Need Some Support

Learn about structural design by creating a structure that will support many textbooks. A performance factor is presented to encourage trade-offs.

Engineering Design Process Outline

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Step 2: Your Challenge

Step 3: Specifications and Constraints

Step 4: Design Criteria

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Step 8: Plan and Build Prototype

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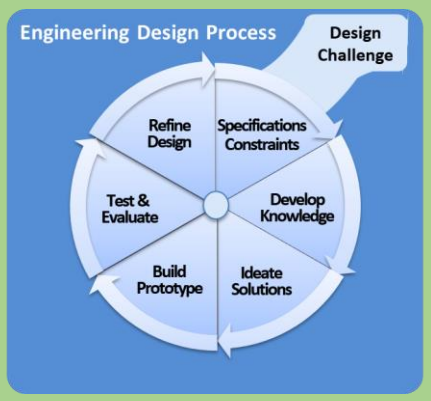
Step 10: Refine Design

Step 11: Design Solution



Step 1: Need Some Support?

In many different parts of the world, people need or want to live elevated above the ground. For example, in many countries, including the U. S., people live in stilt houses which allow them to live over water or to stay dry when hurricanes or monsoons create flooding.

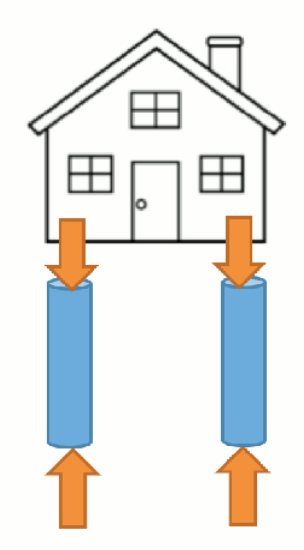


Strong and stable foundations help very tall buildings to rise as well.


To design structures that are stable and strong, people must think like **Structural Engineers*** and consider the forces (pushes and pulls) that act the structure.

*To view a short career video on structural engineering hold Ctrl and click to follow this link or copy and paste this link into your browser: https://www.youtube.com/watch?v=mkBLhUBCQn8

Step 2: Your Challenge: Build a Foundation



One type of force structural engineers are concerned about is compression. The weight of a structure pushes down on the ground. The ground pushes back on the building. What they build must be strong enough to withstand this **"**squeezing" force.

Your **challenge** is to make a strong and stable foundation that can support weight (5 textbooks) for at least 15 seconds at least 5 inches above the surface.

You will have **limited time and materials** to build your foundation.

Your materials include:

- 10 (3 x 5 inch) index cards
- 2 pieces of paper
- 12 inches of masking tape
- Ruler
- Scissors
- Paper for sketching

Step 3: Specifications and Constraints

To design a solution to our challenge, we must first identify the specifications and constraints.

Specifications are what your solution must do. They are the requirements. For example, specifications for structural engineers might be that they have to design a foundation that can support a building that weighs 100,000 pounds.

Constraints are things that limit your solution. A constraint may be how much you can spend on materials or how much time you have to complete the challenge. For example, a constraint for a structural engineer designing a foundation might be that it cannot cost more than $7000.

What are the specifications and constraints for this challenge? Check off answers below.

	SPECIFICATION	CONSTRAINT
Limited time provided by facilitator	☐	☐
Make a foundation that supports 5 textbooks	☐	☐
Limited materials	☐	☐
Make a foundation that supports weight for 15 seconds	☐	☐
Distance of structure above the surface	☐	☐

Step 4: Design Criteria

Good job identifying the specifications and constraints! Now that you know what you are supposed to do, here are some criteria that you will use to evaluate your foundation.

Below is what you will use to rate your design. Use it to think about how you will build your foundation!

Foundation Rating	1	2	3	4
Weight	Supports 0-1 book	Supports 2-4 books	Supports 5 - 9 books	Supports 10 books or more
Time	Collapses immediately	Supports 5 books less than 15 seconds	Supports 5 books 15-59 seconds	Supports 10 books for 60 seconds or more
Foundation Height	0-2 inches	2-4 inches	5 inches or more	
Bonus	Uses all the materials provided	Uses half of the materials	Uses less than half of the materials	

Step 5: Develop Knowledge

Before designing solutions, engineers often research and develop knowledge about the problem.

What are foundations?

The lowest part of a building that supports the weight of the building is called a foundation.

What features would make a useful foundation?

- Strong enough to withstand squeezing, or compression forces, by the structure's weight and the earth.
- Provide stable structural support so that building does not fall over.
- Be able to support the building for long periods of time.

Step 6: Self-Quiz!

Based on what you read on the previous page, answer the following questions as best as you can.

