**Objective:** To introduce basic engineering principles, road construction and material science. Students will learn how material properties and strength can be affected. Students will become Civil Engineers by both creating Asphalt cookies and by creating their own asphalt samples in the Rutgers University Center for Advanced Infrastructure and Transportation.

**Day 1:**

**Warm Up:** Name 2 items that you think are in Asphalt.

**Materials:**
* 6-7 Asphalt Samples from Local Highways
* “Asphalt Lab” Worksheet
* “Which Highway???” Worksheet
* “My Road” Homework Sheet
* Magnifying Glasses

**Background:**
Asphalt is a combination of “aggregate” and “binder”. Aggregates are textures rocks and sand-like materials. Aggregates can come in different sized and textures: coarse, fine or very fine. Most aggregates come from nature: crushed rock or gravel for coarse aggregates; natural sand or finely crushed rocks for fine aggregates. Very fine aggregates are called “fillers”. Common fillers are limestone or cement. The binder is the material that holds (binds) the mixture together. Both tar and a substance called bitumen are used as binders. When the binder is heated to 300 degrees F, it turns into a liquid. When it cools it turns into a hard solid mass. Rocks or aggregate are added to the binder to make asphalt stronger. Engineers select and calculate the correct quantities of each rock size needed to produce a strong asphalt pavement. Calculated percentages of the different sizes of rocks are combined to determine the appropriate blend of rock materials. The mixture of rocks and asphalt binder are then compacted and put through a series of tests which smash, stretch, and freeze the pavement to determine the best blend of rocks to use in a certain climate. Different measuring techniques are used in the field than in the laboratory. In the field engineers use huge quantities of each rock size and weigh them.
on scales as large as a garage. In the laboratory, much smaller quantities of each material are needed and ordinary measuring utensils are used.

Procedure:
1) Students will read the background information about what goes into making asphalt and the process.
2) Students will choose a highway or street and create a hypothesis about what they believe goes into making that highway. Students will also state characteristics that their chosen roadway needs on the “Asphalt Lab” Worksheet.
3) The teacher will obtain 6 asphalt samples from local highways. Give one sample to each group. The students will observe each sample and decide which highway they think the sample was taken from. They can use magnifying glasses if necessary to get a closer look. Students will write down their observations as well as their guesses on the “Which Highway???” Homework Sheet.
4) Each group will volunteer to discuss their observations aloud. Each group can compare and contrast their findings with other groups.

Evaluation: Observation of group work and hypothesis creation.

Homework: “My Road” Worksheet

Day 2:

Warm Up: Describe 2 things you saw when observing your road last night.

Materials: Cookie Ingredients for 8 Students
* 1/3 Cup Cocoa Powder or Carob
* 1/2 Cup Milk
* 1/4 Pound Butter (1 Stick = 1/4 Pound)
* 2 Cups Sugar
* 8 Tablespoons Chopped Walnuts In A Plastic Bag
* 8 Tablespoons Flaked Or Shredded Coconut In A Plastic Bag
* 1 Cup Old Fashion Oats In A Plastic Bag
* 1 Cup Quick Cooking Oats In A Plastic Bag

Supplies:
* Medium (2 Quart) Pot Crock Pot Or Other Heat Source

* Extension Cord
* Large Wooden Spoon
* Ladle
* 1/4 Measuring Cup
* 1/8 Measuring Cup
* Tablespoon Measure

For Each Student:

* Steep Sided Bowls or Large Paper Cup
* Sturdy Spoons
* Wax Paper Cut Into 12" squares
* 16 oz. Sealed Can or Rolling Pin

Background: When asphalt is heated it changes from a solid to a sticky liquid. Small rocks are mixed into the asphalt. As the mixture cools the asphalt hardens. This asphalt and rock mixture is much stronger than the original solid asphalt and can be used for paving roads.

Like the asphalt, the chocolate you use in this recipe becomes a liquid when heated. As you mix other tasty ingredients into your "chocolate asphalt" you'll observe the cookies harden and become stronger as they cool.

Procedure:

1) Students will create no bake cookies which models asphalt pavement production.

