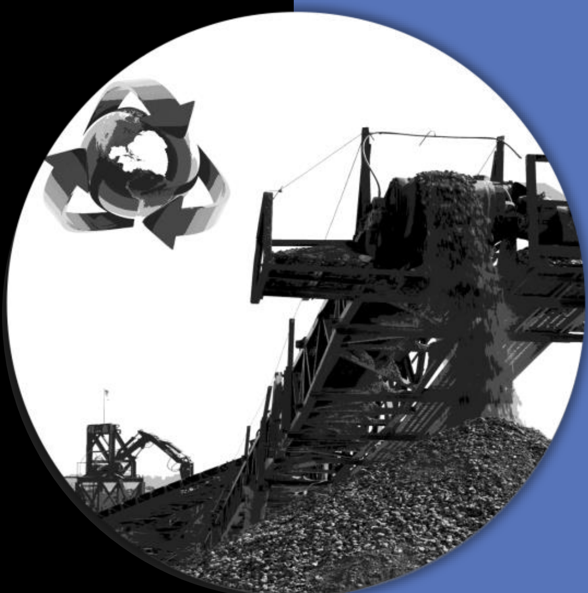
HMEC

Highway Materials Engineering Course

PARTICIPANT WORKBOOK



Evaluating Recycled Materials for Beneficial Uses in Transportation

MODULE

H

U.S.Department of Transportation
Federal Highway Administration

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About This Workbook

This workbook has been developed as a resource for participants. This workbook can be used during the training session to follow along with the instructor and take notes, as well as for reference after the module has ended.

Course Overview

The Federal Highway Administration (FHWA) Highway Materials Engineering Course (HMEC) is a comprehensive multi-week training event that consists of eight content “modules” that provide students with the knowledge to develop materials specifications and guidance, make effective acceptance decisions, and design, construct, and maintain assets with a long service life. Modules range in duration for the number of days they take to complete. The modules are:

- Module A: Quality Assurance
- Module B: Soils and Foundations
- Module C: Steel, Welding, and Coatings
- Module D: Aggregates for Transportation Construction Projects
- Module E: Mechanistic Empirical Pavement Design Guide
- Module F: Asphalt Materials and Paving Mixtures
- Module G: Portland Cement Concrete
- Module H: Evaluating Recycled Materials for Beneficial Uses in Transportation

Introduction

Module H: Evaluating Recycled Materials for Beneficial Uses in Transportation Construction is the eighth and final module in the FHWA HMEC. This module is an emerging area. While recycling has been around for a long time, even in the highway industry, the process for generically evaluating a new product is not well-defined.

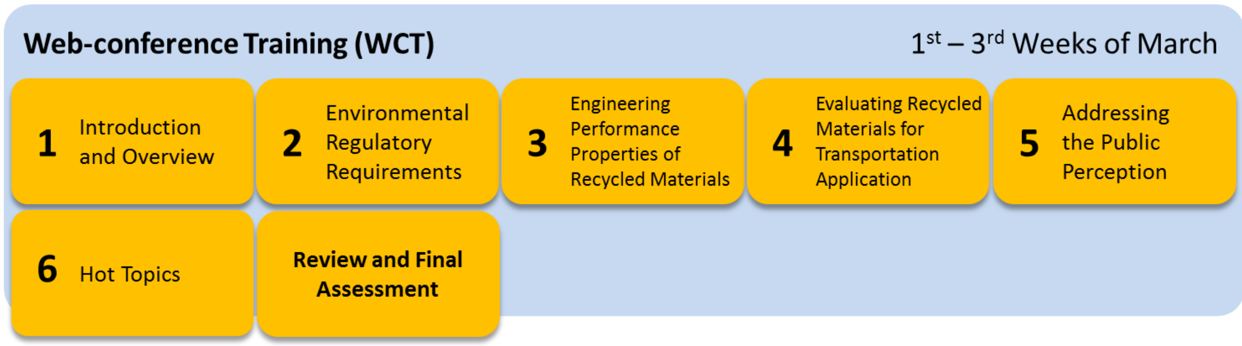
Although a prior version of the course contained a recycling module, Evaluating Recycled Materials for Beneficial Uses in Transportation Construction is a new development. The goal of this module is to convey a process to evaluate potential new materials from both an engineering and environmental perspective as well as to present some success stories of established and emerging recycled materials.

Module H focuses on the process of evaluating recycled materials through the lens of economics, environmental impact, engineering properties, and public opinion. Participants will discuss and review possibilities based upon intended application, or use, of a material. The final outcome is evaluation of a material for a variety of uses, guided by practical, generic processes such as that found in AASHTO PP-56.

