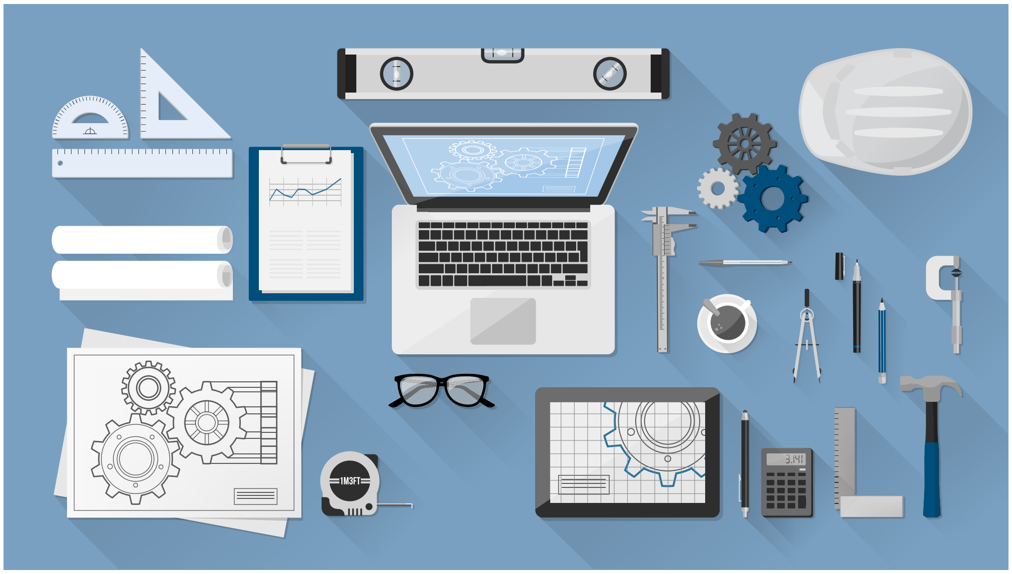

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STRUCTURAL ENGINEERING

The adult leaders should read through all the meeting activities ahead of time. If this is your first time managing a Lab, please review the Lab Leaders Operations Guide, which contains general instructions, lab setup information, the Scout Oath and Scout Law, and more.

Print DOUBLE-sided

Pledge of Allegiance and Scout Oath and Scout Law

Prior to every meeting, have a Scout volunteer to lead the group in the Pledge of Allegiance and the Scout Oath and Scout Law.

Pledge of Allegiance (hand over heart)

I pledge allegiance to the flag of the United States of America and to the Republic for which it stands, one nation under God, indivisible, with liberty and justice for all.

Scout Oath (Scout sign)

On my honor I will do my best
To do my duty to God and my country
and to obey the Scout Law;
To help other people at all times;
To keep myself physically strong,
mentally awake, and morally straight.

Scout Law (Scout sign)

A Scout is—
Trustworthy
Loyal
Helpful
Friendly
Courteous
Kind
Obedient
Cheerful
Thrifty
Brave
Clean
Reverent

Module Overview

Structural engineers spend their careers designing buildings and structures that can withstand the pressures and forces of their environment. In fact, structural engineering is one of the oldest engineering disciplines and without it, where would we be?

In this module, Scouts are going to build their knowledge of structural foundations, symmetrical balance, tension, compression, and gravity. Using various materials, Scouts will design and engineer their own bridge and tower structures. They will then apply their knowledge to build more complex bridges and towers from a kit that requires implementation of team collaboration, communication, resilience, and critical thinking.

Grades 6–8
Next Generation Science Standards:
MS-ETS1-1, 1-2, and 1-3

MODULE COAUTHORS

Some lessons in this module were developed for STEM Scouts by Eduporium. Eduporium (www.eduporium.com) is an all-encompassing partner of schools, districts, and educational organizations, specializing in creating innovative educational and computer technology solutions to enhance the meaningful use of STEM technology in education and to help students develop crucial 21st-century skills. Their experts creatively combine technology tools into custom solutions for use in classrooms, makerspaces, libraries, and after-school programs. Eduporium encourages early exposure to invention, problem-solving, coding, and collaboration in an effort to inspire lifelong STEM learning for our educators and future generations in the classroom!

Meeting 1: Bridge Basics (75–90 minutes)

Scouts will explore the career of a structural engineer and the important role structural engineering plays in our world. Then, after gaining knowledge about the forces of tension and compression, Scouts will learn about the four major types of bridges (basic beam, arch, truss, and suspension). They will then work in teams to design and engineer any type of freestanding bridge they want and will compete to see which one can hold the most weight.

Meeting 2: "Truss-t" Me! (75–90 minutes)

Scouts will apply their knowledge of tension and compression to the construction of a beam bridge and a truss bridge. They will explore the structural elements that make up each bridge, including beams and trusses, and discover the effect of deflection, or bending, due to the force of the load.

Meeting 3: Bridge the Gap (75–90 minutes)

Scouts will apply their deep knowledge of tension and compression to the construction of a tied-arch bridge. They will explore the structural elements that make up arch bridges and suspension bridges, including arches and cables, and discover the shape of a catenary, which is employed in some bridge designs.

Meeting 4: Towering Heights (75–90 minutes)

Scouts will continue to explore the career of a structural engineer and will build on their knowledge of tension and compression by learning about the various types of load structures carry. Through collaboration and hands-on learning, Scouts will design and engineer the tallest freestanding tower that will also compete for heaviest load carried.

Meeting 5: Race to the Top (75–90 minutes)
Scouts will continue to apply their knowledge of tension and compression to the construction of a skyscraper. They will explore the structural elements that make up skyscrapers, including columns and plates, and build on their understanding of dead and live loads.

Meeting 6: Shake Things Up (75–90 minutes)
Scouts will apply their cumulative knowledge of structural engineering to the test of their skyscraper. They will learn about shear and torsion, and how they affect a structure. Scouts will test and compare their structure's ability to withstand the horizontal load of light and major earthquakes, and design reinforcements to improve their structure's stability. *Leaders, please complete the survey at end of module; pg. 97.*

Meeting Prep at a Glance

The following are lists of kit materials as well as council- and unit-supplied materials for this module. Unit-supplied materials can often be supplied by parents or guardians if requested well in advance.

PLEASE USE PACKING SLIP to check kit contents **one week prior** to first meeting. Slip can be found in the Kit Shipment email and/or the STEM Scouts Portal (where this guide was downloaded). Please **DO NOT** skip this part!

Scouts will be divided into teams of **FOUR** for this module. Material quantities are defined below for **EACH TEAM.**

Meeting 1

Materials From Kit

- 1 chenille stem
- 5 feet of masking tape
- 25 regular craft sticks
- 25 index cards
- 15 jumbo craft sticks
- 1 pair of scissors
- 1 measuring tape
- 10 feet of string
- 10 flexible straws
- 1 weight set

Printed Materials

- Meeting 1 handout sheets from Scout Notebook

Materials Needed But Not Provided in Kit

- 1 laptop (council-supplied) to show videos:
    - For introduction discussion:
        - **Fresh Perspective With Ashraf - "Heroes: Structural Engineers"** www.youtube.com/watch?v=5KaRA-2kBQ8 – Video 1 (stop after 1:10 minutes)
        - **What Is Structural Engineering?** www.youtube.com/watch?v=od_MpNUzeCE – Video 2 (stop at 2:45 minute)
    - STEM Innovator Moment:
        - **Day in the Life: Structural Engineer – Josh Falco** www.youtube.com/watch?v=mqwdgS7jWr8

Meeting 2

Materials From Kit

- Thames & Kosmos Structural Engineering Kit
- 1 weight set
- 1 measuring tape

Printed Materials

- Meeting 2 handout sheets from Scout Notebook

Materials Needed But Not Provided in Kit

- **Optional:** Additional items to test load from around the meeting space (heavy and light, like a book and a pencil)

Meeting 3

Materials From Kit

- Thames & Kosmos Structural Engineering Kit
- 1 weight set
- 1 measuring tape
- 1 pair of scissors

Printed Materials

- Meeting 3 handout sheet from Scout Notebook

Materials Needed But Not Provided in Kit

- None

Meeting 4

Materials From Kit

Activity: Tower Build

- 5 feet of masking tape
- 25 regular craft sticks
- 25 jumbo craft sticks
- 15 chenille stems
- 10 flexible straws
- 25 index cards
- 1 weight set
- 1 pair of scissors
- 1 measuring tape

Optional Extension Activity:

- 15 balloons
- 5 feet of masking tape
- 1 measuring tape

Printed Materials

- Meeting 4 handout sheets from Scout Notebook

Materials Needed But Not Provided in Kit

- None

Meeting 5

Materials From Kit

- Thames & Kosmos Structural Engineering Kit
- Masking tape (to make small tags for the skyscrapers with team names at the end of the meeting)

Printed Materials

- Meeting 5 handout sheet from Scout Notebook

Materials Needed But Not Provided in Kit

- None

Meeting 6

Materials from Kit

- Thames & Kosmos Structural Engineering Kit
    - Thames & Kosmos kit box (Scouts will shake to simulate an earthquake)
- Skyscraper model built in Meeting 5

Printed Materials

- Meeting 6 handout sheets from Scout Notebook

Materials Needed But Not Provided in Kit

- None

Service Project Idea: Giving Back!

After Scouts complete this six-week module, Scouts could choose a non-profit engineering organization and start a campaign to raise money for the structural needs of communities across the US!

Check the STEM Scout Portal download files for more service project ideas!

Meeting Facilitation Tips

- Choose an **Attention Getter** with your Scouts. This is a "call and response" technique used to capture the Scouts' attention for a focused moment.

  Step 1: Have Scouts *vote* on an Attention Getter. For example, you could use

Making the Scout salute, you say:	**Making the Scout salute, they respond:**
One, two, three!	All eyes on me!
Scout's honor!	Scout's duty!
Potential energy!	Everybody freeze!
Holy moly!	Guacamole!

  Step 2: Have Scouts decide *with you* what is expected when this attention getter is used.

  For example, the expectations may be to have mouths closed, hands still, ears open, and eyes on you. (Post the expectations, if possible.)

  Step 3: Practice!

- For a **calming moment** at any point during the activity, get the Scouts' attention by using the Attention Getter, then have them take two or three deep breaths together to reset or refocus.

- **"Guide by the side."** Walk around the space to guide Scouts through the activity. Instead of giving the answers, ask open-ended, leading questions to help them think through the challenges.
  Note: This is a *safe* time for Scouts to discover, experiment, and even possibly fail. This helps build a growth mindset and resilience. What matters is how much *effort* we put into our work, not our ability to get it right the first time. That's what STEM is all about—failure is a part of the process!

- For the various types of learners, use the **Key Terms** page in each meeting plan for Scouts to pass around, hold, and read. Note: If possible, post these terms in the room.

- **Meet the Scouts where they're at.** Use the Activity Adaptations section in the meeting plan to adjust activities based on each Scout's behavior and/or ability. If you notice a Scout struggling with an activity or a Scout who has finished early, use these adaptations to continue to keep the Scout engaged and excited about learning!

- **Team dynamics.** If teams are too rowdy, or you notice some unhealthy team behavior, feel free to move members to different teams at any time. This will help to establish a healthy learning environment, and it will support you in facilitating and "guiding by the side."

- **Remember,** it's OK if you don't know the answer to something. Discover *with* the Scouts and learn together!

MEETING PREVIEW AND SETUP

Meeting 1: Bridge Basics	**STEM Focus:** Structural Engineering

After this meeting, Scouts will be able to

- Describe the difference between tension and compression
- Build a bridge out of various materials that can stand on its own and hold the most weight

Scout Law Character Focus

Thrifty

Total Meeting Time

75–90 minutes

Opening (Pledge, Oath, Law):

5 minutes

Introduction Discussion and Activities:

15–25 minutes

Safety Moment:

1 minute

Activity:

45 minutes

Reflection:

3–5 minutes

STEM Innovator Moment:

2 minutes

Announcements/Cleanup:

5–10 minutes

Meeting Prep Time: 30 minutes

Activity Prep

- **Collect** supplies needed for the meeting.
- **Print the Scout Notebook.** Distribute the Meeting 1 handout sheets from the Scout Notebook (one per team).
- **Collect** one laptop (council-supplied).
- Load **video** on laptop: www.youtube.com/watch?v=5KaRA-2kBQ8 – Video 1 (stop at 1:10 minutes)

Space Needed

Tables or a space for Scouts to design and build bridges

Teams of Four

In each team, there will be three engineering roles for this module. Have the Scouts decide who does what:

Structural Engineer: Collects all materials**,** works with team to collaborate on bridge materials used, and oversees cost.