2) Prepare the "chocolate asphalt" in advance. In a medium size pot combine the cocoa powder, milk, butter and sugar. Heat, stirring frequently until the mixture boils for 2 minutes. Pour into the crock pot set at highest temperature. Yields 2 cups (8 1/4 cup portions). Double or triple as needed.

3) Using the measuring cup and tablespoon, measure the following ingredients and pour them into your mixing bowl or paper cup:
   1/8 cup old fashion oats
   1/8 cup quick oats
   1 tablespoon walnuts
   1 tablespoon coconut

Contributed by: D. Gioffre, Hillsborough Middle School, Hillsborough, NJ 08844
www.engineeringplanet.rutgers.edu
4) Look at the liquid form of the chocolate asphalt in the crock pot. When asphalt binder is heated to 300°F, it is also a liquid. Using the ladle, spoon and measure 1/4 cup chocolate asphalt into the materials mixture.

5) Stir until all of the materials are well coated. Notice - the mixture cools while you stir it, becomes stiffer and starts to stick together. Asphalt behaves in the same manner.

6) When the materials are thoroughly mixed, pour the mixture into a mound on a square of wax paper. Cover with a second piece of wax paper.

7) In the field, the pavement is spread with a paver and then rolled into a thin mat with a roller. The roller is very heavy and pushes all of the air out of the pavement. This helps make the asphalt very strong. Use a can or rolling pin to roll your cookie mixture 1/4"-1/3" thick. Can you still identify the different materials in the cookies?

8) Place your hand over the top of the cookie. Do you feel the heat? When asphalt pavement is first rolled out it is still very hot. Just like the asphalt, the cookies will harden as they cool. (Do you think that the cookies would be as strong if you use less edible materials? More edible materials?) When the cookies have cooled and hardened (20-30 minutes), you can peel off the wax paper and eat.

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Day 3:

**Warm Up:** What was the aggregate in your Asphalt Cookie? What was the Binder?

**Materials:**
* “The Cost of Asphalt” Worksheet

**Background Information:** Give students the task of designing a new road in your town. How long will it be? How wide should it be? How many tons of
asphalt will they need to pave the road? Supply them this formula, given that one square yard of asphalt that is 6 inches deep weighs about 650 pounds:

\[
(\text{Length (in feet)} \times \text{width (in feet)} \div 9 \text{ sq. feet/sq. yd}) \\
\times 650 \text{ pounds/sq. yd} = \text{total pounds}
\]

There are 5,280 feet in a mile. There are 2,000 pounds in a ton. A two-lane road can be anywhere from 24 feet to 40 feet wide. How much does it cost? Assume asphalt costs about $30 per ton.

Procedure:

1) Students will be involved in the task of designing a new road in your town. They will need to decide on a few things before they can do this. Have them fill in the information on the “The Cost of Asphalt” Worksheet.

2) Working in pairs students will decide on a name for their road and decide how long and wide the road will be. They will then need to calculate how many tons of asphalt they will need to pave the road and how much it will cost. Students need to show all of their work in the space provided.

3) After all the pairs have completed the Asphalt Worksheet take volunteers to share what they have decided for their road.

Day 4:

Warm Up: Name 1 local road that you think needs to be milled and Asphalted.

Materials:

* “Design Your Own Highway!!!” Worksheet

* 6-7 Asphalt samples for the students to examine

Background Information:

Different characteristics that the students may want to design for:
**Strength** - (this can be with larger aggregates or stiffer binder or both)

**Noise/Permeability** - (higher permeability = less noise. With a higher permeability, we are also helping to get the water off the roadway surface providing better wet condition surface friction)

**Smoothness** - (using smaller aggregates)

**Location** - (designing for highways, we take into consideration the amount of traffic volume that the pavement will see. Therefore, they can actually design for traffic volume on something like the turnpike or a traffic volume similar to outside their house.)

**Procedure:**

1) Hand out the “Design Your Own Highway!” Worksheet. Read aloud the directions. The students will be working in groups of 4 to create their own asphalt that they will be designing in the Center for Advanced Infrastructure and Transportation at Rutgers University on a field trip.

2) Each group will need to pick a local road or highway and then choose the characteristics that they feel that the roadway should have.