Content from the following modules is applied to evaluate properties of various materials and their appropriate uses: Module A: Quality Assurance, especially as applied to specifications, variability, and risk; Module D: Aggregates, especially as applied to their beneficial uses; Module F: Asphalt, including its properties, design, specifications, and requirements; Module G: Portland Cement Concrete (PCC), including recycled aggregates, fly ash, and ground granulated blast-furnace slag (GGBFS).

Module H Overview

Below is a visual overview of all of the lessons covered in this module:



Module Goals

The goals for this module are as follows:

- Identify common variables that drive or hinder the use of recycled materials
- Identify existing and potential opportunities for using recycled materials in transportation applications
- Identify the benefits and challenges of using a variety of recycled materials
- Locate available resources to aid in complying with standard regulatory processes as applied to recycled materials
- Identify appropriate engineering properties, and select the standards to test those properties, for each potential application of recycled materials
- Using a given process, include engineering, environmental, regulatory, processing, and economic considerations to evaluate recycled materials for their suitability in transportation applications
- Address barriers to the use of recycled materials in transportation applications

Learning Outcomes

Lesson 1: Introduction and Overview

- LO 1.1: Identify historical uses of recycled materials
- LO 1.2: Describe the main drivers for deciding to use recycled materials in transportation construction
- LO 1.3: Describe considerations for evaluating the potential for a recycling application
- LO 1.4: Identify common materials that are being currently recycled, and describe the potential benefits and challenges of using them
- LO 1.5: Discuss emerging trends and innovative uses of recycled materials

Lesson 2: Environmental Regulatory Requirements

- LO 2.1: Describe the Federal regulations that govern the use of recycled materials
- LO 2.2: Describe variations in State and local regulations that govern the use of recycled materials
- LO 2.3: Explain the process for determining the applicable guidance when conflicting regulations exist
- LO 2.4: Address traditional practices that can negatively affect environmental sustainability

Lesson 3: Engineering Performance Properties of Recycled Materials

- LO 3.1: Explain how specifications affect the use of recycled materials
- LO 3.2: Relate performance properties of a recycled material to an intended use

- LO 3.3: Evaluate a recycled material to assess its use as a replacement for other materials
- LO 3.4: Evaluate existing specification requirements to determine applicability to an intended use of a recycled material
- LO 3.5: Identify test methods that are appropriate for a variety of recycled materials
- LO 3.6: Describe application standards, such as specifications and best practices, that are available for recycled materials

Lesson 4: Evaluating Recycled Materials for Transportation Applications

- LO 4.1: Assess a variety of materials for their most beneficial application(s) in highway construction
- LO 4.2: Apply the AASHTO R 65 (formerly AASHTO PP 56) process to evaluate recycled materials for transportation applications

Lesson 5: Addressing the Public Perception

- LO 5.1: Identify common real and perceived barriers to the use of recycled materials
- LO 5.2: Develop strategies that address specific concerns over the use of recycled materials

Lesson 6: Analyzing Data

- LO 6.1: Discuss new initiatives, emerging technology, trends, and issues that affect recycling
- LO 6.2: Identify best practices from a variety of effective, in-use DOT programs
- LO 6.3: Address emerging practices that might unintentionally affect environmental sustainability

Adobe Connect Virtual Classroom

The Adobe Connect virtual classroom is open 24 hours per day, 365 days per year. In the classroom, the facilitator and participants may find the following layouts:

Welcome Layout: This layout houses all of the administrative items associated with the module; e.g., file share pods for downloadable files, such as the Participant Workbook and pre-module assignments. This layout will be displayed before and after each session of the module.

Presentation Layout: This layout is used for sharing the slides for each module, keeping track of attendees, and facilitating ongoing chat discussions. It utilizes a variety of pods to perform these functions.

Some example layouts are provided below:

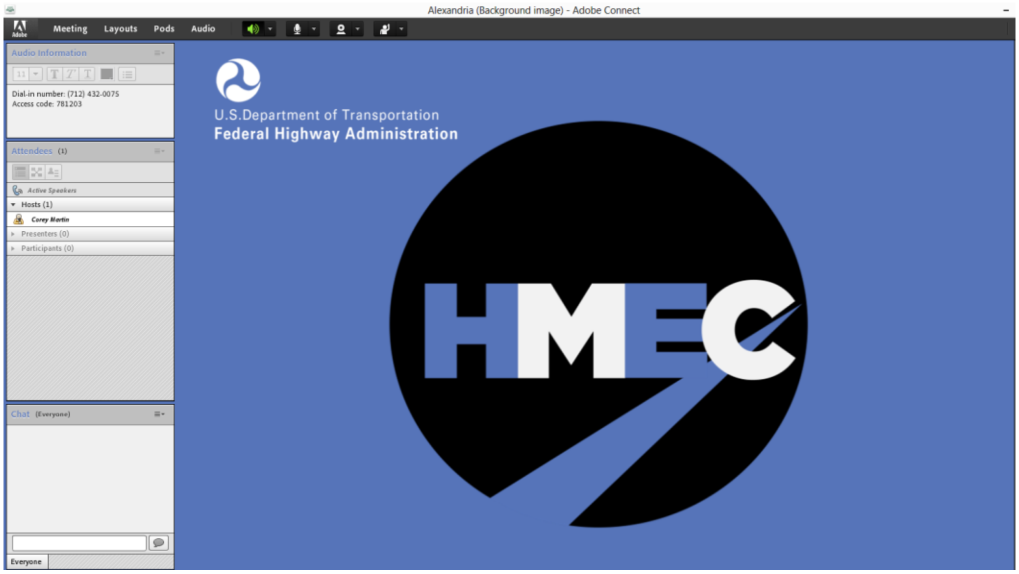


Figure 1: Welcome Layout Screen Shot with Various Pods

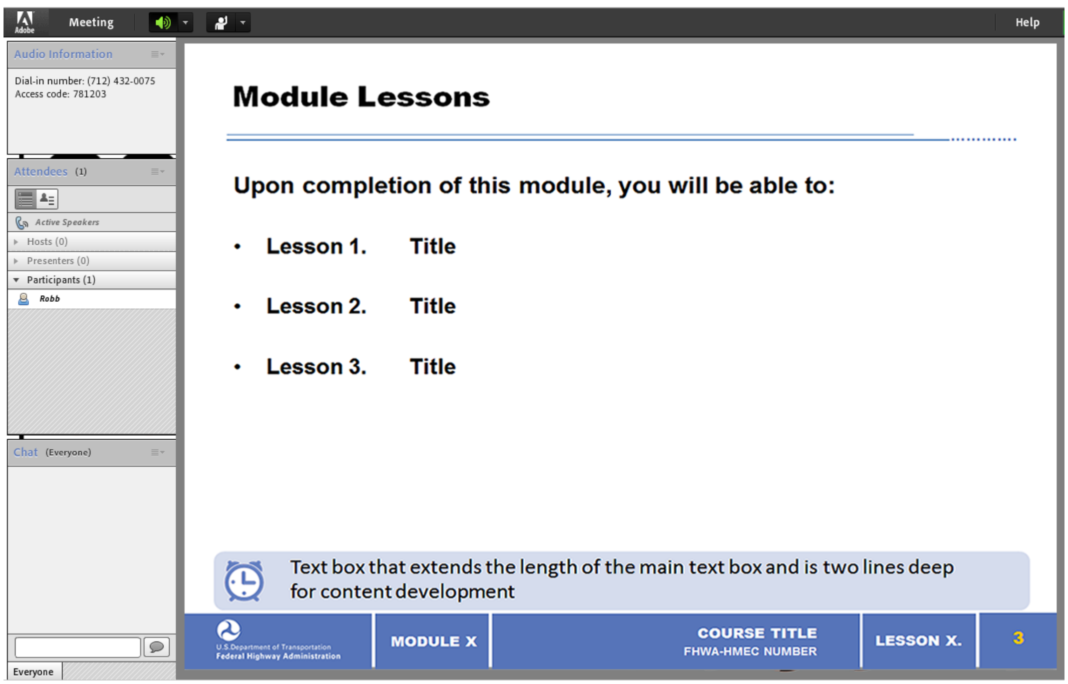


Figure 2: Adobe Connect Presentation Layout

WCT Facilitation Icons

These icons appear on the slides as a cue to the facilitator and learners:

Icon	Icon Name	Typical Use
	Timer	▪ Call out the estimated time for the lesson
	Chat Pod	▪ Ask and answer open-ended question(s). ▪ Post hyperlinks to Web sites. ▪ Provide further information to select attendees. ▪ Encourage attendees to share ideas with each other. ▪ Email contents of the pod.
	Note Pod	▪ Capture discussion points. ▪ Provide a way for small groups to document their results. ▪ Email contents of the pod.
	Whiteboard Tool	▪ Edit illustrations, such as diagrams, charts, documents, maps, and photographs. ▪ Record participant responses. ▪ Create visual examples.
	Poll Pod	▪ Ask multiple-choice questions with one or more correct answers. ▪ Gather opinions, i.e., conduct a survey. ▪ Prioritize a list of text items.
	Web Share Pod	▪ Share new content or resources. ▪ Instruct participants to search for information.