Surveyor: Works with team to make sure all bridge specs are met and documents all observations in Scout Notebook.

Architect: Works with team to collaborate on overall bridge design/look and prepares all drawings needed in Scout Notebook.

Remaining Scout: Ensures all Scouts have the opportunity to participate and that everyone is collaborating through all ideas and challenges.

Materials From Kit <u>Per Team</u>	**Materials Needed But NOT Included in Kit**
• 1 chenille stem • 5 feet of masking tape • 25 regular craft sticks • 25 index cards • 15 jumbo craft sticks • 1 pair of scissors • 1 measuring tape • 10 feet of string • 10 flexible straws • 1 weight set: Scouts will share to test bridge strength at the end of the activity.	• 1 laptop (council-supplied) to show videos: For Introduction Discussion: — **Fresh Perspective With Ashraf - "Heroes: Structural Engineers"** www.youtube.com/watch?v=5KaRA-2kBQ8 – Video 1 (stop after 1:10 minutes) — **What Is Structural Engineering?** www.youtube.com/watch?v=od_MpNUzeCE – Video 2 (stop at 2:45 minutes) STEM Innovator Moment: — **Day in the Life: Structural Engineer – Josh Falco** www.youtube.com/watch?v=mqwdgS7jWr8 **Lab Leader's Optional Notes Section** *(This section is for YOU! List notes, reminders, and/or responsibilities and roles of the Scouts. You may also create a list of successes and challenges you experience during this activity and send it our way!)*

MEETING PLAN

Meeting 1: Bridge Basics	**STEM Focus:** Structural Engineering

Activity Overview

Scouts will explore the career of a structural engineer and the important role structural engineering plays in our world. Then, after gaining knowledge about the forces of tension and compression, Scouts will learn about the four major types of bridges (basic beam, arch, truss, and suspension). They will then work in teams to design and engineer any type of freestanding bridge they want and will compete to see which one can hold the most weight.

PART 1

Introduction/Background Information

Use the questions and background information below to engage Scouts. *(Typical answers are in italics.)*

Prior to starting the discussion, break Scouts up into teams of four.

- What is a natural disaster? *(A natural disaster is a natural event such as a flood, earthquake, or hurricane that causes destruction and even loss of life.)*
- What are some recent natural disasters? *(The Montecito mudslides and wildfires in California, Hurricane Florence in North Carolina, Hurricane Michael in Florida, etc.)*
- What do you think has to be done after something like that? *(Start over; rebuild houses, schools, and other buildings; clean up, etc.)*
- One thing we may not think about is how **much** has to be done after a natural disaster to get society back on track. Where do you begin when you have whole cities destroyed? You start to rebuild, and that means structural engineers are on the clock.
- So let's take a step back. What does an engineer do? *(Builds/designs/creates buildings and roads; works on machines; creates software; and uses math, science, and technology to solve problems.)*
- What types of engineers are there? *(Civil, mechanical, chemical, aerospace, electrical, computer, environmental, and lots more!)*
- In this module we are going to be exploring structural engineering by building various bridges and towers.
- What type of engineer do you think designs bridges and towers? *(Civil engineers)*. And civil engineers can specialize in what's called **structural engineering.**
- Using physics and math, structural engineers analyze and design the physical integrity of buildings, bridges, and other structures. They find the simplest way to do something. They solve problems. They build the world around us. As a structural engineer, you will always be needed.

- **Play Two Videos: Life as a Structural Engineer (5 minutes; enable closed captions)**
    - www.youtube.com/watch?v=5KaRA-2kBQ8 – Video 1 (stop at 1:10 minutes)
    - www.youtube.com/watch?v=od_MpNUzeCE – Video 2 (stop at 2:45 minutes)

- Structural engineers have a VERY important role to play in our world. Without them, we wouldn't have structurally sound buildings or bridges. And every time there was a natural disaster, we wouldn't be able to rebuild.

- Today you are going to be introduced to bridges by exploring the two main forces that are in play: tension and compression.

- All bridges, buildings, and other structures have a certain amount of weight they can hold before collapsing. They have a certain capacity for the amount of **tension** and **compression** they hold. *(For visual learners, use the key terms on page 21 for these two terms. Scouts can repeat words out loud.)*

- Tension force pulls or stretches materials apart.

- Compression force presses or squeezes materials together.

- Both tension and compression happen when an external force is applied to an object, such as a car driving over a bridge or people in a skyscraper. Both of these structures contain materials that can only take a certain amount of tension and compression before breaking.

- Structural engineers have to be well educated about both of these forces so that they can build structures that have integrity under pressure.

Demonstration: 1 flexible straw for Leader and each Scout (2 minutes)
- Without bending the straw, have everyone look at the bend section.
- Have Scouts <u>slowly</u> bend their straw while observing the bend section.
- Next, ask them to share where they saw **tension** and **compression**.
- Tension (stretching) was happening underneath the bend; the scrunched-up straw started to stretch out and unfold.
- Compression (pressing) was happening in the middle of the bend; the scrunched-up part in the bend began to move even closer together, squeezing together.

Tension and compression experiment: (5 minutes; in Scout Notebook)
- In an experiment to test tension and compression, you will put various objects under these two forces and make observations in your Scout Notebook. *(For example, stretching a rubber band demonstrates tension. But what happens when the rubber band is put under compression?)*

Have Scouts follow the procedures in their Scout Notebook.

- Test each object's integrity by applying both tension and compression to the object—bend, twist, pull, squeeze, and press! Use the table below to document your observations.
- What happens to each object?
- Where did you see **tension**? **Compression**?
- Observe how much tension/compression each object can take before losing its integrity.

Object	Tension Applied–Observations	Compression Applied–Observations
Index card		
Spring		
Chenille stem		
Craft stick		

Circle up to discuss their observations! (2 minutes)

- Over the next <u>three</u> meetings, we are focusing on bridges. Today is considered your introduction and you will be exploring the four main types of bridges and then constructing your own.

- Take a look at page 4 in your Scout Notebook. What are the four main types of bridges that we are going to cover? *(Suspension, beam, truss, and arch.)*

- In these pictures you can see where each bridge holds its tension and compression when weight, or a **load,** is added on the bridge.

- **Load** is the weight of something, like a truck going over a bridge. Weight is simply the gravitational force acting on an object, giving it weight as it pulls it toward the center of the earth.

Have Scouts take turns describing out loud where they see tension and compression for each bridge picture.

- Now take **2–3 minutes** to fill in the chart on page 5 of your Scout Notebook, reading the pros and cons of each bridge.

- Today you will have 45 minutes to design and build any type of bridge you want. The goal is to build a freestanding bridge that can hold the most weight without collapsing!

- You have several bridge specifications, or "bridge specs," you will need to meet, and you must document them in your Scout Notebook.

PART 2

Discuss the Scout Law Character Focus

Today we are focusing on the character point **Thrifty**.

What does it mean to be thrifty? *(To use resources carefully and creatively, not wastefully.)*

When we build our bridge, how can we practice being thrifty?

PART 3

Safety Moment

- Do NOT run, point, or play with the scissors.
- Be mindful of your movements when holding the scissors.
- When the scissors are not being used, they must be kept on the table or work area.

PART 4

Activity Steps

Give Scouts about 45 minutes to build their bridge (teams of four).

- The goal is to build a freestanding bridge that can hold the most weight without collapsing!
- Scouts must fill out the Bridge Specs table in their Scout Notebook.

***LEADER GUIDE:** During the activity*

1. As the Lab Leader, walk around the space to “guide by the side.” Help to resolve conflicts as needed and ask leading questions to guide Scouts through any challenges.
   — Feel free to pass out extra tape or other extra materials to reward any healthy team/leader behavior you see from the Scouts! If you see a Scout team struggling, ask them a question about bridge types, or tension and compression, to award them more tape.
2. When time is up or when all the bridges have been finished, have each team take a turn telling the Lab about their bridge design and reviewing their Bridge Specs document details.
3. After a team has described their bridge design, test their bridge’s strength by using the weights provided and have the Surveyor make notes in their Bridge Specs document.
4. Finally, choose one or two of the bridges to discuss and analyze where the Scouts see tension and compression in the structure as weight is added. Remember, compression is a *pushing* force and tension is a *pulling* force.

Have Scouts follow the procedures in their Scout Notebook.

Bridge Specs

Engineering Firm Name:	
Bridge Name:	**Date:**
Architect Name:	
Structural Engineer Name:	
Surveyor Name:	
Bridge Purpose: (Use your imagination to describe the purpose of your bridge, where it will be built, etc.)	

OPTIONAL: Scouts can calculate the bridge budget

**5 feet of masking tape – FREE; $100 per foot after that*

Material/Cost Per Unit	Quantity Used	Total Cost of Materials
Straws — $750.00 each		
Regular craft sticks — $500.00 each		
Jumbo craft sticks — $750.00 each		
Index cards — $500.00 each		
String — $500.00 per foot		
TOTAL CONSTRUCTION COST:		

Activity Adaptations for Scouts, as Needed

If Scouts finish early:

- Have them build a second bridge using a new design.
- Challenge them to use the fewest components or to remove an obvious one.

If Scouts are too challenged:

- Walk them step-by-step through the creation of a simple beam bridge, using two upside-down small paper cups as the bridge supports and several index cards as the beams and deck of the bridge (taped together). Feel free to have them use craft sticks for more support on or under the index card "beams."

PART 5

Circle Up for Reflection Questions

- How did you feel when you were building your bridge? What were the challenges? What things succeeded?
- What was it like working in your team? How did your team practice our character point Thrifty?
- What is one thing you would do differently if you built your bridge again?
- This activity was very open-ended, in that there were no specific instructions on how to build your bridge or which materials to use. Sometimes, life is the same way! Life quite often gives you scenarios that don't come with "instructions" or a "how-to" video that's easy to find on YouTube!
- But to get through these life challenges, you must recall information that you've learned in the past, think through all possible outcomes, and do your best—just like when you built your bridge!
  - You had to recall everything you learned about the four basic bridges, think about possible outcomes with the materials in certain places, and then do your best.
  - Don't forget to have confidence in yourself and do your best, even if the scenario is new. And it's ALWAYS OK to ask a trusted adult or friend for advice. Remember, you weren't alone when you built your bridge!

PART 6

STEM Innovator Moment (laptop): Josh Falco

Show Scouts the following video to hear an interview with Josh Falco, a structural engineer.

***Title**: "Day in the Life: Structural Engineer – Josh Falco"*

www.youtube.com/watch?v=mqwdgS7jWr8

PART 7

Leaving It Better Than We Found It!

- Have Scouts help clean up supplies, return scissors to the Lab Leader, and throw away trash.
- Make any needed announcements.

