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| **Activity 2.1.1** **Aerospace Materials Investigation** |

Introduction

Within aerospace design, material selection has a large impact on overall design performance as well as production and maintenance costs. Aerospace designers and developers must always be aware of the impact that material selection has on design specifications ranging from propulsion requirements to environmental factors.

In this activity you will investigate properties of materials in several categories. Within each category you will consider the suitability of the materials in aerospace applications.

Equipment

* Computer with Internet access
* Engineering notebook
* Pencil

Procedure

1. Open the PBS Forces Lab at the following link : <http://www.pbs.org/wgbh/buildingbig/lab/forces.html>
2. Click the Forces tab along the top.
3. Click Squeezing option. Click and drag the slider and observe the effect on the material.
4. Observe images by clicking See It In Real Life.
5. Repeat this exploration for each force and use what you learned to complete the following table.

| **Forces** | **Engineering term****(look above the block)** | **Definition****(in your own words)** | **Two examples of how this force can affect airplanes (your ideas)** |
| --- | --- | --- | --- |
| **Squeezing** | **Compression** | **A force that makes an object smaller by pushing the two sides closer together.** | **When the plane is moving and the force of the wind acts on the front and back of the plane and on the wings of the plane.** |
| **Stretching** | **Tension** | **A force that starts to pull apart a material from both sides of the material.** | **When a plane is flying and as it gets faster a force will pull it apart.** |
| **Bending** | **Bending** | **A force acting on a material causing it to curve. A part of the material is being pulled apart and the other closer together.** | **If the material of a plane is improperly chosen then the plane’s wings will improperly bend.**  |
| **Sliding** | **Shear** | **A force that causes the opposite sides of a material to slide against one another.** | **If forces act on a plane in a certain way then the plane then the materials may bend or shear.** |
| **Twisting** | **Torsion** | **An action when a material will begin to twist from a force acting on it.** | **Wrong chosen materials causing the plane to twist when wrong forces are acted on it.** |

1. Now that you understand forces, let’s observe various materials used in aerospace applications. Click on the tab labeled Materials.

**Metals**

1. Click on each material shown below and move the slider until the material cracks. Use the tick marks on the scale to assign a number to the force, cost and weight. Record this number on the following table. Move the slides completely to the maximum to see a message about the material. Complete the table below using what you learn.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Type of Material | Strength in Tension (Stretching) | Strength in Compression (Squeezing) | Cost | Weight | Pros and Cons | Applications |
| Aluminum |  **4** |  **4** |  **9**  |  **2** | **Strengths: Lightweight, doesn’t rust, strong in compression and tension.****Weaknesses: Expensive** | **Airplane wings, boats, cars, skyscraper “skin”****Example: Petronas Towers** |
| Steel |  **5.2** |  **5** |  **6.8** |  **9** | **Strengths: One of the strongest materials used in construction, strong in compression and tension.****Weaknesses: Rusts, loses strength in extremely high temperatures** | **Cables in suspension bridges, trusses, beams and columns in skyscrapers, roller coasters** **Example: Sears Tower** |

1. Based on your results, in which loading condition (tension or compression) are metals strongest?

**They are stronger in compression.**

1. Even though steel is an exceptionally strong metal, why wouldn’t it be a good choice for use inside jet engines?

**A jet engine can produce high temperatures and steel loses strength at high temperatures.**

**Polymers**

1. Click on the material shown below and move the slider until the material cracks. Use the tick marks on the scale to assign a number to the force, cost and weight. Record this number on the following table. Move the slides completely to the maximum to see a message about the material. Complete the table below using what you learn.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Type of Material | Strength in Tension (Stretching) | Strength in Compression (Squeezing) | Cost | Weight | Pros and Cons | Applications |
| Plastic | **4** | **4** |  **9** |  **1.5** | **Strengths: Flexible, lightweight, long-lasting, strong in compression and tension****Weaknesses: Expensive** | **Umbrellas, inflatable roofs over sports arenas****Example: Georgia Dome** |

1. As noted in the investigation, plastics are strong and very light, both of which are desirable characteristics to engineers. However, watch carefully as you apply tension and compression to the plastic. Note how it behaves. Based on your observations, would plastic be a suitable alternative to aluminum for airplanes, or steel for buildings? Why or why not? **Yes it would be because it is a lightweight material that can stretch and compress easily with high pressures without breaking and it is a very flexible material compared to steel and aluminum.**

**Ceramics**

1. Click on the material shown below and move the slider until the material cracks. Use the tick marks on the scale to assign a number to the force, cost and weight. Record this number on the following table. Move the slides completely to the maximum to see a message about the material. Complete the table below using what you learn.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Type of Material | Strength in Tension (Stretching) | Strength in Compression (Squeezing) | Cost | Weight | Pros and Cons | Applications |
| Brick |  **2** | **4** |  **2.2** |  **4** | **Strengths: Cheap, strong in compression****Weaknesses: Heavy, weak in tension** | **Walls of early skyscrapers and tunnels, domes****Example: Original Thames Tunnel** |

