Arches Part 1:

How History Shaped a Powerful Design

Facilitator's Guide

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Ansys Software Used

This resource uses Ansys Granta EduPack™ teaching software for materials education.

This guide supports the integration of "Arches Part 1: How History Shaped a Powerful Design" into the classroom.

Arches are common features in many historic buildings. They look grand and impressive — but how and why did people come up with this shape?

This case study tells the story about how history shaped the invention of an arch, covering topics such as material availability, material properties, manufacturing options, means of transport, and other historical connections.

This is part 1 of our set of resources on the topic of arches. Part 2 is also available online and focuses more on understanding forces in general, leading up to forces acting within an arch and understanding why the shape is so stable.

Part 1 and 2 do not depend on each other and can be used individually.

Zip File Contents:

1. Read Me Facilitator's Guide (this document)
2. PDF Case Study
3. Arch toy-size CAD model STL file (made using Ansys Discovery)
4. Arch building support CAD model STL file (made using Ansys Discovery)

Age Range: **14-99**

This resource is designed to tell a story, give food for thought and inspire knowledgeable discussions. It is worth noting, that we intentionally use simplified language avoiding specific jargon, to make the topic understandable and relatable for children (**age 14+**) and anyone trained outside of this subject area. The focus is on getting the participants (whether young or old) to talk about STEM topics as a group, no matter at which depth, and think outside the box and be inspired.

Learning Objectives:

After going through this case study, learners will be able to:

- Understand how historical context influenced architectural design
- Understand the properties and availability of different construction materials
- Understand the limitations of manufacturing and transport in the past
- Understand different structural solutions for spanning gaps (blocks, beams, arches)
- Understand why the arch became a widely used and long-lasting architectural solution

Format Suggestion:

We expect it to take approximately 45 to 90 minutes to go through this case study in detail, allowing time for questions and student exploration of topics.

Prior/Supplemental Knowledge Required:

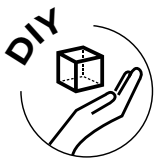
The topics listed here are concepts mentioned during this unit that are not explicitly discussed. They are recommended to either cover in a prior unit or leave time during the arch case study for additional explanation.

- Stress in materials
- Density

Fundamental concepts covered:

This resource highlights the evolution of materials and manufacturing processes as well as material properties such as strenght in different directions.

Optional Extension Activities:



Hands-on Exercise- Build your own Arch!

Using the included CAD model, have students build their own arch to physically test the information from the case study.

Multiple options exist for materials; we have split them by equipment needs below.

Equipment Needs	Space/tool Requirements	Description
Minimal	Classroom, scissors or other tools to cut foam, paper template	Use foam (a stiffer foam like styrofoam would work best) to cut out the voussoirs. *We recommend creating a paper template of the side profile of a voussoir to make this part easier. You can either create your own version of an arch or print the last page of this document.
Medium	Need a wood shop or access to a jigsaw	If, as an educator, you would prefer having a set of voussoirs for students to use for multiple years, having a wood shop cut out the shapes could be an option.
Advanced	Access to a 3D printer	If your school has a 3D printer, the voussoirs could be printed there using the CAD model[1]. *Additional design idea: explore different printing materials and compare how they perform

1 Please note that, as of publication, this CAD model has not been tested for 3D printing. Some adjustments may be necessary

Once arch materials have been acquired, students can assemble their structure. Once all voussoirs are in place, the arch should be stable and self-supporting.

Tip: you might want to use some support to keep each voussoir in place while you add the next (i.e. cardboard or a helping hand)

Questions to ask students: during assembly, did you feel how the voussoirs press against each other?

Ansys Software Activities:

If you have access to Ansys Granta EduPack:

1. Open the "Built Environment" database
2. Browse materials and get familiar with a materials record
3. Read the science notes for properties, by clicking on the properties, such as: date first used, superstructure, compressive strength, tensile strength, Durability: rural atmosphere, marine atmosphere; and any other you may find interesting
4. Try the search function (i.e. search for "span")

Additional Topics for discussion/expansion:

1. What materials are used today in construction? When were they invented?
2. What structures are used today to span an opening? What shapes do those structures have and how are they manufactured?
3. Do arches still exist in modern buildings? What purpose do they serve (i.e. visual appeal, structural significance)?