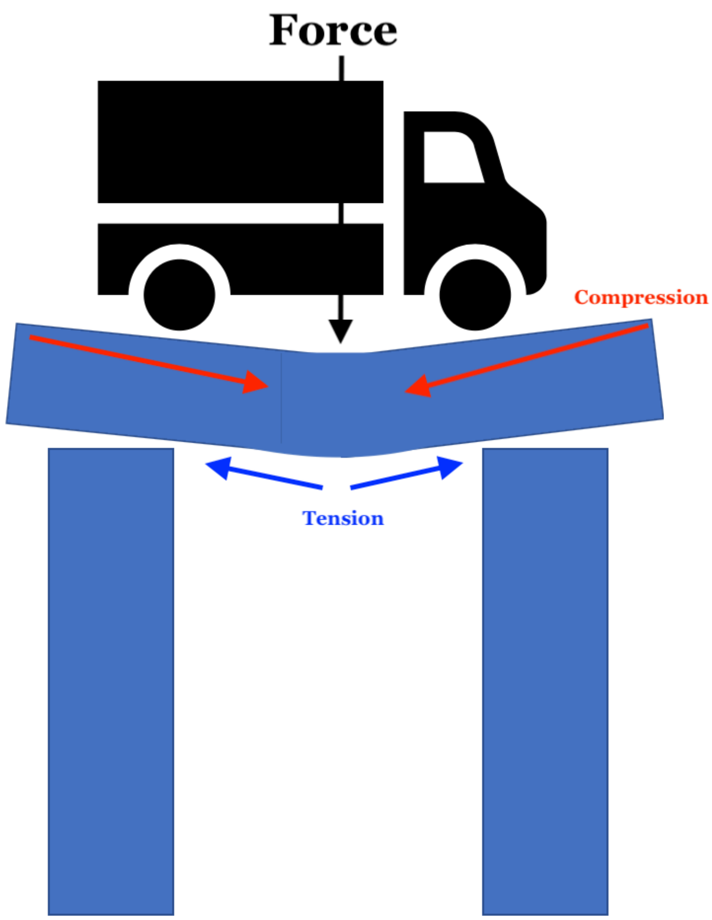
Key Terms

- **STRUCTURAL ENGINEER:** *A person who analyzes and designs the physical integrity of buildings, bridges, and other structures using math and physics.*

- **TENSION:** *The state of being stretched when force is applied.*

- **COMPRESSION:** *Flattening, squeezing, or pressing that takes place when force is applied.*

- **LOAD:** *The weight of something; the gravitational force acting on an object.*



MEETING PREVIEW AND SETUP

Meeting 2: "Truss-t" Me!	**STEM Focus:** Structural Engineering

After this meeting, Scouts will be able to

- Understand two different types of structural elements—beams and trusses—and how they can be utilized to build bridges
- Describe the effect of deflection
- Build a beam bridge and experiment with different loads

Scout Law Character Focus
Trustworthy

Total Meeting Time

75–90 minutes

Opening (Pledge, Oath, Law):

5 minutes

Introduction Discussion and Activities:

15–25 minutes

Safety Moment:

1 minute

Activity:

45 minutes

Reflection:

3–5 minutes

STEM Innovator Moment:

2 minutes

Announcements/Cleanup:

5–10 minutes

Meeting Prep Time: 10 minutes

Activity Prep

- **Collect** supplies needed for the meeting.
- **Scout Notebook:** Meeting 2 (one per team)

Space Needed
Tables or a space for Scouts to design and build bridges

Teams of Four
In each team, there will be three engineering roles for this module. Have the Scouts decide who does what:

Structural Engineer: Collects all materials and works with team to collaborate on bridge materials used.

Surveyor: Works with team to make sure all bridge specs are met and documents all observations in Scout Notebook.

Architect: Works with team to collaborate on overall bridge design/look.

Remaining Scout: Ensures all Scouts have the opportunity to participate and that everyone is collaborating through all ideas and challenges.

Materials From Kit <u>Per Team</u>	**Materials Needed But NOT Included in Kit**
• Thames & Kosmos Structural Engineering Kit • 1 weight set (Scouts will share) • 1 measuring tape	• **Optional:** Additional items to test load from around the meeting space (heavy and light, like a book and a pencil)
	Lab Leader's Optional Notes Section *(This section is for YOU! List notes, reminders, and/or responsibilities and roles of the Scouts. You may also create a list of successes and challenges you experience during this activity and send it our way!)*

MEETING PLAN

Meeting 2: "Truss-t" Me!	**STEM Focus:** Structural Engineering

Activity Overview

Scouts will apply their knowledge of tension and compression to the construction of a beam bridge and a truss bridge. They will explore the structural elements that make up each bridge, including beams and trusses, and discover the effect of deflection, or bending, due to the force of the load.

PART 1

Introduction/Background Information

Use the questions and background information below to engage Scouts. *(Typical answers are in italics.)*

Prior to starting the discussion, break Scouts up into teams of four.

- In this meeting we are going to dive deeper into the beam and truss bridge models. To do so, we are going to build on our knowledge from our previous meeting.

- Let's review. What are the definitions of **tension**, **compression**, and **load**? *(An object is under tension when it is being pulled, an object is under compression when it is being squeezed or pressed together, and a load is the weight of something.)*

- What is the role of a **structural engineer**? (*To analyze and design the physical integrity of buildings, bridges, and other structures using math and physics.)*

- Structural engineers combine many different elements to build complex structures. What are some structural elements used in bridges? *(Beams, columns, cables, plates, arches.)* What these structural elements have in common is that they are well-understood, so structural engineers can use their physical properties to predict how they will work together in a complex structure. Today we will explore two of these elements: beams and trusses.

- A **beam** is a flat structural element that is able to resist weather forces like wind and rain, but is weak in resisting loads placed on top of it, like people and cars. Why do you think beams are weak in resisting these types of loads? (*Beams are not strong and rigid enough on their own to counteract them.)*

- As you may have guessed, a **beam bridge** is made up of beams laid across two or more supports. It is the simplest type of bridge. However, due to its simplicity, it lacks structural support and can't transfer moments through its structure. Thus, it is not used to span long distances.

- Hmm, but what is a moment? A **moment** is the measure of a force's tendency to rotate or twist an object about a specific point. Imagine pushing a door open. When you push on the door handle, the door opens, rotating on its hinges. The force of pushing on the door caused the door to rotate.

- A **simple truss** is a structural element made up of multiple triangles. It uses a relatively small amount of material to achieve a large amount of stability.

- What is an example of a truss in real life, other than a bridge? (*House, bicycle frame, metal cable tower.*)
- A **truss bridge** is made of pieces connected in triangular units, adding strength and support to the deck of the bridge, and can be above or below the deck.
- As we reviewed, load is the amount of weight a bridge can withstand. However, bridges also have weaknesses.
- A sign of weakness of a bridge is shown by the amount of **deflection** it exhibits. Deflection is the degree to which a bridge is displaced under a load. If the force of a load is too big for a bridge, the bridge deflects, or bends, because the materials making up the bridge are not strong or rigid enough to counteract the load. Sometimes, if the deflection is so great, the bridge may collapse!
- For example, trusses distribute forces throughout a bridge, so the middle of the bridge deflects less. Some of the rods in a truss are under tension, while others are under compression. The rods and connection points are thus strong enough to hold up to the forces acting on it.
- Today you are going to build a beam bridge and test its ability to hold a load.
- You will work with your team—just as structural engineers work with a team that includes architects, surveyors, construction teams, other types of engineers, and many others, depending on the project!

PART 2

Discussion the Scout Law Character Focus

Today we are focusing on the character point **Trustworthy**.
What does it mean to be trustworthy? *(To tell the truth and to be honest and dependable.)*
When we build our bridges, how can we practice being trustworthy?

PART 3

Safety Moment

- Review the first page in the Experiment Manual for safety information and assembly tips before you start.
- If you can't tell what a piece is, reference the Kit Content guide on the first page of the Experiment Manual.
- Keep track of the small building pieces.
- Make sure you have enough room between teams so building pieces do not get mixed up.
- When testing loads, do not stand underneath the bridge or put your hands under it in case it falls.
- When disassembling your models, be gentle when pulling pieces apart so they do not snap. Use the yellow tool to remove small pieces.

PART 4

Activity Steps

Leader Note

In the experiment manual, the weights are hung below the bridges. In our experiments, we will be placing the weights on top of the bridges.

Have Scouts follow the procedures in their Scout Notebook.

Bridge Construction

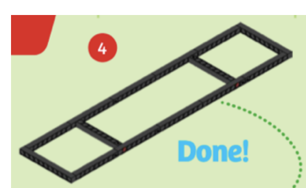
Materials:

- 1 weight set
- Thames & Kosmos Structural Engineering Kit
- 1 measuring tape
- Optional: Loads (heavy and light items like books and pencils)

Activity Steps:

Part 1a: BUILD A BASIC BEAM BRIDGE

1. Turn to page 13 in the Experiment Manual.
2. Follow steps 1–3 to construct a basic beam bridge as seen in the image on the right.



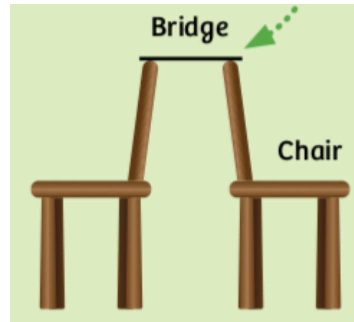
   You will need the following materials:
   - 12 x piece #15
   - 12 x piece #2
   - 2 x piece #16
   - 4 x piece #1

   You can find the piece numbers on page 1 in the Experiment Manual.

3. Put two chairs or tables back to back with some space in between so you can balance your beam bridge across the gap.

4. Find two loads to place on top of the beam bridge. You can use the weights from the set or find items around your meeting space:

   - Find one that is light, like a pencil, and one that is heavy, like a book.
   - Place the light one on first, then take it off and place the heavy one on the bridge.



5. Observe what happens to the bridge when you place each load on it.

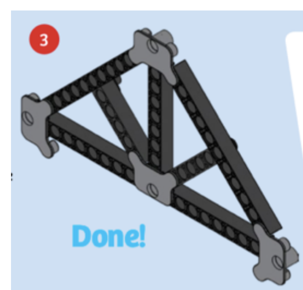
   - Write your observations in the table on page 11.
   - Extra rows are included if you want to test more loads!

6. Compare what happens when you put the heavy load on the bridge versus the light load.

7. Do you notice **deflection**? If so, measure the space between the lowest part of the bridge at the middle and the height of the chairs or tables that the bridge rests on. Add this to the table. If you don't notice deflection with any loads, you may need to find some heavier loads!

8. Do not disassemble your basic beam bridge, as you will be using it in the next experiment.

Part 1b: BUILD A SIMPLE TRUSS



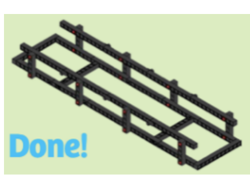
1. Turn to page 7 in the Experiment Manual. Follow steps 1 and 2 under Simple Truss (second half of the page) to build the model seen in the image to the right.

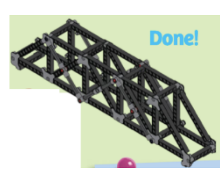
2. Push and pull on the corners of the simple truss. Observe how it responds to these forces.

Part 2: REINFORCE YOUR BRIDGE

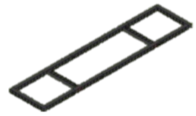
1. Now examine your basic beam bridge. How could you reinforce it? For example, would you want to add some trusses for support? Jot down your team's ideas below and be sure to include WHY they would strengthen your bridge.

Need some ideas? See the reinforced beam bridge on page 14 and the truss bridge on pages 15–16 in the Experiment Manual.





2. Pick a few of your favorite ideas and draw them on the model below.



3. Choose the improvement you deem to be most critical but also feasible considering the materials you have left. Add this improvement to your design.

4. Repeat steps 3–7 from Part 1a, testing the same loads on your newly reinforced beam bridge. Make sure you compare the amount of deflection from your basic beam bridge with the deflection from your reinforced beam bridge.

5. **Optional:** If time permits, add further reinforcements from your design to your beam bridge. Test it with the same loads as you did before and fill out your observations in the table on page 11. Make sure you compare the amount of deflection.

6. Disassemble your bridge and simple truss.

Activity Adaptations for Scouts, as Needed

If Scouts finish early:

- Challenge them to add further reinforcement ideas to their model and test them.
- Create the Reinforced Beam Bridge on page 14 or the Truss Bridge on page 15–16 in the Experiment Manual.

If Scouts are too challenged:

- Skip Part 1b. Only build and test the basic beam bridge and develop design ideas for the reinforced bridge.
- Skip Part 1b and Part 2. Only build and test the basic beam bridge.

PART 5

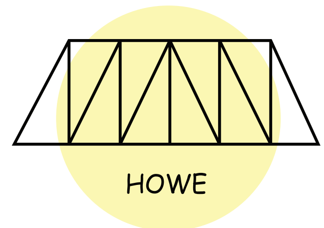
Circle Up for Reflection Questions

- What challenges did you face today when building your bridges?
- What things succeeded? Why?
- What was it like working in your team? How did your team practice our character point Trustworthy?
- How would you describe a beam bridge and a truss bridge? *(A beam bridge is the simplest form of bridge; made of beams and laid across two or more supports, it is not very strong at holding loads on top of it. A truss bridge is made of trusses, which are groups of connected triangles, that give it more strength and support.)*
- What did you learn about deflection during your experiments? *(Deflection is the degree to which the bridge is displaced under the load. It is also known as bending. When a load was too heavy for the bridge and it could not support it, the bridge bent in the middle and sometimes collapsed.)*
- In the next meeting we are going to experiment with two more complex bridge types, arch and suspension!

PART 6

STEM Innovator Moment: William Howe

There are many types of truss designs for bridges, but one of the first was the Howe truss. The Howe truss was designed by William Howe, an American architect, in the 1840s. The design involves diagonal structural beams that slope toward the bridge's center. Due to its innovation and strength at the time, it was the most popular bridge design in the U.S. during the late 1800s.



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Remarkably, two of William Howe's bridges remain today: the Jay Covered Bridge in New York and the Sandy Creek Covered Bridge in Missouri (pictured). Both have suffered partial destruction due to floods but have been restored and still stand today.