Icon	Icon Name	Typical Use
	Phone Discussion	▪ Facilitate introductions. ▪ Ask and answer verbal questions. ▪ Explain new ideas, concepts, or methods. ▪ Encourage learners to answer each other's questions.
	Breakout Rooms	▪ Assign small-group activities. ▪ Create a customized workspace for each breakout group to differentiate assignments for each group. ▪ Monitor breakout room discussions using chat pod and provide feedback.
	Important Information	▪ Call out important information.
	Q & A	▪ Check for understanding or agreement. ▪ Survey participants. ▪ Solicit feedback.

Slide 1


HMEC
Highway Materials Engineering Course
Lesson 1: Introduction and Overview
Evaluating Recycled Materials for Beneficial Uses in Transportation Construction
U.S.Department of Transportation
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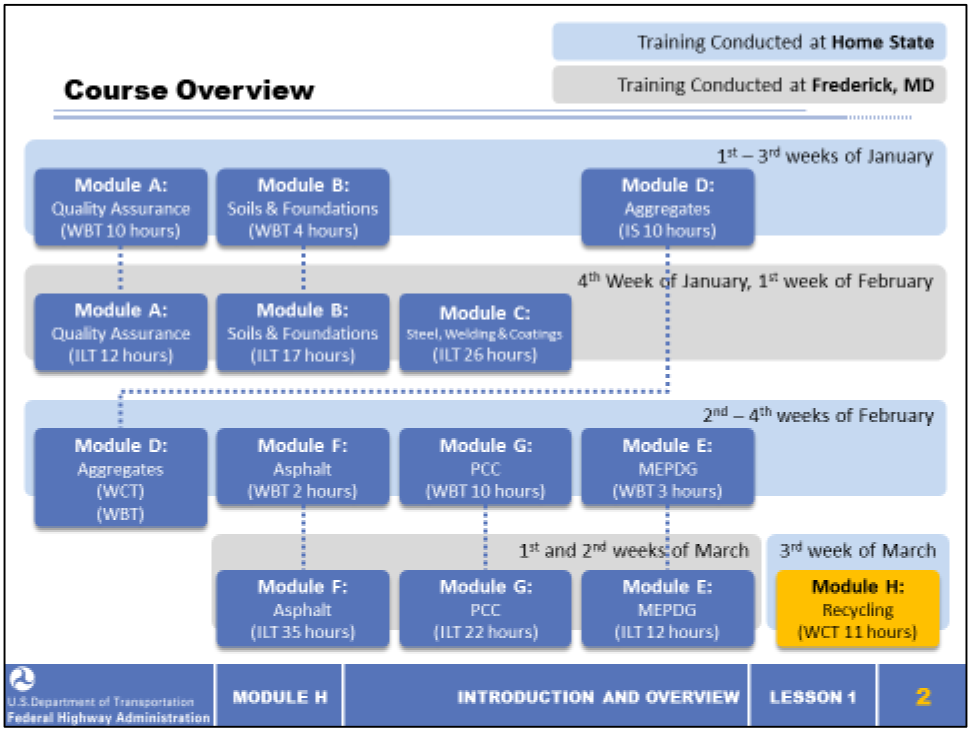
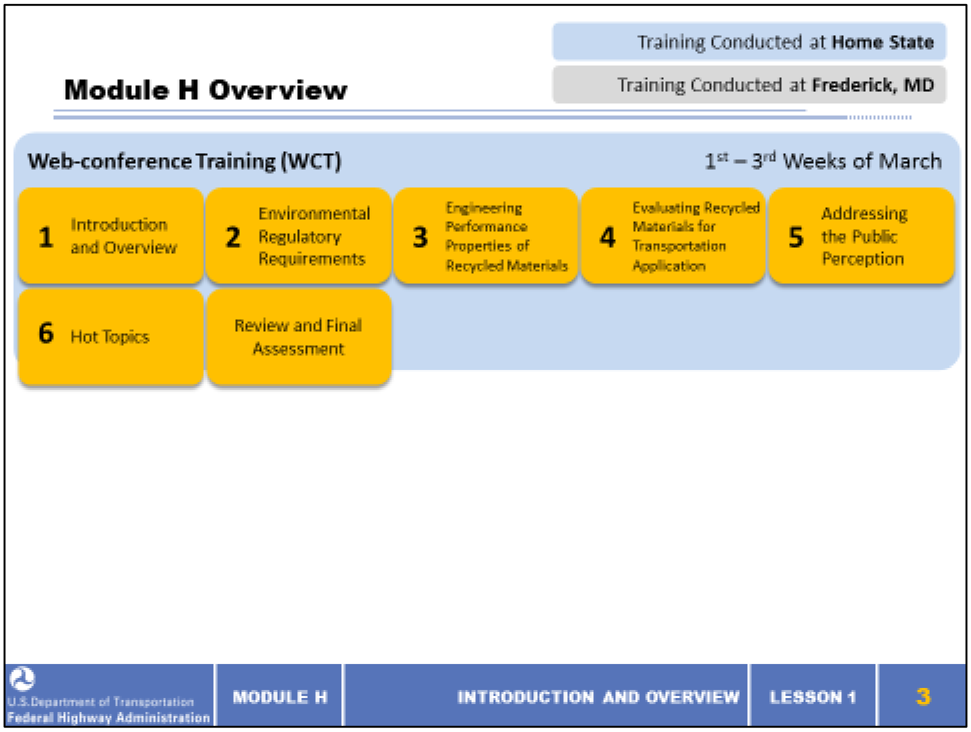
Slide 2