1. Based on your observations, in which method of loading (tension or compression) are ceramics strongest? In your opinion, why do you think ceramics behave this way? **They are strongest when they are compressed. When the clay is pulled apart it is easier to pull apart then compressing it.**
2. Since ceramics can be so strong (and relatively inexpensive), why aren’t they used to make aircraft or other transportation machines? Why do we only seem them used in buildings or structures? **Because buildings are so big, there is much weight compressing down on the brick and it is stronger when compressed compared to others such as steel. A plane is not compressed as much as a building is so material that can stretch just as much as it can compress is used.**
3. Why wouldn’t brick be used to make the cables which hold up a suspension bridge? **Because a bridge would require the cables to expand causing the brick to easily pull apart.**

**Composites**

1. Click on each material shown below and move the slider until the material cracks. Use the tick marks on the scale to assign a number to the force, cost and weight. Record this number on the following table. Move the slides completely to the maximum to see a message about the material. Complete the table below using what you learn.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Type of Material | Strength in Tension (Stretching) | Strength in Compression (Squeezing) | Cost | Weight | Pros and Cons | Applications |
| Wood | **3** | **4** |  **2.1** |  **1** | **Strengths: Cheap, lightweight, moderately strong in compression and tension****Weaknesses: Rots, swells and burns easily** | **Bridges, houses, two-to-three-story buildings, roller coasters****Example: Son of Beast- Cincinnati, Ohio** |
| Reinforced Concrete | **4** | **4** |  **4.4** |  **6** | **Strengths: Low cost, fireproof and waterproof, molds to any shape, strong in compression and tension****Weaknesses: Can crack as it cools and hardens** | **Bridges, dams, domes, beams and columns in skyscrapers****Example: Hoover Dam** |

1. Note the arrangement of the steel rods in the reinforced concrete and the fibers of the wood. Why were these materials strongest pulled along the rods and fibers? **The rods give it more strength against forces pushing or pulling on it making it stronger than regular concrete.**
2. In your opinion, what would have happened if we would have pulled on the wood/reinforced concrete from the top and bottom instead of the sides? Why? **In my opinion it would be stronger because you are putting force on the surface with more surface tension then the sides.**
3. Click on the unreinforced concrete and perform a tension/compression test. How does adding the steel rods improve the strength of the concrete (and in which mode, tension or compression)? Explain. **The rods are holding the concrete together more tightly making it stronger. It is more stronger when stretched because the rods pull it together tightly.**
4. As noted in the investigation, wood and reinforced concrete are relatively strong and inexpensive. Why don’t we use these particular composite materials to construct aircraft or other transportation vehicles? **Because the metals used on the air plane can withstand better in harsh conditions compared to wood which is very flammable and if it was by an engine it would start to burn causing the plane to be hazardous.**
5. The PBS Forces Lab is a resource designed to show qualitative comparisons between broad material categories. Engineers need accurate material properties to design safe and predictable products. These material properties were measured using stringent testing standards. These properties are published in sources for reference such as MatWeb <http://www.matweb.com>. Use this site or a similar site to find properties of the materials shown below.

|  |  |  |  |
| --- | --- | --- | --- |
| Material | Density or Specific Gravity | Tensile Strength(Yield) | Elongation at Break(if available) |
| Steel(AISI Type S14800 Stainless Steel condition A) | **0.278lb/in^3** | **65300 psi** | **20%** |
| Aluminum(6061-T8) | **0.0975lb/in^3** | **40000 psi** | **8.0%** |
| Plastic(PVC, Extruded) |  **.0485 lb/in^3** | **331 – 8330 psi** | **10.0 – 720 %** |
| Wood(American Sitka Spruce) | **.0134lb/in^3** | **3000 psi** |  |

1. Based on the information from the table rank the material for selection for an aircraft material choice for best strength to weight ratio. Use density as a substitute for weight. Show calculations.

**Psi/density**

**1. Aluminum-40000psi/.0975lb/in^3= 410256.41**

**2. Steel-65300psi/.278lb/in^3= 234892.08**

**3. Wood-3000psi/.597lb/in^3= 223880.597**

**4. Plastic-5250psi/.0485lb/in^3= 108247.42**

**Conclusion**

1. What role does material selection have in aerospace design?

**The material should be chosen that can stretch as well as compress in certain conditions so the plane for example can be as aerodynamic as possible because of aluminum for example is a material with key conditions to work.**

1. Why would an aerospace designer specify an inferior material compared to other materials if both materials meet the design specifications?

**One may just not be practical to apply to a certain area or it may not be as plentiful to find. The cost of it may also affect it so many factors come into choosing a material even though it may meet the design specifications.**