Standard:	Big Idea:
7.MS-ETS3-4(MA). Show how the components of a structural system work together to serve a structural function. Provide examples of physical structures and relate their design to their intended use. s ● Examples of components of a structural system could include foundation, decking, wall, and roofing. ● Explanations of function should include identification of live vs. dead loads and forces of tension, torsion, compression, and shear. ● Examples of uses include carrying loads and forces across a span (such as a bridge), providing livable space (such as a house or office building), and providing specific environmental conditions (such as a greenhouse or cold storage).	Systems are made of many parts (called subsystems) that work together to achieve a goal (the output). Feedback helps us improve systems.

Point:

How do arch bridges work?

- Each stone in an arch bridge is under compression. The arch shape transfers compression forces downward from the live load, outward to the abutments.
- Arch bridges are extremely strong and use inexpensive materials, but can't span large distances and require abutments. Therefore, they can only be used in particular situations.

Practice:

Obtain information

Vocab:

Review: compression
New: arch bridge, abutments

Materials:

For the teacher:

- Arch bridge model
- How to do the demo: https://www.youtube.com/watch?v=vNtqkIy1q6M

Slate (10 min)

Week 37, slides 4-6

Do Now (4 min)

1. What do you notice about these bridges?
   - They all have arches

Intro to the lesson (1 min)

2. This is our last type of bridges: Arch bridges. We will again figure out how they work. Then we will look at what criteria they meet really well and what constraints there are on arch bridges.

How do arch bridges work? (20 min)

3. Arch bridges are one of the oldest type of bridges, dating back thousands of years. A benefit of arch bridges is that they are extremely strong and can be made out of really inexpensive materials like stone or unreinforced concrete. A drawback of arch bridges is that their spans are relatively short. Another drawback is they require abutments to stand up.

Arch bridges handle their loads completely through a single force, but still extremely strong. Let's find out how:

4. Video focus question: How do arches strengthen bridges?

5. https://www.youtube.com/watch?v=Ac6iqzSuTwQ

6. How do arches strengthen bridges?
   - Arches strengthen bridges by absorbing the compressive forces of the live load by spreading the forces out to the abutments.

7. I am going to show you a bit about how an arch bridge works using a model of an arch bridge. As I am doing the demo, you are going to focus on this question: Why are abutments so important to arch bridges?
   - Do the demo as shown in this video: https://www.youtube.com/watch?v=vNtqkIy1q6M
   - The abutments are important because they prevent the sides of the arch from being pushed out the sides.

8. What are the abutments in this bridge structure?
   - The natural hill

Sometimes engineers have to build abutments, but often arch bridges are built in valleys or over rivers where there are natural rises in the land on either side of the bridge.

9. Relate this gif to Newton's 3rd law.
   - Link for the gif in case it doesn't work.

- The live load pushes down on the keystone, which compresses the stone out to the abutments. Then the abutments provide a reaction force back in the other direction to hold up the load.

Transferring the forces in this way makes arch bridges very strong and durable. There are arches from Roman times that still exist today.

But in order for arches to transfer forces in that way, they need to be a very specific shape. That means that you can't widen them without making them taller. And if they are taller, then they need taller abutments. Therefore, the span of arch bridges has to stay pretty short.

Takeaway: Each stone in an arch bridge is under compression. The arch shape transfers compression forces downward from the live load, outward to the abutments.

Criteria and constraints (10 min)

10. Notes:
    - Arch Bridges: resist compression
    - Criteria arch bridges meet:
        - Very strong.
        - Uses inexpensive materials like stone.
    - Constraints on arch bridges:
        - Short spans.
        - Require abutments.

11. Turn and talk. How do you think engineers overcome the constraint of arch bridges having relatively short spans?

We know that arch bridges have relatively short spans. But engineers found a way around this! We are going to go through a list of ways that arch bridges can be confused. Keep a running list in your notebook as we talk about them.

12. Ancient engineers also figured out how to use arch bridges to cover longer distances: they put a bunch of arches together in a row to make a larger total span. In these situations, two adjacent arches served as the abutments for each other.
    - This should remind you of the beam bridges with multiple spans.

The arch on the left in this picture is acting as the abutment for the arch on the right, and vice versa. The stonework on the river banks act as the outside abutments.

13. This is a series of arches on tall piers.

14. To make tall aqueducts (bridges for carrying water), they stacked arches on top of arches. This bridge is over 2,000 years old and is still standing.

All of those bridges were made of stone. Later, engineers learned to use metal to make arch bridges that were longer and required less total material.

15. This arch is made of metal, but works similarly to the ones that you saw earlier. Notice how tall and long it is.

16. This bridge is a composite, meaning that includes two different types of bridge structures. Can you see them?

- Arch bridge and a suspension bridge.

Takeaways:

- **Arch bridges are extremely strong and use inexpensive materials, but can't span large distances and require abutments. Therefore, they can only be used in particular situations.**

Cyclical review (15 min)

17. Most modern communication systems are digital. When information was first digitized and computers were slow, what was the drawback of encoding information in digital form?

- Disadvantages of digital: some data precision is lost converting the analog signal to digital. Remind them of the pixelated images of old school mario

Follow-up: What benefits of digital communication have encouraged our society to fully embrace digitalization?

- encoding and decoding with computers
- signal is easier to store and transmit without loss of quality.

18. Which of the following is an input of building a house foundation?

- Pouring concrete.
- **Concrete**
- A concrete wall

Follow up:

- Input = concrete
- Process = pouring the concrete
- Output = concrete wall

19. What is the purpose of an antenna?

- To encode information to the radio station.

- To transmit information to the radio station.
- **To receive information from the radio station.**
- To decode information from the radio station.

Remember that a receiver is anything that takes in the signal at the destination - a mailbox, a satellite dish, a telephone or antenna.

20. How could you improve the strength of this table?
    - ids should say to make a triangular brace. Have them sketch in notebook, then have someone come up and show on the board image.
    - They should add diagonal wood to create triangles.
    - Show on slide 21.

22. During which parts of the universal systems model would engineers want to collect data or information?
    - **input**
    - process
    - output
    - **feedback**

Data can be an input. You want to collect data before you do any kind of project.
Data can also be important to gather during feedback.

23. Identify the live and dead loads on this bridge.
    - Live loads = trucks on the bridge
    - Dead loads = weight of the bridge itself
    - Total load = live + dead load

24. Identify the propulsion, structural and control systems of this bike.
    - Propulsion = pedals, gears, chain
    - Structural = frame
    - Control = brakes, handlebars

25. Which force do you think the deck of the bridge experiences?
    - compression
    - tension
    - **bending**
    - shear

Bending is the most important (though it will also experience shear and torsion forces from wind - but I wouldn't get into that). The deck of most bridges bend under loads. Remind them of the penny / card bridges

26. Which part(s) of a communication system change the form of a signal?
    - Encoder
    - Decoder
    - **Both a and b**
    - Neither a nor b

27. What would be a drawback of using **planes** to carry tanks from the US to Europe?
    - Tanks are heavy and bulky - not the best for planes.

Follow-up: What would be a better alternative
    - Ships