Let’s look at where this module fits within the course.

• Module B – Soils & Foundations: Many recycled materials are used in the construction of embankments including from coal combustion byproducts, shredded tires, and crushed concrete;
• Module C – Steel: Much of the steel manufactured today is derived from recycling existing steel products;
• Module D – Aggregates: Recycled concrete aggregate is commonly used throughout the country in lieu of virgin materials;
• Module E – MEPDG: (Now called DarWin-ME) recognizes the use of recycled materials in pavement structures;
• Module F – Asphalt: The use of reclaimed asphalt pavement (RAP) is a standard practice in most of the country, and the use of shingles is also accepted in many States; and
• Module G – PCC: The use of fly ash and other pozzolans is a common practice in the production of concrete, and crushed concrete is also being used to produce concrete mixtures in some locations.

Slide 3


Training Conducted at Home State
Training Conducted at Frederick, MD
Module H Overview
Web-conference Training (WCT)
1st – 3rd Weeks of March
1 Introduction and Overview
2 Environmental Regulatory Requirements
3 Engineering Performance Properties of Recycled Materials
4 Evaluating Recycled Materials for Transportation Application
5 Addressing the Public Perception
6 Hot Topics
Review and Final Assessment
U.S. Department of Transportation
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INTRODUCTION AND OVERVIEW
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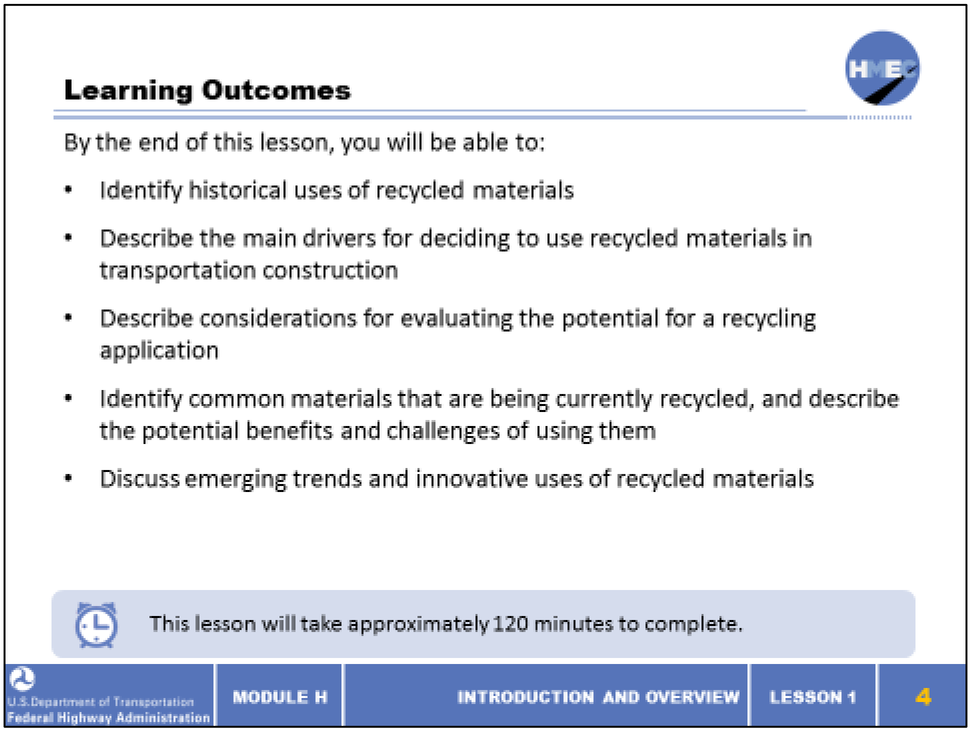
Slide 4