Sources:
www.britannica.com/biography/William-Howe
www.historyofbridges.com/facts-about-bridges/howe-truss/


Shutterstock.com–©Steven Schremp

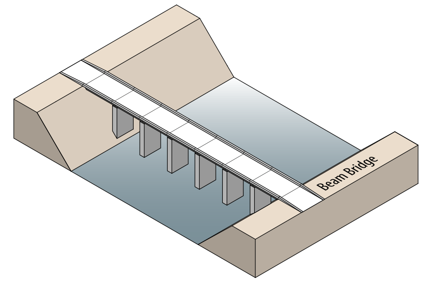
PART 7

Leaving It Better Than We Found It!

- Have Scouts help clean up supplies and throw away trash.
- Make any needed announcements.

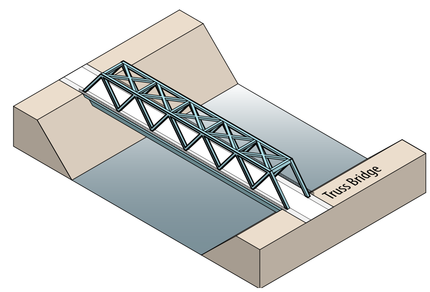
Key Terms

- **BEAM BRIDGE:** *A beam bridge is the simplest form of bridge, made up of beam(s) laid across two or more supports.*



Shutterstock.com–©Zern Liew

- **TRUSS BRIDGE:** *A truss bridge is made of struts connected in triangular units to give strength and support to the deck of the bridge.*



Shutterstock.com–©Zern Liew

- **DEFLECTION:** *Deflection is the degree to which the bridge is displaced under the load. Also known as bending.*

Shutterstock.com–©Ruud Morijn Photographer

Simple wooden beam bridge

Shutterstock.com–©cpaulfell

Truss bridge in Washington state

MEETING PREVIEW AND SETUP

Meeting 3: Bridge the Gap	**STEM Focus:** Structural Engineering

After this meeting, Scouts will be able to

- Understand two new types of structural elements—arches and cables—and how they can be utilized to build bridges
- Describe a catenary
- Build a tied-arch bridge, test its ability to hold a load, and make observations about where the tension and compression is

Scout Law Character Focus

Brave

Total Meeting Time

75–90 minutes

Opening (Pledge, Oath, Law):

5 minutes

Introduction Discussion and Activities:

15–25 minutes

Safety Moment:

1 minute

Activity:

45 minutes

Reflection:

3–5 minutes

STEM Innovator Moment:

2 minutes

Announcements/Cleanup:

5–10 minutes

Meeting Prep Time: 10 minutes

Activity Prep

- **Collect** supplies needed for the meeting.
- **Scout Notebook:** Meeting 3 (one per team)

Space Needed

Tables or a space for Scouts to design and build bridges

Teams of Four

In each team, there will be three engineering roles for this module. Have the Scouts decide who does what:

Structural Engineer: Collects all materials and works with team to collaborate on bridge materials used.

Surveyor: Works with team to make sure all bridge specs are met and documents all observations in Scout Notebook.

Architect: Works with team to collaborate on overall bridge design/look.

Remaining Scout: Ensures all Scouts have the opportunity to participate and that everyone is collaborating through all ideas and challenges.

Materials From Kit Per Team	**Materials Needed But NOT Included in Kit**
• Thames & Kosmos Structural Engineering Kit • 1 weight set (Scouts will share) • 1 measuring tape • 1 pair of scissors	• NONE
	Lab Leader's Optional Notes Section *(This section is for YOU! List notes, reminders, and/or responsibilities and roles of the Scouts. You may also create a list of successes and challenges you experience during this activity and send it our way!)*

MEETING PLAN

Meeting 3: Bridge the Gap	**STEM Focus:** Structural Engineering

Activity Overview

Scouts will apply their deep knowledge of tension and compression to the construction of a tied-arch bridge. They will explore the structural elements that make up arch bridges and suspension bridges, including arches and cables, and discover the shape of a catenary, which is employed in some bridge designs.

PART 1

Introduction/Background Information

Use the questions and background information below to engage Scouts. *(Typical answers are in italics.)*

Prior to starting the discussion, break Scouts up into teams of four.

- In this meeting we are going to dive deeper into the arch and suspension bridge models. To do so, we are going to build on our knowledge from our previous meeting.

- Let's review. What are the definitions of **tension**, **compression**, and **load**? *(An object is under tension when it is being pulled, an object is under compression when it is being squeezed or pressed together, and a load is the weight of something.)*

- What are the two types of structural elements we focused on last time and what are they used for in bridge construction? *(Beams and trusses. A beam is a structural element that is able to resist weather forces like wind and rain but is weak in resisting loads placed on top of it, like people and cars. It is laid across two or more supports to form a beam bridge. A truss is a structural element made up of multiple triangles. It uses a relatively small amount of material to achieve a large amount of stability. Trusses are connected together to form the main support for truss bridges.)*

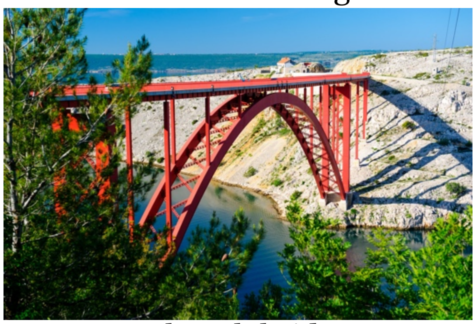
- In this meeting we will be looking into two new elements—arches and cables—and two new bridge types that employ these elements—arch bridges and suspension bridges.

- An **arch** is a symmetrical curved structure that spans an opening. Due to its curved shape, arches transform forces that push down on top of them into forces that push outward at their bases.

- An **arch bridge**, naturally, is made of one or more arches with an abutment at each end. The arch is constantly under compression but can't resist much force in tension. The arch can be above, below, or even through the deck of the bridge. Be sure to check out some of the different types in your Lab Notebook on page 15.


Corbel arch bridge


Aqueduct


Deck arch bridge


Through arch bridge


Tied-arch bridge

Shutterstock.com–corbel arch bridge, ©Khun Ta; aqueduct, ©Lepneva Irina; deck arch bridge, ©Alex Tihonovs; through arch bridge, ©Trong Nguyen; tied-arch bridge, ©Tupungato

- Arch bridges are often short but can include arches back to back to increase length and strength. These types of bridges date back to the fourth century BC, when they were constructed out of stone. Nowadays, arch bridges are most often made of metal and concrete.

- A **cable** is a thick rope of wire typically used for construction. Cables provide support for bridges by creating tension by pulling on other structural elements.

- Gather a piece of string from one of the Thames & Kosmos kits and hold an end in each hand so it hangs down freely in the middle.
    - Have students observe the shape that the string naturally forms due to gravity.
    - This curve is called a **catenary** curve. Ropes and cables assume this shape, and it is often employed in bridge construction to provide support by pulling on other structural elements, like pillars, through tension.

- For example, a rope bridge is the most basic bridge that uses cables. The cables hang freely to form a catenary curve. Cables are also used in arch bridges but are most often associated with suspension bridges and cable-stayed bridges.

- A **suspension bridge** is supported by cables that hold up the deck. These cables are hung by towers that are anchored in the ground or in cement blocks, and the main cables form a catenary curve.

- Suspension bridges were first built in the early 1800s. They are often medium to long in length and generally require fewer materials compared to other bridge types.

- What are some famous suspension bridges that exist today? *(The double-decked George Washington Bridge that connects New York to New Jersey, the Golden Gate Bridge in San Francisco, California.)*

- Any load on a suspension bridge is transformed into tension in the cables and compression in the pillars.

- Today you are going to build a tied-arch bridge, a combination of an arch bridge and suspension bridge! A tied-arch bridge has an arch on either side of the deck and a tie between the two opposite ends of the deck. The tie is usually the deck, which is suspended via vertical cables from the arch.

- You will work with your team, just as structural engineers work with a team that includes architects, surveyors, construction teams, other types of engineers, and many others, depending on the project!

- **Leader Note:** *In this lesson, Scouts are going to learn about both arch and suspension bridges but only build the arch bridge.*

    - *Should they finish early or should one team want to build a suspension bridge instead of an arch bridge, they can do so. Have them follow the detailed instructions starting on page 36 in the Experiment Manual.*
    - *Note that the meeting is not long enough for each team to build both models.*

PART 2

Discuss the Scout Law Character Focus

Today we are focusing on the character point **Brave**.

What does it mean to be brave? *(To be courageous.)*

When we build our bridge, how can we practice being brave?

PART 3

Safety Moment

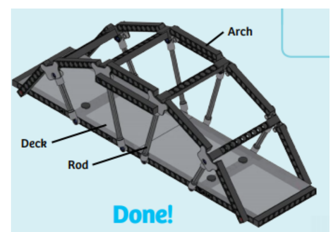
- Review the first page in the Experiment Manual for safety information and assembly tips before you start.
- If you can't tell what a piece is, reference the Kit Content guide on the first page of the Experiment Manual.
- Keep track of the small building pieces.
- Make sure you have enough room between teams so building pieces do not get mixed up.
- When testing loads, do not stand underneath the bridge or put your hands under it in case it falls.
- When disassembling your models, be gentle when pulling pieces apart so they do not snap. Use the yellow tool to remove small pieces.

PART 4

Activity Steps

Have Scouts follow the procedures in their Scout Notebook.

Bridge Construction



Part 1: BUILD A TIED-ARCH BRIDGE

Materials:

- Thames & Kosmos Structural Engineering Kit

Activity Steps:

1. Turn to page 28 in the Experiment Manual to find the instructions for the tied-arch bridge (pictured above). Gather the necessary pieces for construction.
2. Note that you will need to repeat steps 7–8 within the Experiment Manual so that you have two sides for your bridge.

Part 2: TEST YOUR BRIDGE

Materials:

- Tied-arch bridge model
- 1 weight set
- 1 measuring tape
- 1 pair of scissors

Activity Steps:

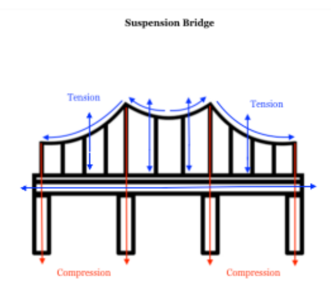
1. Put two chairs or tables back to back with some space in between (like you did in the previous meeting) so you can balance your tied-arch bridge across the gap.
2. Using your knowledge of tension and compression, how do you expect the tied-arch bridge to react to the load? Make predictions here.

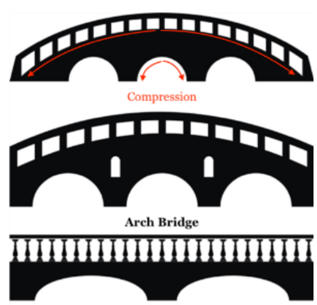
3. Gradually add weights from the set onto the deck of the arch bridge. Every time you add a weight, watch the bridge elements closely to observe what the force of the weights does to the bridge.

4. Use the measuring tape to measure the amount of deflection from the middle point of the bridge. Write your observations and measurements in the table below.

Load (Weight)	Observations	Deflection

5. From what you know about tension and compression on arch bridges and suspension bridges, where do you expect the tension and compression to be on tied-arch bridges? Label the tension and compression with arrows on the tied-arch bridge picture below.





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Activity Adaptations for Scouts, as Needed

If Scouts finish early:

- Challenge them to build the deck arch bridge on pages 25–27 in the Experiment Manual.
- Have them follow the detailed instructions starting on page 36 in the Experiment Manual to build a suspension bridge.

If Scouts are too challenged:

- Have them only build the model, and if there's time, test one or two loads.

PART 5

Circle Up for Reflection Questions

- Where did the bridge fail first? In the towers, cables, deck, somewhere else?
- What can you infer about the forces acting on the different structural elements of the bridge based on the way it fell (or did not fall)?
- How did your team practice our character point Brave?
- How would you describe an arch bridge and a suspension bridge? *(An arch bridge has a curved design marked by abutments at each end. A suspension bridge is supported by cables that hold up the deck. The cables are hung by towers that are anchored in the ground.)*
- Define a catenary and give an example of when and where it is used in bridge design. *(A catenary is the natural curve formed by a wire, chain, or rope when it is hanging freely from two points. It can be found in rope bridges or suspension bridges, when the cables hang down freely and provide tension to the structure.)*
- Although there is plenty more to learn about bridges, it is time we transition to a new topic—towers! In the next few meetings, we are going to be learning, building, and testing our own models.

