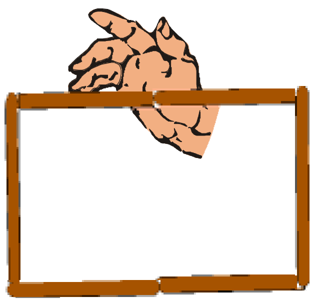
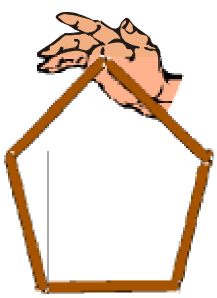
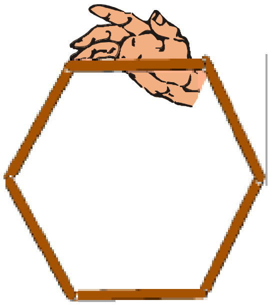
Spreadsheet Example

BLM 7.4.3

	A	B	C	D	E	F
1	**SPREADSHEET OF DATA ACCUMULATED DURING**					
2		**BRIDGE CONSTRUCTION ACTIVITY**				
3						
4			**DYNAMIC LOAD**	**STATIC LOAD**	**LOAD RATIO**	
5			(pail & sand)	(bridge itself)	* expressed as a quotient	
6			in kilograms	in kilograms		
7	**GROUP NAME & BRIDGE DESIGN**					
8	**Group A - crossover bridge**		10	3	3.3333333333	
9	**Group B - triangle bridge**		22	5.5	4	
10	**Group C - piled bridge**		17.25	7	2.4642857143	

Strength of Two-Dimensional Shapes

BLM 7.4.4

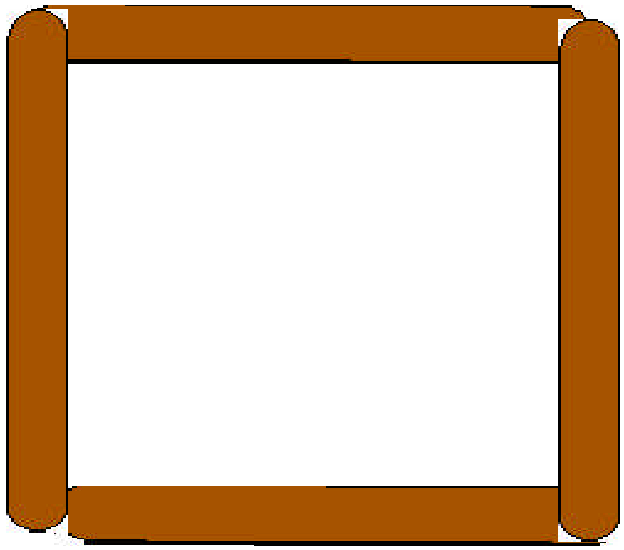
Shape	Graphic	Conclusion (strongest to weakest shape)
Triangular		
Square		
Rectangular		
Pentagonal		
Hexagonal		

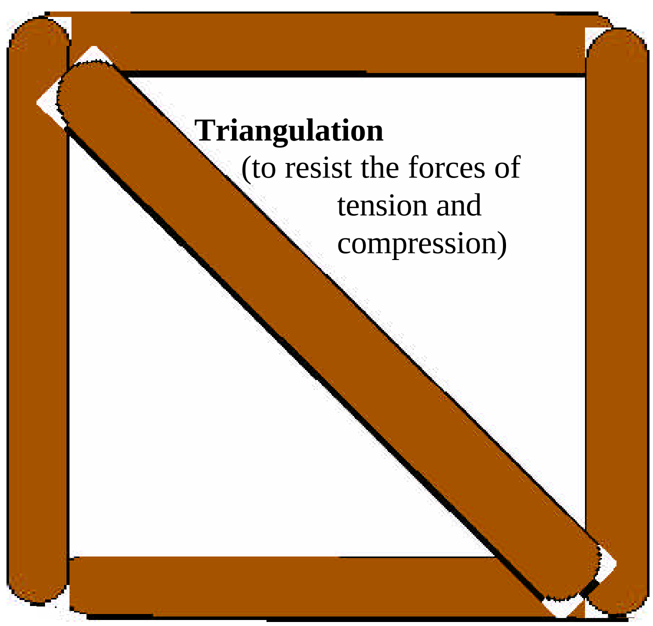
Struts and Ties

BLM 7.4.5

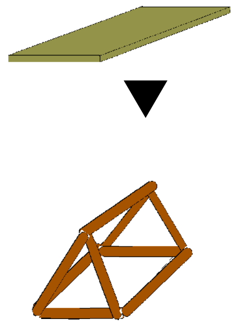
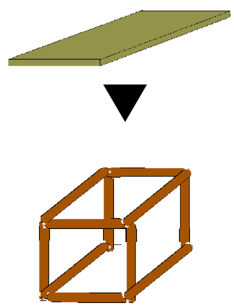
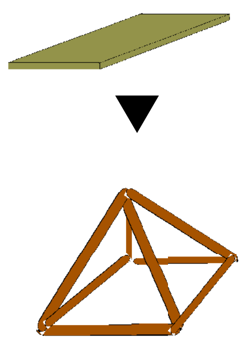
▼ **Ties** (under tension)▼

Struts
(under compression)➧





Strength of Three-Dimensional Shapes

Shape	Graphic	Mass (in grams) supported	Conclusion (strongest to weakest shape)
Triangular Prism			
Rectangular Prism			
Square-Based Pyramid			

Method:

Build 4 small models of each-three dimensional shape. A wooden board should be placed on top of the four models, with a model under each corner of the board. Masses should be placed on top of the board until the shapes under the board collapse. Record the last mass supported before the collapse.