Learning Outcomes
HMEC
By the end of this lesson, you will be able to:
• Identify historical uses of recycled materials
• Describe the main drivers for deciding to use recycled materials in transportation construction
• Describe considerations for evaluating the potential for a recycling application
• Identify common materials that are being currently recycled, and describe the potential benefits and challenges of using them
• Discuss emerging trends and innovative uses of recycled materials
This lesson will take approximately 120 minutes to complete.
U.S. Department of Transportation
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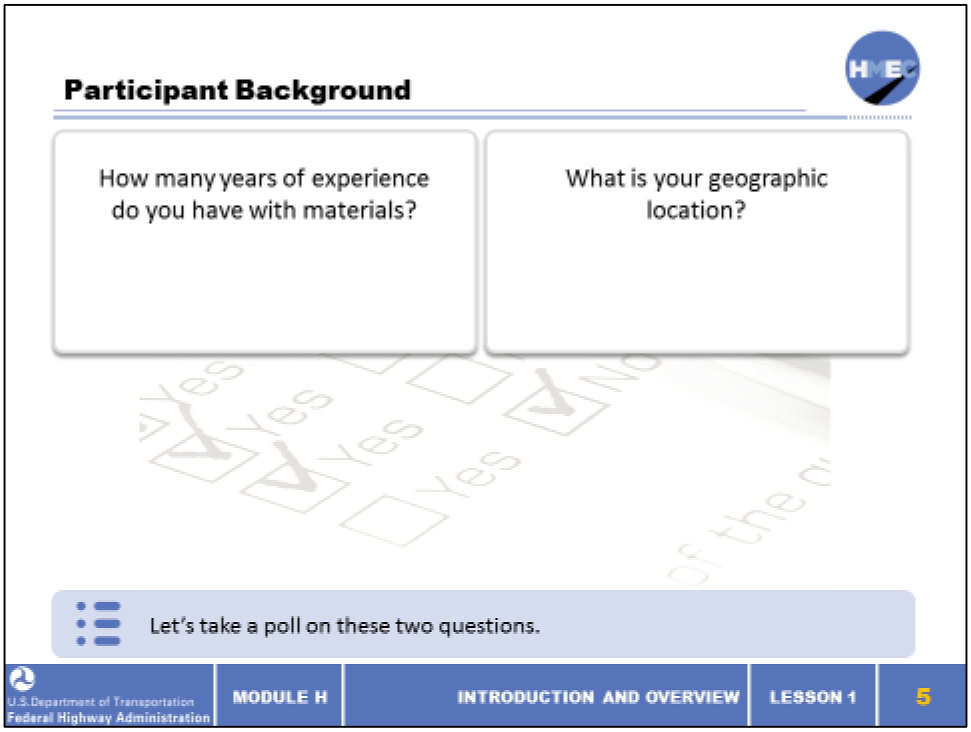
Participant Background
How many years of experience do you have with materials?
What is your geographic location?
Let's take a poll on these two questions.
U.S. Department of Transportation
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INTRODUCTION AND OVERVIEW
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Range of Recycled Materials
THINK GREEN
What is the most unique recycled material and application you have used in your area?
U.S. Department of Transportation
Federal Highway Administration
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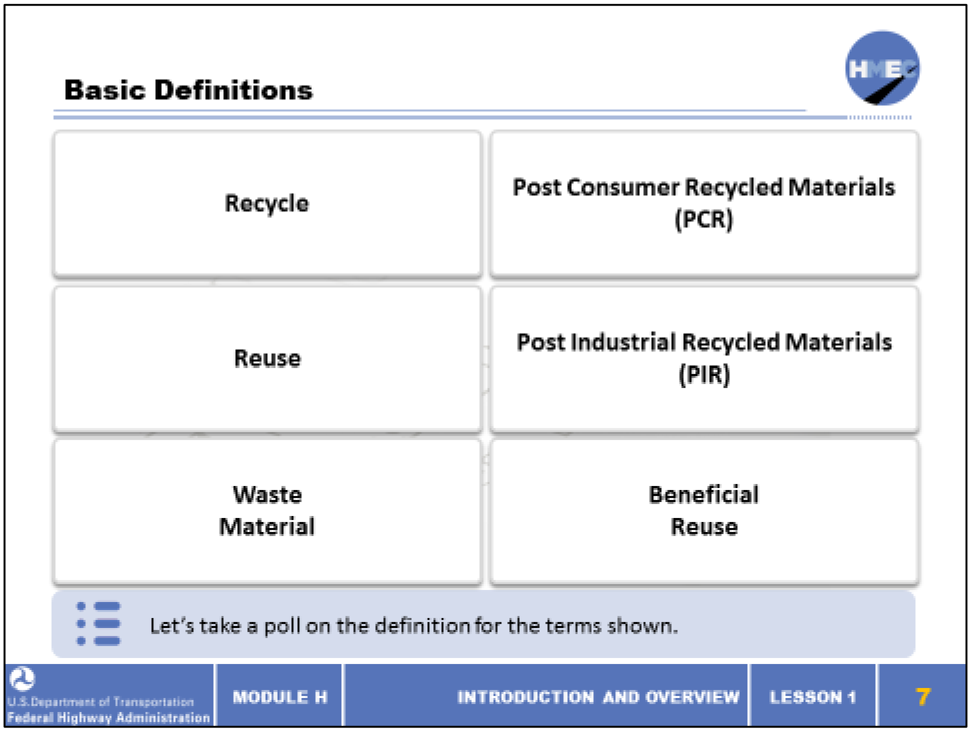
Slide 7