PART 6

STEM Innovator Moment: Antonio da Ponte

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One of the most famous arch bridges in the world is the Rialto Bridge that spans the Grand Canal in Venice, Italy. Antonio da Ponte was a Venetian architect and engineer who redesigned the bridge out of stone, after the original wooden version collapsed in 1524.

Many famous architects submitted designs for the bridge, including Michelangelo, but Antonio da Ponte's was selected due to its simplicity and elegance. It was constructed from 1588-1591.

The bridge inclines at a significant angle of 15 degrees, which is no longer permitted in modern-day bridge construction.

Rows of shops line each side of the bridge, and there are three passageways, one in the middle in between the shops and two on the sides. It is still actively used as a market and is widely popular with tourists.

It is a true icon of Venice and can often be spotted in films.

Sources:
https://en.wikipedia.org/wiki/Antonio_da_Ponte
www.historyofbridges.com/famous-bridges/rialto-bridge/

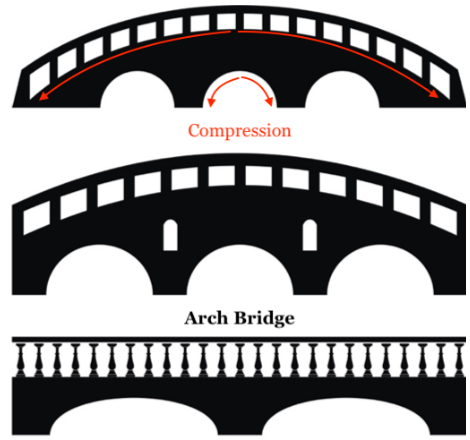
PART 7

Leaving It Better Than We Found It!

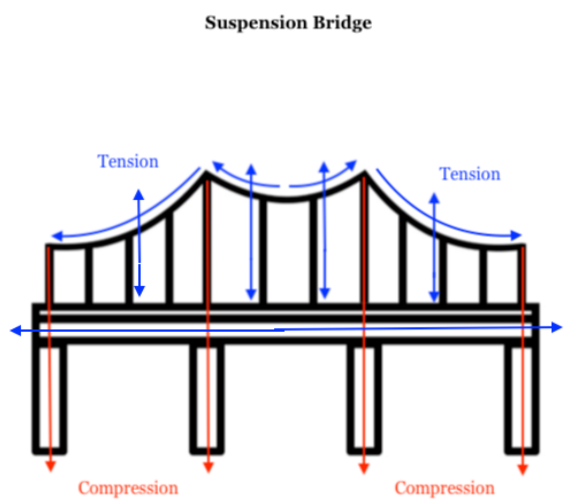
- Have Scouts help clean up supplies and throw away trash.
- Make any needed announcements.

Key Terms

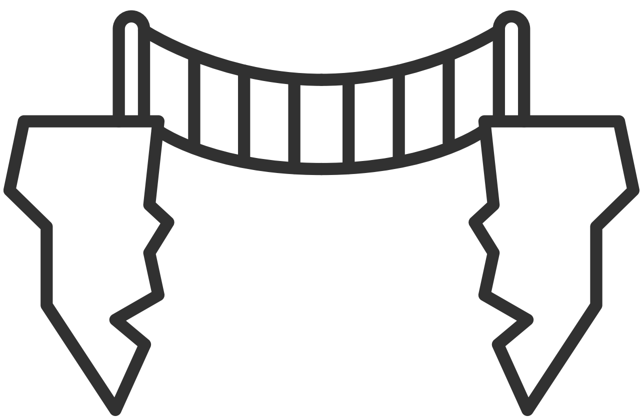
- **ARCH BRIDGE:** *An arch bridge has a curved design marked by abutments at each end.*



- **SUSPENSION BRIDGE:** *A suspension bridge is supported by cables that hold up the deck. The cables are hung by towers that are anchored in the ground.*



- **CATENARY:** *A catenary is the natural curve formed by a wire, chain, or rope when it is hanging freely from two points.*



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MEETING PREVIEW AND SETUP

Meeting 4: Towering Heights	**STEM Focus:** Structural Engineering

After this meeting, Scouts will be able to

- Understand the importance of the foundation and how weather greatly impacts a tower
- Describe vertical and horizontal loads
- Build out of various materials a tower that can stand on its own and hold the most weight

Scout Law Character Focus

Cheerful

Total Meeting Time

75–90 minutes

Opening (Pledge, Oath, Law):

5 minutes

Introduction Discussion and Activities:

15–25 minutes

Safety Moment:

1 minute

Activity:

45 minutes

Reflection:

3–5 minutes

STEM Innovator Moment:

2 minutes

Announcements/Cleanup:

5–10 minutes

Meeting Prep Time: 20 minutes

Activity Prep

- **Collect** supplies needed for the meeting.
- **Scout Notebook:** Meeting 4 (one per team)

Space Needed

Tables or a space for Scouts to design and build towers

Teams of Four

In each team, there will be three engineering roles for this module. Have the Scouts decide who does what:

Structural Engineer: Collects all materials, works with team to collaborate on which materials to use, and oversees cost.

Surveyor: Works with team to make sure all building specs are met and documents all observations in Scout Notebook.

Architect: Works with team to collaborate on overall building design/look and prepares all drawings needed in Scout Notebook.

Remaining Scout: Ensures all Scouts have the opportunity to participate and that everyone is collaborating through all ideas and challenges.

Materials From Kit Per Team

Activity: Tower Build

- 25 regular craft sticks
- 25 jumbo craft sticks
- 15 chenille stems
- 10 flexible straws
- 25 index cards
- 5 feet of masking tape
- 1 weight set (Scouts will share)
- 1 pair of scissors
- 1 measuring tape

Optional Extension Activity

(page 63 of this guide)

- 15 balloons
- 5 feet of masking tape
- 1 measuring tape

Materials Needed But NOT Included in Kit

- NONE

Lab Leader's Optional Notes Section

(This section is for YOU! List notes, reminders, and/or responsibilities and roles of the Scouts. You may also create a list of successes and challenges you experience during this activity and send it our way!)

MEETING PLAN	
Meeting 4: Towering Heights	**STEM Focus:** Structural Engineering

Activity Overview

Scouts will continue to explore the career of a structural engineer and will build on their knowledge of tension and compression by learning about the various types of load structures carry. Through collaboration and hands-on learning, Scouts will design and engineer the tallest freestanding tower that will also compete for heaviest load carried.

PART 1

Introduction/Background Information

Use the questions and background information below to engage Scouts. *(Typical answers are in italics.)*

Prior to starting the discussion, break Scouts up into teams of four.

- In this meeting we are going to start our exploration of towers and skyscrapers. To do so, we are going to build on our knowledge from our previous meetings.
- Let's review. What are the definitions of tension and compression? *(An object is under tension when it is being pulled, and an object is under compression when it is being squeezed or pressed together.)* Both of these forces apply to towers the same way they apply to bridges!
- Now, what does an **architect** do? *(Blends art and science by designing structures for our society's needs. They think about safety, function, cost, and environmental impact.)*
- A **skyscraper** is a very tall multistory building usually found in cities. Typically, skyscrapers are at least 492 feet tall and have 40 or more floors.
- The term "skyscraper" was first coined in the 1880s and referred to buildings with 10-20 floors. The first steel-frame skyscraper was the 10-story Home Insurance Building, built in Chicago, Illinois, in 1885 and reaching 138 feet.
- If you were to work with an architectural firm to build a skyscraper, what are the main things you would want to focus on and include? *(Scouts can get creative with this! If they get stuck, ask them how many floors they would want, what types of materials they would use, where it is, what type of weather it can withstand, any special features or technology, colors, what each floor is used for, etc.)*
- What is the tallest skyscraper you can think of? Maybe it's one you have seen in real-life or on TV!
- Why do you think these skyscrapers, and others, exist? *(To maximize space in cities; provide office space, living space, and in some cases entertainment; set records of design and skill; and add aesthetic to a skyline.)*

- The three main obstacles that skyscrapers have to overcome are gravity, foundation, and wind.

- What is a foundation and why is it the most important part of a structure? *(The foundation is typically below ground level and is the lowest load-bearing part of a structure.)*

- Every structure must have a foundation, especially skyscrapers that tower over other buildings in height and weight, or load. Structural engineers are constantly problem-solving when it comes to setting the foundation for a skyscraper. Sometimes the ground on which it will stand is hard and sometimes it is soft.

- For example, the Shard, a 95-story building in London, sits on top of a giant concrete slab. When digging for the foundation, workers came across a soft clay. The structural engineers used concrete piles, or columns, to help support the concrete slab that went about 53 meters underground!

- In Dubai, when digging the foundation for the world's tallest tower, the Burj Khalifa, workers came across highly salted water that was running through the soil! Structural engineers had to use a special type of concrete that was more resistant to saltwater soaking through because salt water can be extremely corrosive. They also add another type of metal within the concrete to protect the steel in the foundation from corrosion.
  - The Burj Khalifa opened in 2010. It is 2,717 feet tall, has 163 floors above ground, and has 53 elevators!

- Though this tower is currently the tallest in the world, there is one about to surpass its height. The Jeddah Tower in Saudi Arabia is scheduled to open in 2020 and will be 3,281 feet tall!

- Today you are going to have a competition to see who can build the tallest tower that can hold the most weight (or load).

- There are several types of load:
  - **Vertical/gravity:**
    - "Dead load"—permanent; the weight of the structure itself (walls, floors, fixtures, and mechanical systems)
    - "Live load" —temporary; the weight of the structure's contents and occupants, including snow!)
  - **Horizontal/lateral:**
    - All forces from weather (wind, rain, earthquakes, and even explosions)

- As with the construction of bridges, structural engineers work with a team that includes architects, surveyors, construction teams, other types of engineers, and many others, depending on the project!

- When you get started, make sure to identify each role.

PART 2
Discuss the Scout Law Character Focus Today we are focusing on the character point **Cheerful**. What does it mean to be cheerful? *(To look for the bright side of life. Cheerfully do tasks that come your way. Try to help others be happy.)* When we build our tower, how can we practice being cheerful?

PART 3
Safety Moment • Do NOT run, point, or play with the scissors. • When the scissors are not being used, they must be kept on the table or work area.

PART 4

Activity Steps

Give Scouts about 45 minutes to build their tower (teams of four).

- The goal is to build a freestanding tower that can hold the most weight without collapsing.
- Scouts must fill out the Tower Specs table in their Scout Notebook.

During the activity

1. As the Lab Leader, don't forget to "guide by the side."
2. When time is up or when all the towers have been finished, have each team take a turn telling the Lab about their tower design and reviewing their Tower Specs document details.
3. After a team has described their tower design, test their tower's strength by using the weights provided and have the Surveyor make notes in their Tower Specs document.
4. Finally, choose one or two of the towers to discuss and analyze where the Scouts see tension and compression in the structure as weight is added. Remember, compression is a *pushing* force and tension is a *pulling* force.

Have Scouts follow the procedures in their Scout Notebook.

Materials:

- 5 feet of masking tape,
- 25 regular craft sticks,
- 25 jumbo craft sticks,
- 15 chenille stems,
- 10 flexible straws,
- 25 index cards,
- 1 weight set
- 1 pair of scissors
- 1 measuring tape

Tower Specs

Engineering Firm Name:	
Tower Name:	**Date:**
Architect Name:	
Structural Engineer Name:	
Surveyor Name:	
Tower Purpose: (Use your imagination to describe the purpose of your tower, where it will be built, etc.)	
Tower Height:	**Tower Load:**

Let's measure and test load!

Leader facilitation:

1. Go around to each team to measure the towers.
2. Scouts will record their tower's height.
3. Next, facilitate one team at a time to use the weights to test how much load their tower can hold.
4. Scouts will record their tower's load.

Optional: Scouts can calculate the tower budget

**5 feet of masking tape – FREE; $100 per foot after that.*

Material/Cost Per Unit	Quantity Used	Total Cost of Materials
Regular craft sticks — $500.00 each		
Jumbo craft sticks — $750.00 each		
Chenille stems — $750.00 each		
Index cards — $500.00 each		
Straws— $250.00 each		
TOTAL CONSTRUCTION COST:		

Activity Adaptations for Scouts, as Needed

If Scouts finish early:

- Challenge them to use the fewest components or to remove an obvious one.
- Have them build a second tower using a new design if there are extra materials.