3) Students will work as a group and choose characteristics on the chart according to what they feel their highway needs. Students can observe the Asphalt Samples of all the local highways to gain ideas for their highway.

4) Groups can share their ideas aloud with the class. Students will be bringing their highway ideas to the Rutgers University Center for Advanced Infrastructure and Transportation in order to work with the instruments to assist researchers in concocting the Asphalt.

**Evaluation:** Observation of group work and review of Asphalt ideas.

**Day 5: Field Trip To The Center for Advanced Infrastructure and Transportation at Rutgers University in the Department of Civil and Environmental Engineering**

**Materials:**

* "Design Your Own Highway!!!" Worksheet

**Procedure:**
1) Students will use their information on the "Design Your Own Highway!!!" Worksheet on a field trip to assist Researchers at the Rutgers University Center for Advanced Infrastructure and Transportation to create the Asphalt for their highway and then run tests on it to check for Permeability and Strength.

2) Students will go in three groups of 40 to Rutgers University. Students will run tests, write results for their Asphalt and come up with a conclusion.

**Evaluation:** Observation of Lab work at Rutgers University. Review of results and conclusion.

**Day 6:**

**Warm Up:** What was the most interesting thing you saw at the Center for Advanced Infrastructure and Transportation at Rutgers University yesterday?

**Materials:**

* "Which Highway???” Worksheet

* 6-7 Asphalt Samples

**Procedure:**

1) Discuss the Warm Up question aloud - taking all children's answers.
2) Debrief about Rutgers University Center for Advanced Infrastructure and Transportation Field trip.
3) Students will take out the “Which Highway???” Worksheet. Give them 10 minutes to review their answers from last week and then decide if they still agree with their Sample guesses from last week. They can change their guesses or leave them the same based on their knowledge of Asphalt.
4) Teacher will hold up each sample and have volunteers guess as to what highway they think it is. Describe the characteristics of each and give the correct highway.

**Evaluation:** Observation of understanding and review of group work.
Asphalt is a combination of “aggregate” and “binder”. Aggregates are textures rocks and sand-like materials. Aggregates can come in different sized and textures: coarse, fine or very fine. Most aggregates come from nature: crushed rock or gravel for coarse aggregates; natural sand or finely crushed rocks for fine aggregates. Very fine aggregates are called “fillers”. Common fillers are limestone or cement. The binder is the material that holds (binds) the mixture together. Both tar and a substance called bitumen are used as binders. When the binder is heated to 300 degrees F, it turns into a liquid. When it cools it turns into a hard solid mass. Rocks or aggregate are added to the binder to make asphalt stronger. Engineers select and calculate the correct quantities of each rock size needed to produce a strong asphalt pavement. Calculated percentages of the different sizes of rocks are combined to determine the appropriate blend of rock materials. The mixture of rocks and asphalt binder are then compacted and put through a series of tests, which smash, stretch, and freeze the pavement to determine the best blend of rocks to use in a certain climate. Different measuring techniques are used in the field than in the laboratory. In the field engineers use huge quantities of each rock size and weigh them on scales as large as a garage. In the laboratory, much smaller quantities of each material are needed and ordinary measuring utensils are used.

1. Choose a local highway that you would like to investigate: ______________________________

2. Describe what kind of roadway this is (heavy vehicles, fast cars, a lot of traffic). ____________________________________________________
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________

3. What materials do you think should be put into this highway because of the roadway that you described in question 2? __________________________
Write down your observations in the correct box of each sample and then take a guess as to which highway you think the sample is from. Be very descriptive when explaining the aggregate and the binder.

<table>
<thead>
<tr>
<th>Sample #1</th>
<th>Sample #2</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Which Highway? ___________</td>
<td>Which Highway? ___________</td>
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</tbody>
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<table>
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<tr>
<th>Sample #3</th>
<th>Sample #4</th>
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<tr>
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<td>Which Highway? ___________</td>
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<th>Sample #6</th>
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<tr>
<td></td>
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<tr>
<td>Which Highway? ___________</td>
<td>Which Highway? ___________</td>
</tr>
</tbody>
</table>
Go outside and take a good look at the road you live on. Describe and/or draw what your road looks like below. Be descriptive about the aggregates and the binder. Describe the color and the texture as well. You may write or draw whatever you see below.
Follow the directions to make Asphalt Cookies.
The following instructions for the "chocolate asphalt" will be prepared in advance. In a medium size pot combine the cocoa powder, milk, butter and sugar. Heat, stirring frequently until the mixture boils for 2 minutes. Pour into the crock-pot set at highest temperature.