Basic Definitions
Recycle
Post Consumer Recycled Materials (PCR)
Reuse
Post Industrial Recycled Materials (PIR)
Waste Material
Beneficial Reuse
Let's take a poll on the definition for the terms shown.
U.S. Department of Transportation Federal Highway Administration
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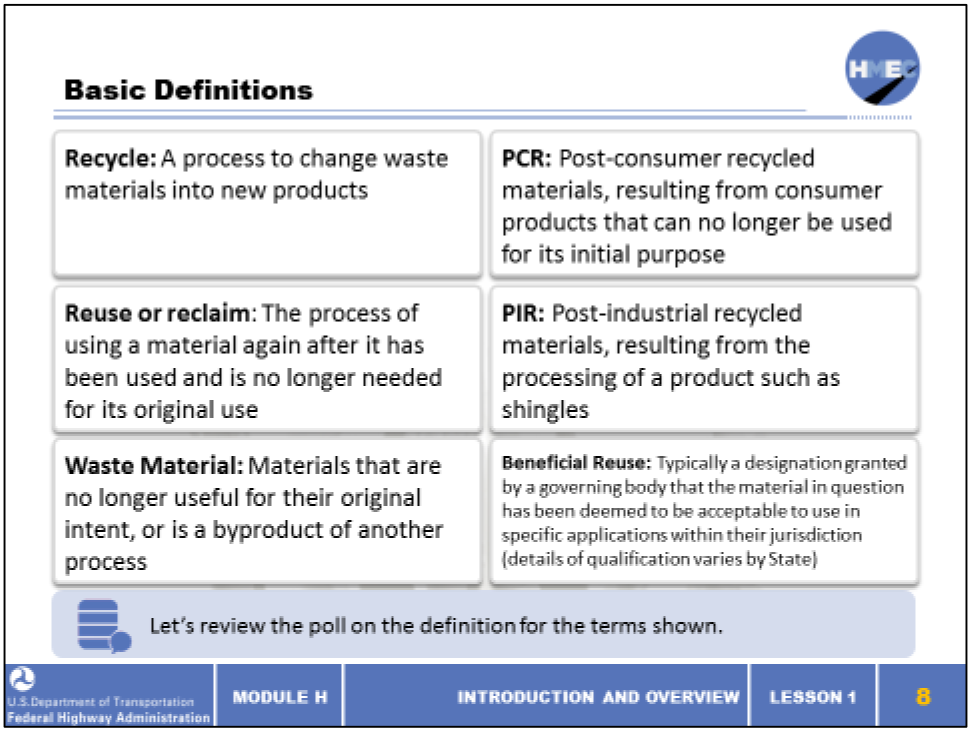

- Recycle: A process to change waste materials into new products;
- Reuse or reclaim: The process of using a material again after it has been used and is no longer needed for its original use;
- Waste Material: Materials that are no longer useful for their original intent, or is a byproduct of another process;
- PCR: Post-consumer recycled materials;
- PIR: Post-industrial recycled materials, resulting from the processing of a product such as shingles; and
- Beneficial Reuse: Typically a designation granted by a governing body that the material in question has been deemed to be acceptable to use in specific applications within their jurisdiction (details of qualification varies by State).