If Scouts are too challenged:

- Let them tape their foundation to the work surface.
- Have them focus on using the craft sticks and tape to create a square base for the foundation and then use the craft sticks and tape to build upward, one floor at a time.

PART 5

Circle Up for Reflection Questions

- How did you feel when you were building your tower? Describe how your team worked together.
- What were the challenges? What things succeeded? Why?
- How did your team practice our character point Cheerful?
- How would you describe vertical load and horizontal load? *(Vertical load has two types, dead load and live load. Dead load is the actual weight of the building and its fixtures, and live load is the temporary weight like people and snow. Horizontal load is any added force from weather that hits the sides of the building.)*
- Over the next two meetings we are going to explore more about towers using a kit and more complex materials.

PART 6

STEM Innovator Moment: Gustave Eiffel

Architecture plays a huge role in cultures around the world. Architecture allows societies to express their culture and beliefs and to even tell stories. Think about the ancient architecture in China and Rome, and the Great Pyramids in Egypt.

Take the Eiffel Tower, for example. It is a symbol for Paris, France, that is known across the entire globe! The Eiffel Tower, designed and built by Gustave Eiffel, was completed in 1889. The tower is 300 meters tall. The plan was to build a tower with a square base that had four different "legs" that met together at the top.

Shutterstock.com–©andersphoto

Source: www.toureiffel.paris/fr/le-monument

At Home: To learn more about the world's tallest building, give Scouts the following video link:
- Title: "The Tallest Building On Earth: BURJ KHALIFA"
- Link: www.youtube.com/watch?v=6HxpBM8ubIA

PART 7

Leaving It Better Than We Found It!

- Have Scouts help clean up supplies and throw away trash.
- Make any needed announcements.

Key Terms

- **ARCHITECT:** *A person who blends art and science by designing structures for our society's needs. They think about safety, function, cost, and environmental impact.*

- **SKYSCRAPER:** *A very tall multistory building usually found in cities. Typically, skyscrapers are at least 492 feet tall and have 40 or more floors.*

- **FOUNDATION:** *Typically below ground level; the foundation is the lowest load-bearing part of a structure.*

- **VERTICAL/GRAVITY:**
  - *"Dead load"—Permanent; the weight of the structure itself (walls, floors, fixtures, and mechanical systems).*
  - *"Live load"—Temporary; the weight of the structure's contents and occupants, including snow!)*

- **HORIZONTAL/LATERAL:**
  - *All forces from weather (wind, rain, earthquakes, and even explosions).*

Optional Extension Activity

Should Scouts finish early, facilitate the below activity!

Balloon Tower Activity: 15 minutes total

Materials: 12 balloons and 5 feet of tape per team

1. Scouts will work in teams of four.
2. Teams will have **10 minutes** to build the tallest freestanding tower out of 12 balloons and 5 feet of masking tape.
3. They are **not** allowed to tape their tower to the floor or anything else in the meeting space!
4. They are allowed to get up to three extra balloons if balloons pop.
5. When time is up, have everyone circle up for a quick discussion about their building process!
    - How did they feel?
    - What was working and what was not working?
    - How did they demonstrate strong teamwork?
    - The foundation is the most important part if you are wanting to build a skyscraper!

6. After discussion, use the measuring tape to see whose tower is the tallest (or you might be able to tell by just looking).

Burj Khalifa skyscraper in Dubai, United Arab Emirates
2,717 feet | 163 floors

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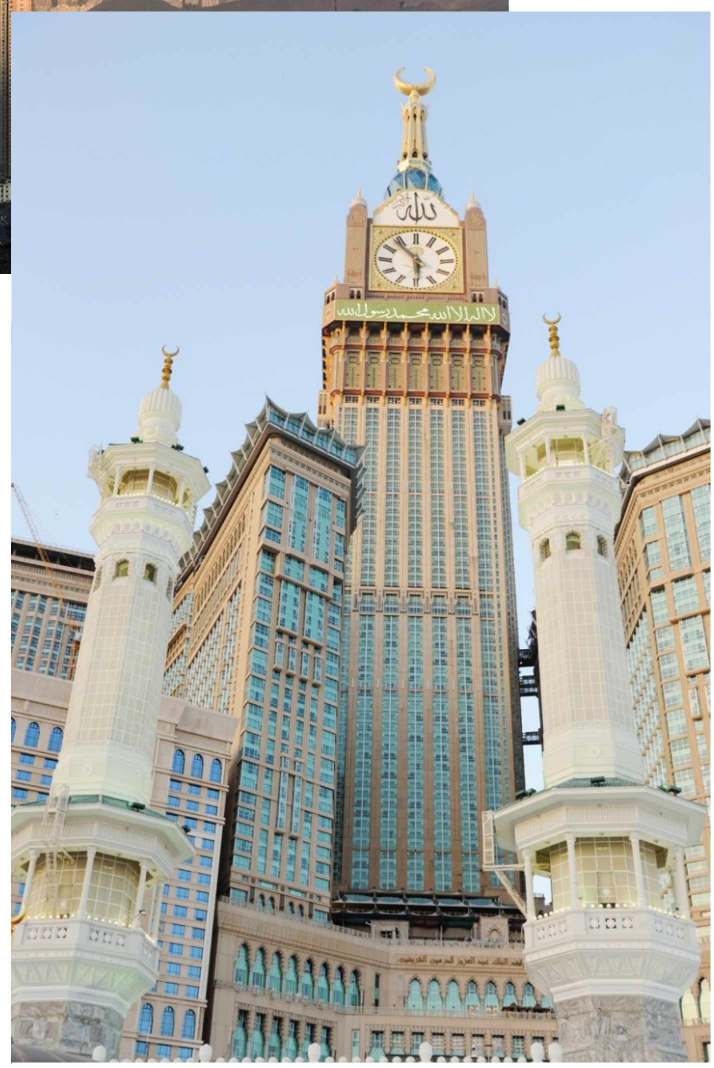
Shutterstock.com–©IURII BURIAK

Shutterstock.com–©atiger

Shanghai Tower in Shanghai, China
2,073 feet | 128 floors

Shutterstock.com–©Abrar Sharif



Makkah Royal Clock Tower in Mecca, Saudi Arabia
1,972 feet | 120 floors

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Shutterstock.com–©Leonard Zhukovsky

One World Trade Center in New York City, New York
1,776 feet | 94 floors

Shutterstock.com–©spyarm

MEETING PREVIEW AND SETUP

Meeting 5: Race to the Top	**STEM Focus:** Structural Engineering

After this meeting, Scouts will be able to

- Describe a skyscraper
- Understand the different structural elements employed in the construction of skyscrapers, including columns and plates
- Build a skyscraper and identify its structural elements in preparation for testing next meeting

Scout Law Character Focus

Helpful

Total Meeting Time

75–90 minutes

Opening (Pledge, Oath, Law):

5 minutes

Introduction Discussion and Activities:

15–25 minutes

Safety Moment:

1 minute

Activity:

45 minutes

Reflection:

3–5 minutes

STEM Innovator Moment:

2 minutes

Announcements/Cleanup:

5–10 minutes

Meeting Prep Time: 10 minutes

Activity Prep

- **Collect** supplies needed for the meeting.
- **Scout Notebook:** Meeting 5 (one per team)
- **Scouts will** build their skyscrapers during this meeting and test them in Meeting 6. Label the skyscrapers with team names at the end of the meeting using masking tape.

Space Needed

Tables or a space for Scouts to design and build skyscrapers

Teams of Four

In each team, there will be three engineering roles for this module. Have the Scouts decide who does what:

Structural Engineer: Collects all materials and works with team to collaborate on which materials to use.

Surveyor: Works with team to make sure all building specs are met and documents all observations in Scout Notebook.

Architect: Works with team to collaborate on overall building design/look.

Remaining Scout: Ensures all Scouts have the opportunity to participate and that everyone is collaborating through all ideas and challenges.

Materials From Kit <u>Per Team</u>	**Materials Needed But NOT Included in Kit**
• Thames & Kosmos Structural Engineering Kit • Masking tape (to make small tags for the skyscrapers with team names at the end of the meeting)	• NONE **Lab Leader's Optional Notes Section** *(This section is for YOU! List notes, reminders, and/or responsibilities and roles of the Scouts. You may also create a list of successes and challenges you experience during this activity and send it our way!)*

MEETING PLAN

Meeting 5: Race to the Top	**STEM Focus:** Structural Engineering

Activity Overview

Scouts will continue to apply their knowledge of tension and compression to the construction of a skyscraper. They will explore the structural elements that make up skyscrapers, including columns and plates, and build on their understanding of dead and live loads.

PART 1

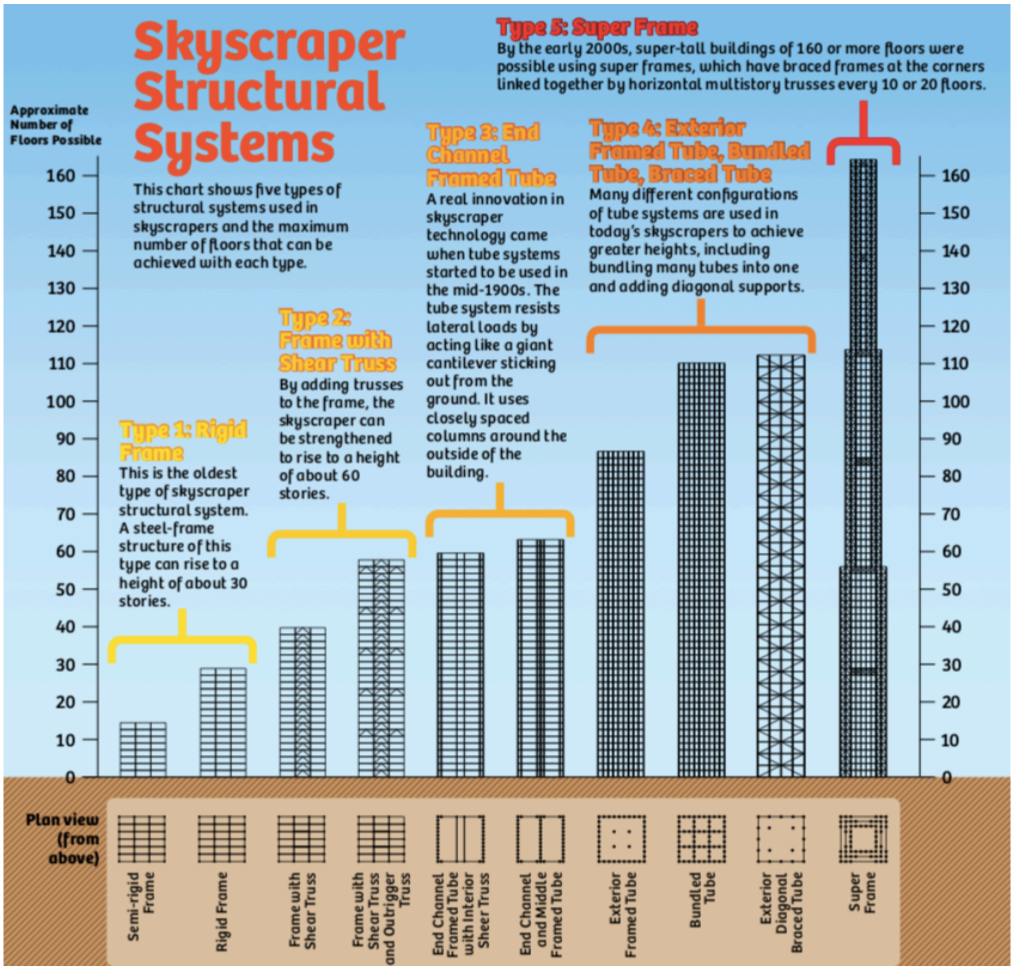
Introduction/Background Information

Use the questions and background information below to engage Scouts. *(Typical answers are in italics.)*

Prior to starting the discussion, break Scouts up into teams of four.

- In this meeting we are going to continue our exploration of towers. To do so, we are going to build on our knowledge from our previous meetings.
- Let's review. What is the definition of a skyscraper? *(A skyscraper is a very tall multistory building usually found in cities. Typically, skyscrapers are at least 492 feet tall and have 40 or more floors.)*
- What are the two different types of loads? *(Vertical/gravity and horizontal/lateral.)* Give examples of each. *(Vertical loads include "dead" loads, like walls, floors, and other permanent building elements, as well as "live" loads, like people, furniture, and other temporary objects in the building. Horizontal loads include forces from weather, like wind, rain, and earthquakes. These can also be classified as "live" loads.)*
- When it comes to designing and building skyscrapers, architects and structural engineers must be very mindful of the variety of forces that their structure must withstand.
- The load a skyscraper encounters is mostly from its own weight of structural materials. Is this a dead load or a live load? *(A dead load.)* However, with super, super tall buildings, the wind load outweighs the dead load. Thus, for these types of buildings, managing the wind load is the most important factor of structural design.
- Review the image on page 26 in your Lab Notebook to see the different structural systems. It can also be found on page 44 in the Experiment Manual.