1. What is a foundation?
   - The floor of a building that houses the executives
   - The place that people park
   - The lowest part of a building that you can see out of
   - The lowest part of a building that supports weight

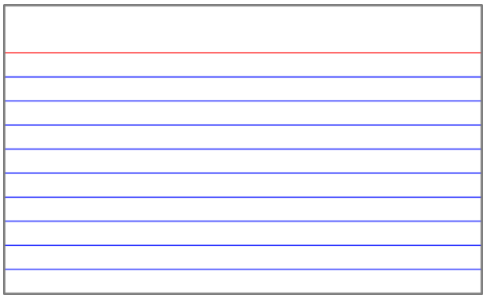
2. Which is NOT a purpose of a foundation?
   - Keeping the structure dry
   - Providing storage space
   - Supporting the weight of the structure
   - Keeping the structure standing upright

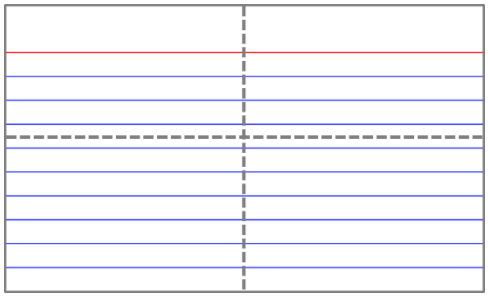
3. Which of the following forces do structural engineers need to think about when they design foundations?
   - The force of the weight of the building on the foundation
   - The force of the earth on the foundation
   - The force of compression
   - All of the above

Step 7a: Foundation Shapes - Experiment A

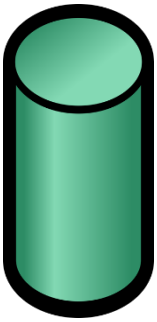
Let's experiment!

1. Use 2 index cards and 2 inches of tape for your experiment.
2. Leave one index card flat. Fold the second index card into quarters, then unfold so it has creases.





3. Roll each index card into a cylinder that is 5 inches tall.



4. Gently apply compression force by pushing down on each cylinder with your hand.

Based on your experiment, answer the following questions as best as you can.

1. What happened when you pushed down on the uncreased cylinder?
   - The card squashed with very little effort.
   - The card resisted until I pushed very hard.
   - The card bent in the middle.
   - The card unrolled.

2. What happened when you pushed down on the creased cylinder?
   - The card squashed with very little effort.
   - The card resisted until I pushed very hard.
   - The card bent in the middle.
   - The card unrolled.

Step 7b: Foundation Shapes - Experiment B

Let's experiment again!

1. Get 2 more index cards and 2 inches of tape for your next experiment.
2. Leave one index card flat and crease the second index card like you did in Experiment A.
3. Fold each card into a 5 inch tall triangular column. Tape the edges so they can stand.

4. Gently apply compression force by pushing down on each column with your hand.

Based on your experiment, answer the following questions as best as you can.

1. What happened when you pushed down on the uncreased triangular column?
   - The card squashed with very little effort.
   - The card resisted until I pushed very hard.
   - The card bent in the middle.
   - The card unrolled.

2. What happened when you pushed down on the creased triangular column?
   - The card squashed with very little effort.
   - The card resisted until I pushed very hard.
   - The card bent in the middle.
   - The card unrolled.

3. Which foundation shape resisted more compression force?
   - The cylinder
   - The triangular column
   - They were the same.

Step 8: Plan and Build a Prototype

Engineers build prototypes, or a first version of a product, to test their design ideas. Remember the design criteria that you will be using to evaluate your foundation!

To plan your design, consider the following:

- materials (index cards, paper, tape)
- number and shape of columns
- placement of columns

Build and test your foundation by carefully stacking textbooks on it. See if it can hold the weight for 15 seconds before you add another book. How much weight can your structure hold before it fails?

Step 9: Test and Evaluate Prototype

Evaluate your foundation using the rubric below

Foundation Rating	1	2	3	4
Weight	Supports 0-1 book	Supports 2-4 books	Supports 5 - 9 books	Supports 10 books or more
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Step 10: Refine Design

Engineers use test results to refine their designs.

Based on your evaluation of your foundation how would you refine your design?

If you have time, revise and rebuild your foundation to improve it.

What could you do to improve your design?

Step 11: Design Solution

Congratulations! You have successfully used engineering design to make a foundation! You have just done what structural engineers do every day - design and construct foundations to support structures and buildings.

If you didn't have a chance to view the video to explore a career in **Structural Engineering** you can do so now. Hold Ctrl and click to follow this link or copy and paste this link into your browser https://www.youtube.com/watch?v=mkBLhUBCQn8