Students will now:
Using the measuring cup and tablespoon, measure the following ingredients and pour them into your mixing bowl or paper cup:

1/8 cup old fashion oats
1/8 cup quick oats
1 tablespoon walnuts
1 tablespoon coconut

Look at the liquid form of the chocolate asphalt in the crock pot. When asphalt binder is heated to 300° F, it is also a liquid. Using the ladle, spoon and measure 1/4 cup chocolate asphalt into the materials mixture.

Stir until all of the materials are well coated. Notice - the mixture cools while you stir it, becomes stiffer and starts to stick together. Asphalt behaves in the same manner

When the materials are thoroughly mixed, pour the mixture into a mound on a square of wax paper. Cover with a second piece of wax paper.

In the field, the pavement is spread with a paver and then rolled into a thin mat with a roller. The roller is very heavy and pushes all of the air out of the pavement. This helps make the asphalt very strong. Use a can or rolling pin to roll your cookie mixture 1/4"-1/3" thick. Can you still identify the different materials in the cookies? ______________________________

Place your hand over the top of the cookie. Do you feel the heat? ______
When asphalt pavement is first rolled out it is still very hot. Just like the asphalt, the cookies will harden as they cool. Do you think that the cookies
would be as strong if you use less edible materials? More edible materials?

_________________________________________________________

_________________________________________________________

_________________________________________________________

When the cookies have cooled and hardened (20-30 minutes), you can peel off the wax paper and eat.
THE COST OF ASPHALT

You will be designing a new road in your town. Before you do this - you need to decide on a few important things.

Name the road. _________________________________________________

How long will it be? ______________feet

How wide should it be? ______________feet

Use this formula, given that one square yard of asphalt that is 6 inches deep weighs about 650 pounds:

\[
\text{Total pounds} = \left( \frac{\text{Length (in feet)} \times \text{width (in feet)}}{9 \text{ sq. feet/sq. yd}} \right) \times 650 \text{ pounds/sq. yd}
\]

There are 5,280 feet in a mile. There are 2,000 pounds in a ton.

A two-lane road can be anywhere from 24 feet to 40 feet wide.

SHOW ALL YOUR WORK!!!

How many tons of asphalt will they need to pave the road? ___________tons

How much does it cost? (Assume asphalt costs about $30 per ton.)
Design Your Own Highway!

Your team has been hired to lay a new layer of Asphalt on a local roadway. This roadway needs to be both cost efficient as well as appropriate for its conditions. You want to make a good highway at a good price! Below are the characteristics that you need to take into consideration for your roadway! You will be working in the Rutgers Center for Advanced Infrastructure and Transportation to concoct this mixture of aggregates and binders at a later time!

What roadway did the town hire you to lay Asphalt on? ________________

With your group you will be deciding what characteristics your roadway needs to have and what kinds of aggregates and binders you should put into your Asphalt. Circle the characteristics below.
<table>
<thead>
<tr>
<th>Strength</th>
<th>Noise/Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggregates</strong></td>
<td><strong>Binder</strong></td>
</tr>
<tr>
<td>More Strength</td>
<td>VERY STIFF</td>
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<tr>
<td>Large</td>
<td></td>
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<tr>
<td>Medium</td>
<td>STIFF</td>
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<td>LESS STIFF</td>
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<tr>
<td>Small</td>
<td>LESS STIFF</td>
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<td></td>
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<tr>
<td><strong>Smoothness</strong></td>
<td><strong>Location</strong></td>
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<tr>
<td>Smaller Aggregates</td>
<td>HIGH TRAFFIC VOLUME</td>
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<td>High Permeability = Less Noise</td>
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<td>Low Permeability = High Noise</td>
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<td>Smaller Stones</td>
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