- Nowadays, there are a variety of skyscraper structural systems that vary by frame type and number of floors they can support.



- Rigid frame
  - Oldest
  - Steel frame structure
  - 30 floors
- Frame with shear truss
  - Steel frame structure supported by trusses
  - 60 floors
- End channel framed tube
  - Tube system with closely spaced columns around the building
  - 70 floors
- Exterior framed tube, bundled tube, braced tube
  - Multiple tubes with trusses
  - 120 floors
- Super frame
  - Braced corner frames linked to horizontal multistory trusses
  - 160+ floors

- What are some structural elements we have explored so far? *(Beams, trusses, arches, and cables).* Engineers employ some of these elements in their construction of skyscrapers, in addition to columns and plates.

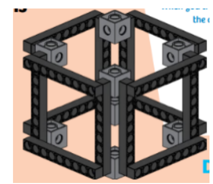
- A **column** is a cylindrical structural element that transmits forces vertically through compression. Columns are strong in resisting vertical forces but weak in resisting horizontal forces. When a column encounters a vertical force and undergoes compression, it shortens and widens. However, the effect is so small that you do not notice it in actual buildings.

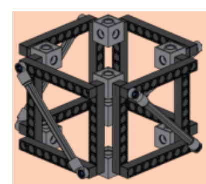
- If a vertical force is too great, a column may experience buckling. Buckling is when a structural element can't withstand a high compressive load and bows to the side. It is like when your knee wiggles to one side when you are off-balance!

Activity: Columns and Beams Experiment (also on page 27 in Scout Notebook)

- In an experiment to test the strength of columns, beams, and cables, you will build a basic cube and a reinforced cube and make observations in your Scout Notebook.

Have Scouts follow the procedures in their Scout Notebook.





1. Turn to page 18 in the Experiment Manual. Build the compression cube and complete Experiment #10. What happens? Write your observations in the space below. *(The cube is able to withstand vertical force but is weak in withstanding horizontal force.)* Do not disassemble.

2. Turn to page 19 in the Experiment Manual. Using your compression cube, build the reinforced cube. Repeat Experiment #10 with the reinforced cube. What is different from the compression cube? Write your observations in the space below. *(The diagonal cables add extra support in withstanding horizontal forces.)* Disassemble.

Circle up to discuss their observations! (2 minutes)

- A **plate** is a flat, solid structural element with minimal thickness compared to its other dimensions, like length, width, and diameter. Plates can be made of a variety of materials, like aluminum or steel. They are often placed on the outside of skyscrapers to counteract forces perpendicular to the plates, like weather elements.

- What does an architect do? *(Blends art and science by designing structures for our society's needs.)* What are some constraints that architects need to consider when designing a skyscraper? *(They think about safety, function, cost, and environmental impact.)*

- What are some engineering constraints that structural engineers need to consider when designing and building a skyscraper? *(Available materials, height and weight of the building, weight of the occupants, location, time, cost, strength and stability needed to withstand forces.)*

- Incredibly, there are plans to construct buildings that are taller than 1 kilometer (3,281 feet).
  - The Jeddah Tower in Saudi Arabia is currently under construction and is on course to be the first building in the world to reach this milestone height. It is made of concrete, steel, and glass and will serve a mixed purpose of commercial and residential.
  - The Jeddah Tower is scheduled to open in 2020!

- Today you are going to build a version of a skyscraper! At the next meeting, we will test how strong our skyscrapers are at withstanding horizontal loads.

- **Leader Note:** Make sure half of the groups are building Version 1 and half of the groups are building Version 2.

PART 2

Discuss the Scout Law Character Focus

Today we are focusing on the character point **Helpful**.
What does it mean to be helpful? *(To volunteer to help others without expecting a reward).*
When we build our skyscraper, how can we practice being helpful?

PART 3

Safety Moment

- Review the first page in the Experiment Manual for safety information and assembly tips before you start.
- If you can't tell what a piece is, reference the Kit Content guide on the first page of the Experiment Manual.
- Keep track of the small building pieces.
- Make sure you have enough room between teams so building pieces do not get mixed up.
- When disassembling your models, be gentle when pulling pieces apart so they do not snap. Use the yellow tool to remove small pieces.

PART 4

Leader Note

- *In this meeting, there are two types of skyscrapers that are being built: Version 1 and Version 2.*
- *Make sure there is an equal number of teams building Version 1 and Version 2.*
    - *Scouts will build their skyscrapers during this meeting and test the structures' ability to withstand earthquakes in Meeting 6. Every Version 1 tower will be pairing up with a Version 2 tower.*
    - *Store the skyscrapers in a safe space for use in Meeting 6.*
- ***At the end of the meeting,*** *use the masking tape to label the skyscrapers with team names so everyone knows which skyscraper is theirs for the next meeting!*

Activity Steps

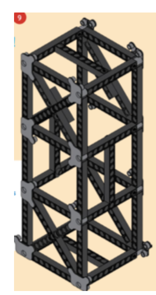
Have Scouts follow the procedures in their Scout Notebook.

Skyscraper Construction

If your team voted to build Skyscraper Version 1, complete Part 1. If your team voted to build Skyscraper Version 2, skip down to Part 2.

Materials:
- Thames & Kosmos Structural Engineering Kit

Part 1: SKYSCRAPER VERSION 1

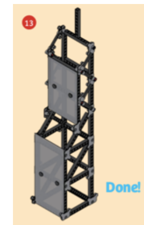


1. Turn to page 21 in the Experiment Manual
2. Follow steps 1–8 to construct Skyscraper Version 1 as seen in the image to the right.
3. Thinking back to past meetings, what structural elements can you identify in your structure?
4. **Do not** disassemble your skyscraper upon completion, as you will be testing and comparing it to the other skyscraper model as they undergo earthquake simulations at the next meeting!

Part 2: SKYSCRAPER VERSION 2

1. Turn to page 23 in the Experiment Manual.

2. Follow steps 1–13 to construct Skyscraper Version 2 as seen in the image to the right.
   - Split into pairs.
   - Simultaneously, one pair should complete steps 1–5 and one pair should complete steps 6–9.
   - Then come together to complete steps 10–13.



3. Thinking back to past meetings, what structural elements can you identify in your structure?

4. **Do not** disassemble your skyscraper upon completion, as you will be testing and comparing it to the other skyscraper model as they undergo earthquake simulations at the next meeting! Make a tag out of masking tape to label your tower with your team name.

LEADER NOTE: Remind the Scouts to use the masking tape to label their skyscrapers with team names so everyone knows which skyscraper is theirs for the next meeting!

Activity Adaptations for Scouts, as Needed

If Scouts finish early:
- Challenge them to build the tetrahedron on page 19 in the Experiment Manual and to complete Experiment #12.

If Scouts are too challenged:
- Let them know it is OK to make adjustments to their model if the instructions are too challenging. For example, they can build a shorter, less complex model.

PART 5
Circle Up for Reflection Questions

- How did you feel when you were building your skyscraper? Describe how your team worked together.

- What were the challenges? What things succeeded? Why?

- How did your team practice our character point Helpful?

- How would you describe the structural elements column and plate? *(A column is a cylindrical structural element that transmits forces vertically through compression. A plate is a flat, solid structural element with minimal thickness compared to its other dimensions.)*

- In the next meeting we are going to test and compare these two models of skyscrapers as they experience various magnitudes of earthquake simulations.

PART 6

STEM Innovator Moment: Natalie Griffin de Blois

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Natalie Griffin de Blois (1921–2013) was an American architect and a pioneer in the male-dominated world of architecture. She earned a degree in architecture from Columbia University in 1944 and went on to design buildings all over the world, including the Pepsi-Cola World Headquarters in New York City.

Several of her buildings are included among the tallest women-designed buildings in the world! She later taught architecture at the University of Texas for over a decade. She received a statewide architectural educator award and a scholarship established in her honor is given to a woman studying architecture at the University of Texas.

De Blois became an early advocate for women in architecture and was a founding member of Chicago Women in Architecture. She helped pave the way for the next generation of women architects by "demonstrat[ing] that women could compete, and succeed, at the highest levels of the architecture profession. Also, in contributing to the design of some of the most iconic U.S. buildings of the twentieth century, she helped define the sleek elegance that is universally associated with American modernism."

Source: https://pioneeringwomen.bwaf.org/natalie-griffin-de-blois/

PART 7

Leaving It Better Than We Found It!

- Have Scouts help clean up supplies and throw away any trash.
- Make any needed announcements.

Key Terms

- **COLUMN:** *A cylindrical structural element that transmits forces vertically through compression.*

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- **PLATE:** *A flat, solid structural element with minimal thickness compared to its other dimensions.*

Shutterstock.com–©Vladimir Nenezic

MEETING PREVIEW AND SETUP

Meeting 6: Shake Things Up	**STEM Focus:** Structural Engineering

After this meeting, Scouts will be able to

- Describe the different forces of shear and torsion, and how they affect a structure
- Understand the purpose of a shear wall
- Test and compare their skyscraper model's abilities to withstand earthquake simulations and determine what reinforcements are needed and where

Scout Law Character Focus

Obedient

Total Meeting Time	**Meeting Prep Time: 10 minutes**
75–90 minutes **Opening (Pledge, Oath, Law):** 5 minutes **Introduction Discussion and Activities:** 15–25 minutes **Safety Moment:** 1 minute **Activity:** 45 minutes **Reflection:** 3–5 minutes **STEM Innovator Moment:** 2 minutes **Announcements/Cleanup:** 5–10 minutes	**Activity Prep** • **Collect** supplies needed for the meeting. • **Scout Notebook:** Meeting 6 (one per team) • **Scouts will** test the towers they built in Meeting 5 during this meeting! **Space Needed** Tables or a space for Scouts to test skyscrapers **Teams of Four** In each team, there will be three engineering roles for this module. Have the Scouts decide who does what: **Structural Engineer:** Collects all materials and sets up the earthquake simulator. **Surveyor:** Documents all observations in Scout Notebook. **Architect:** Assists the Structural Engineer. **Remaining Scout:** Ensures all Scouts have the opportunity to participate in conducting the earthquake simulation.

<table>
<tr>
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Materials From Kit <u>Per Team</u>

- Thames & Kosmos Structural Engineering Kit
  - Thames & Kosmos kit box (Scouts will shake to simulate earthquake)
- Skyscraper model built in Meeting 5

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Materials Needed But NOT Included in Kit

- NONE

Lab Leader's Optional Notes Section

(This section is for YOU! List notes, reminders, and/or responsibilities and roles of the Scouts. You may also create a list of successes and challenges you experience during this activity and send it our way!)

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MEETING PLAN

Meeting 6: Shake Things Up	**STEM Focus:** Structural Engineering

Activity Overview

Scouts will apply their cumulative knowledge of structural engineering to the test of their skyscraper. They will learn about shear and torsion, and how they affect a structure. Scouts will test and compare their structure's ability to withstand the horizontal load of light and major earthquakes, and design reinforcements to improve their structure's stability.

PART 1

Introduction/Background Information

Use the questions and background information below to engage Scouts. *(Typical answers are in italics.)*

Prior to starting the discussion, break Scouts up into teams of four.

- In this meeting our exploration of towers will come to an end. We are going to build on our knowledge from our previous meetings and introduce some new terminology.
- Let's review. What are the definitions of tension and compression? *(An object is under tension when it is being pulled, and an object is under compression when it is being squeezed or pressed together.)*
- There are two more ways loads can affect a structure: shear and torsion.
- **Shear** is a force that causes parallel internal surfaces within an object to slide past each other. For example, when you cut a piece of paper with scissors, each blade of the scissors is a force acting on the paper from opposite directions.
- What is an example of a shear force acting on a skyscraper? *(Most lateral forces like wind and earthquakes are shear forces, as they are perpendicular to the building and result in one part of the surface being pushed in one direction while another part is pushed in the opposite direction.)*
- **Torsion** is a force that causes the twisting of an object due to a moment. Who recalls what a moment is? Can you give an example? *(A moment is the measure of a force's tendency to rotate or twist an object about a specific point. Imagine pushing a door open. When you push on the door handle, the door opens, rotating on its hinges. The force of pushing on the door caused the door to rotate.)*
- What is an example of a torsion force acting on a skyscraper? *(Extreme wind load, like a hurricane, can force a building to twist.)*
- Speaking of loads, what are the two different types of loads? *(Vertical/gravity and horizontal/lateral.)* Give examples of each. *(Vertical loads include "dead" loads, like walls, floors, and other permanent building elements, as well as "live" loads, like people, furniture, and other temporary objects in the building. Horizontal loads include forces from weather, like wind, rain, earthquakes. These can also be classified as "live" loads.)*

- Today, we will be testing how well your skyscraper model holds up to horizontal loads. You and your team will have time to make improvements to your structure in hopes of withstanding an earthquake!