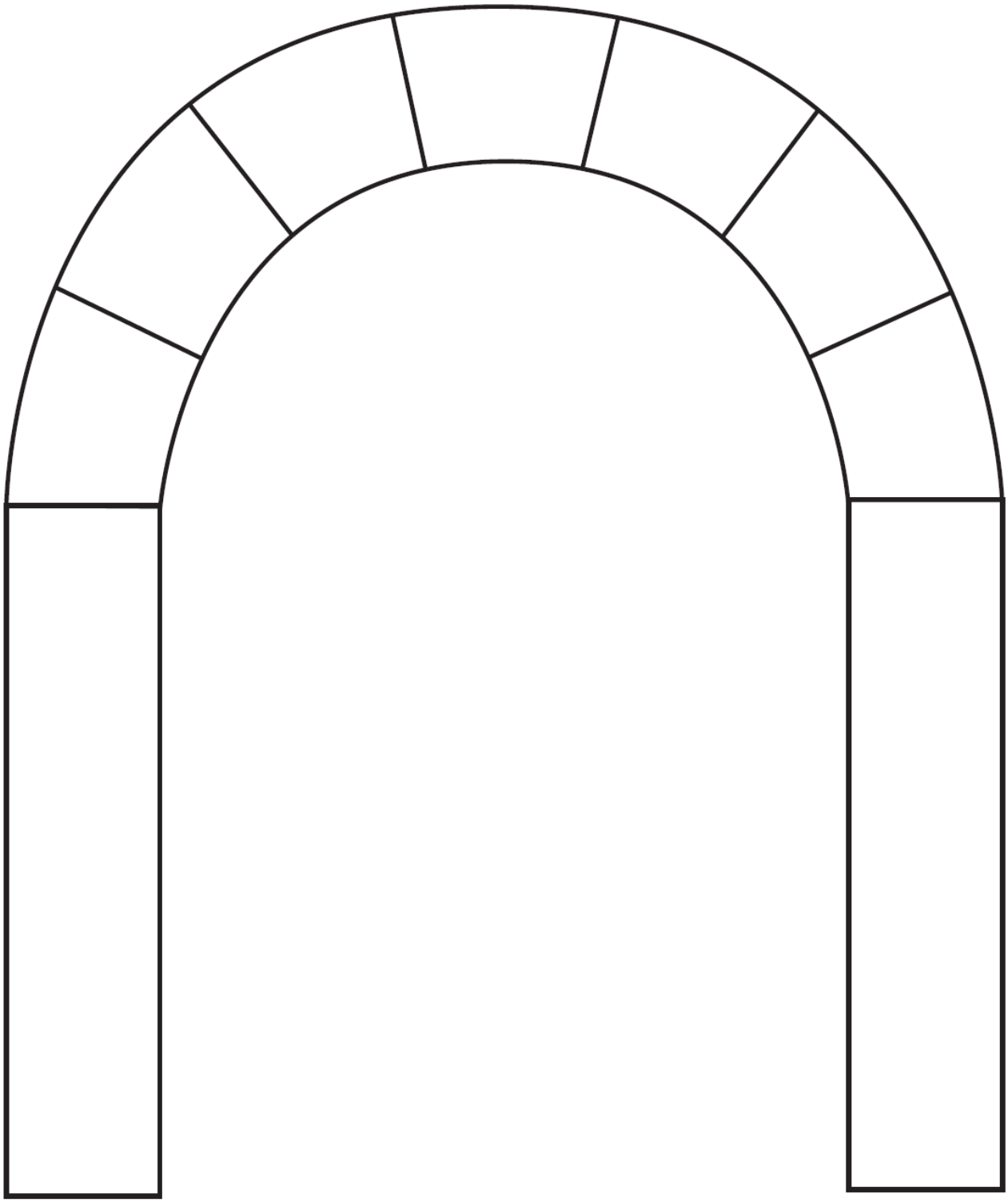
Additional Resources:

Other Ansys pre-university resources:

- **"Arches Part 2: Why the Shape Works: Understanding Forces"**

- "Materials Intelligence: the Card Game"
- "Selecting Materials for Musical Instruments: a Case Example with a Xylophone"
- "Our impact on the planet: let's make it a good one!"
- "Life's Engineering Tales: Grandma's Hip Replacement"
- "Life's Engineering Tales, featuring: An element's journey"
- "Life's Engineering Tales: featuring whale-inspired wind turbines"
- "Life's Engineering Tales: What kind of engineer could you be?"
- "How Walkie Talkies Work: an Exploration for Children using Ansys HFSS Software"
- "Exploring Material Properties via Experiments and Property Charts: the Game"

Example Arch Template for Printing



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Document Information

This case study is part of a set of teaching resources to help introduce students to topics related to fluids.

Ansys Education Resources

To access more undergraduate education resources, including lecture presentations with notes, exercises with worked solutions, microprojects, real life examples and more, visit www.ansys.com/education-resources.

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