- What is an earthquake and how are they caused? *(An earthquake is the shaking of the surface of the Earth caused by the movement of Earth's tectonic plates.)*

- The strength of an earthquake is determined by the Richter magnitude scale, which was developed by Charles Richter in 1935. Earthquakes can be divided into class sizes as well, from minor to great, depending on the magnitude.

- The earthquake with the highest recorded magnitude was the Great Chilean Earthquake in 1960, with a magnitude of 9.5. Sadly, about 6,000 people lost their lives.

- Although scientists cannot predict **when** earthquakes will occur, they do know **where** they may occur, such as along the edges of plates and fault lines.

- When structural engineers are building skyscrapers in earthquake zones, they have to make conscious structural decisions to ensure the structure can withstand an earthquake. For example, the First Interstate World Center building in Los Angeles is the tallest building in the world in a major earthquake zone.

- Designed to withstand an 8.3 magnitude earthquake (or bigger), the skyscraper has a solid concrete core right up the center of the building, and has columns lining the perimeter. The reinforced core and lighter columns form a flexible yet stiff framework that can withstand intense shaking and massive wind force.

- The solid concrete walls that line the core of the First Interstate World Center building have another name—shear walls.

- **Shear walls** provide great stiffness against horizontal forces, and thus are used to counteract horizontal loads like the shaking ground of an earthquake because they create a strong and sturdy backbone for a skyscraper.

- What is another very important aspect of building a solid tall building? *(Foundation.)* What is the foundation and why is it so important? *(The foundation is the lowest load-bearing part of a structure and is typically below ground level. Every structure must have a foundation, and for tall skyscrapers, the foundation is even more important because it holds so much weight and must be strong enough to counteract intense loads and keep the structure in place.)*

- Keep the importance of shear walls and foundation in mind when testing and improving your skyscraper. Let's go!

- **Leader Note:** Facilitate the testing of the models. Group 1 with Version 1 should test first, then Group 2 with Version 2 next, so the paired groups can observe and compare both models.

PART 2

Discuss the Scout Law Character Focus

Today we are focusing on the character point **Obedient**.
What does it mean to be obedient? *(To follow the rules of your community and country.)*
When we test our skyscraper, how can we practice being obedient?

PART 3

Safety Moment

- Review the first page in the Experiment Manual for safety information and assembly tips before you start.
- Keep track of the small building pieces.
- Be careful when shaking the desk or table to ensure no one gets hurt or anything breaks.
- When disassembling your models, be gentle when pulling pieces apart so they do not snap. Use the yellow tool to remove small pieces.

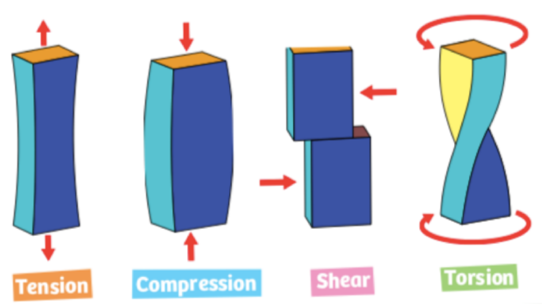
PART 4

Leader Note

Have the Scouts get back into their teams from the last meeting and hand out the skyscraper models they built.

Activity Steps

Have Scouts follow the procedures in their Scout Notebook



Skyscraper Test

If you did not finish building your model in the last meeting, pair up with a group that built the same skyscraper model as you.

Then pair up with a team that built the other version of the skyscraper.

Materials:

- Thames & Kosmos Structural Engineering Kit
    - Thames & Kosmos kit box (will be used to simulate an earthquake)
- Skyscraper model built in Meeting 5

Earthquake Magnitude Scale

Class/Magnitude	Effect	Occurrences Every Year
Minor/<2.5	Usually not felt	900,000
Light/2.5–5.4	Often felt, but only minor damage	30,000
Moderate/5.5–6.0	Slight damage to buildings and other structures	500
Strong/6.1–6.9	May cause a lot of damage in very populated areas	100
Major/7.0–7.9	Serious damage	20
Great/≥8.0	May destroy communities near the epicenter	1 every 5–10 years

Part 1: FIRST EARTHQUAKE

1. Clear off the desk or table you are working on and place your skyscraper in the middle.

2. For your first earthquake, you will simulate a light earthquake. Enter the class and magnitude range in the table below. Reference the Earthquake Magnitude Scale above.

Class/Magnitude	Effect

3. The Scout with the role of Remaining Scout should tape the skyscraper to the cardboard box that the kit came in, and slightly shake the box for 5 seconds to simulate a light earthquake.

    - The other Scouts should observe the effects of the earthquake on the skyscraper while it is shaking.
    - Upon completion, the Scout with the role of Surveyor should document cumulative observations in the table above.

4. If any damage occurred, take the time to put the skyscraper back together.

5. While reassembling, start to brainstorm on some improvements you think your structure would benefit from for preventing damage in an earthquake, but do not make those improvements yet. Jot down any preliminary ideas below.

Part 2: SECOND EARTHQUAKE

1. Time to simulate a stronger earthquake! Make sure the desk or table you are working on is cleared off and place your skyscraper in the middle.

2. For your second earthquake, you will simulate a major earthquake. Enter the class and magnitude range in the table below. Reference the Earthquake Magnitude Scale above.

Class/Magnitude	Effect

3. The Scout with the role of Remaining Scout should again tape the skyscraper to the cardboard box that the kit came in, and vigorously shake the box for 5 seconds to simulate a major earthquake.
   - The other Scouts should observe the effects of the earthquake on the skyscraper while it is shaking.
   - Upon completion, the Scout with the role of Surveyor should document cumulative observations in the table above.

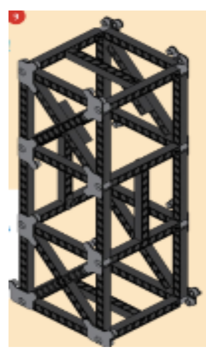
4. Did any damage occur? Examine the structure with your team and take notes below on what was damaged and where the damage occurred.

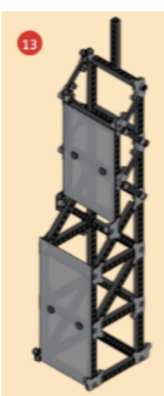
5. Reread your preliminary ideas for improvement from Part 1.

6. Discuss improvements and choose THREE of the most critical improvements you believe your skyscraper needs to withstand earthquakes.

7. Write the improvements below. Include what structural elements are needed, where, and why.
   -
   -
   -

8. The Scout with the role of Architect should now draw the three ideas with input from team members. If your team built Skyscraper V1, draw on the model to the right:





If your team built Skyscraper V2, draw on the model to the left:

9. **Optional:** If time permits, select one or more of the improvements and add it to your model, and/or use less tape to simulate a weaker foundation when shaking the box.

10. Disassemble your skyscraper.

Activity Adaptations for Scouts, as Needed

If Scouts finish early:

- Challenge them to add one or more of their improvements to their model. They can then perform an earthquake simulation to test how their newly improved model performs.
- Have them choose a different magnitude to reenact and repeat the steps in Part 1.

If Scouts are too challenged:

- After they complete the earthquake simulation in Part 1, let them skip the second earthquake simulation and to go straight to Part 2: Steps 8–10.

PART 5

Circle Up for Reflection Questions

- How did you feel when you were testing your skyscraper?
- What were the challenges? What things succeeded? Why?
- What was it like working in your team?
- How did your team practice our character point Obedient?
- How would you describe shear and torsion? *(Shear is a force that causes parallel internal surfaces within an object to slide past each other. Torsion is a force that causes the twisting of an object due to a moment.)*
- What are some of the most important aspects that structural engineers need to be aware of when building in an earthquake zone? *(Strong foundation, strong core/backbone for stability, flexible enough to counteract wind loads.)*

PART 6

STEM Innovator Moment: Elmina Wilson

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Elmina Wilson (1870-1918) is largely regarded as the "first lady of structural engineering." Elmina was the first woman to earn a master's degree in structural engineering. She received her degree from Iowa State University in 1894. Although not the first woman to receive an undergraduate degree in the study, she was the first to earn a master's in structural engineering, the first to practice structural engineering as a job, and the first to become a college professor of the study.

Elmina worked as a structural engineer for Purdy and Henderson in New York City, the country's lead design firm for skyscrapers at the time. She contributed to some historic designs, including the Flatiron Building (pictured) and the Met Life Tower. Upon completion, the Met Life Tower was the tallest building in the world at the time. Notably, Elmina also worked hard on behalf of women's rights, by serving as the president of the Woman Suffrage Club in Manhattan. She worked alongside national leaders for women's voting rights, including Susan B. Anthony and Eleanor Roosevelt!

Source: https://csengineermag.com/article/the-first-lady-of-structural-engineering/

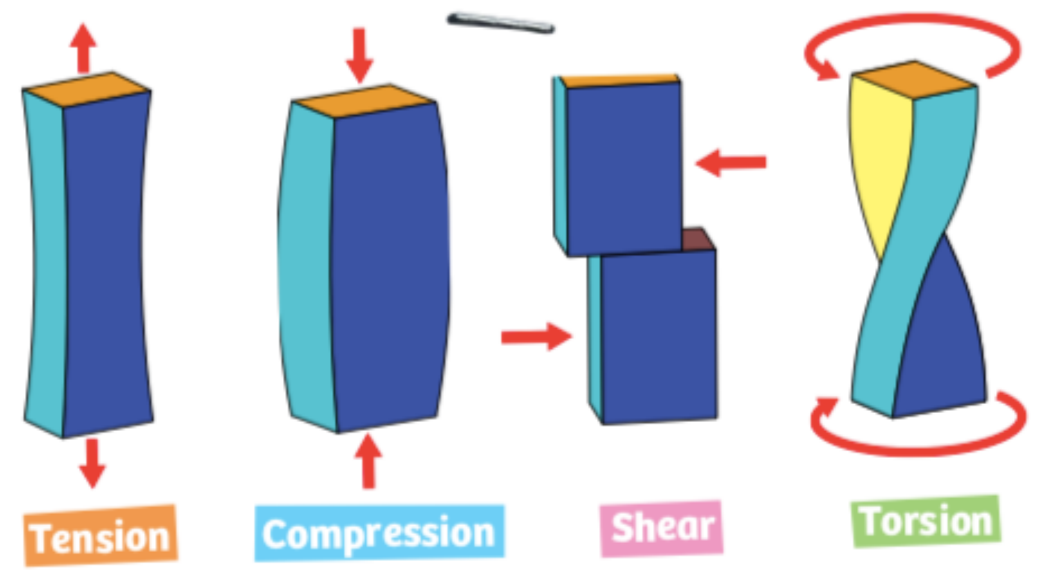
PART 7

Leaving It Better Than We Found It!

- Have Scouts help clean up supplies and throw away any trash.
- Make any needed announcements.

Key Terms

- **SHEAR:** *A force that causes parallel internal surfaces within an object to slide past each other.*
- **TORSION:** *A force that causes the twisting of an object due to a moment.*



- **SHEAR WALL:** *A solid concrete wall that provides great stiffness against horizontal forces.*

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Boy Scouts of America
STEM Scout Module Survey, 2019

iPhone/iPad Directions:

1. Open the Camera app on the iPhone or iPad.
2. Make sure you have adequate lighting so the camera can pick up the QR code.
3. Align the camera with the QR code.
4. The camera will read the QR code and provide you with a notification to access whatever it contains.

Android Instructions:

1. Tap the Navigation (three stripes on the upper left corner).
2. Choose: Settings.
3. Choose: Screen Search.
4. Swipe to activate it.

Computer Instructions:

1. Open a web browser (Explorer, Firefox, Google Chrome).
2. Type in this website:
   http://scouting.co1.qualtrics.com/jfe/form/SV_dmd7eLarNQM62rz