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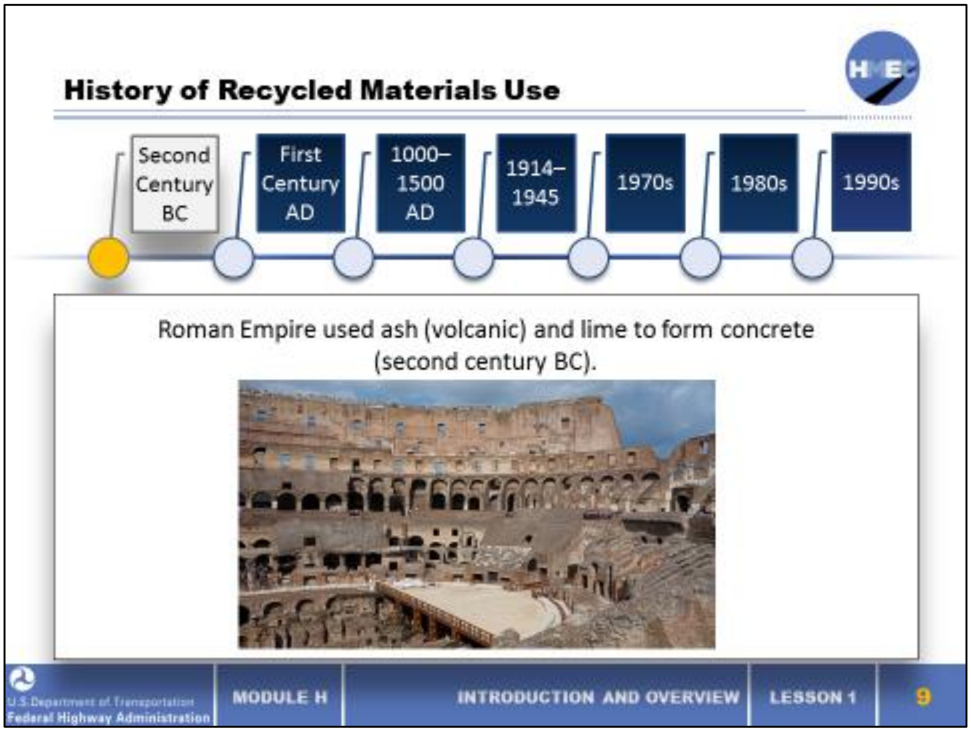
Slide 9



Recycling is not a new concept. Some of the ancient Roman concrete still exists today, so it clearly demonstrates that the use of recycled materials can provide quality materials with a long life cycle.

Recycled materials have been used for approximately 2,000 years. For example, the use of ash dates back to the ancient Roman Empire and some structures still exist.

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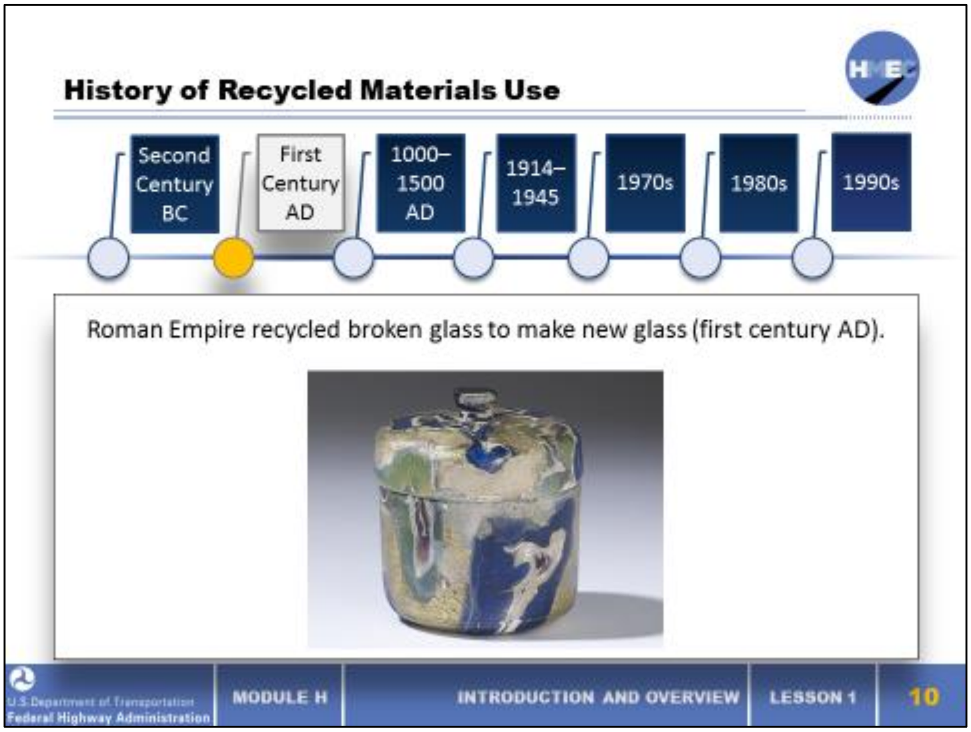
History of Recycled Materials Use
Second Century BC
First Century AD
1000–1500 AD
1914–1945
1970s
1980s
1990s
Roman Empire recycled broken glass to make new glass (first century AD).
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History of Recycled Materials Use
Second Century BC
First Century AD
1000–1500 AD
1914–1945
1970s
1980s
1990s
Vikings melted metal weapons captured in battle forming new objects (first century AD).
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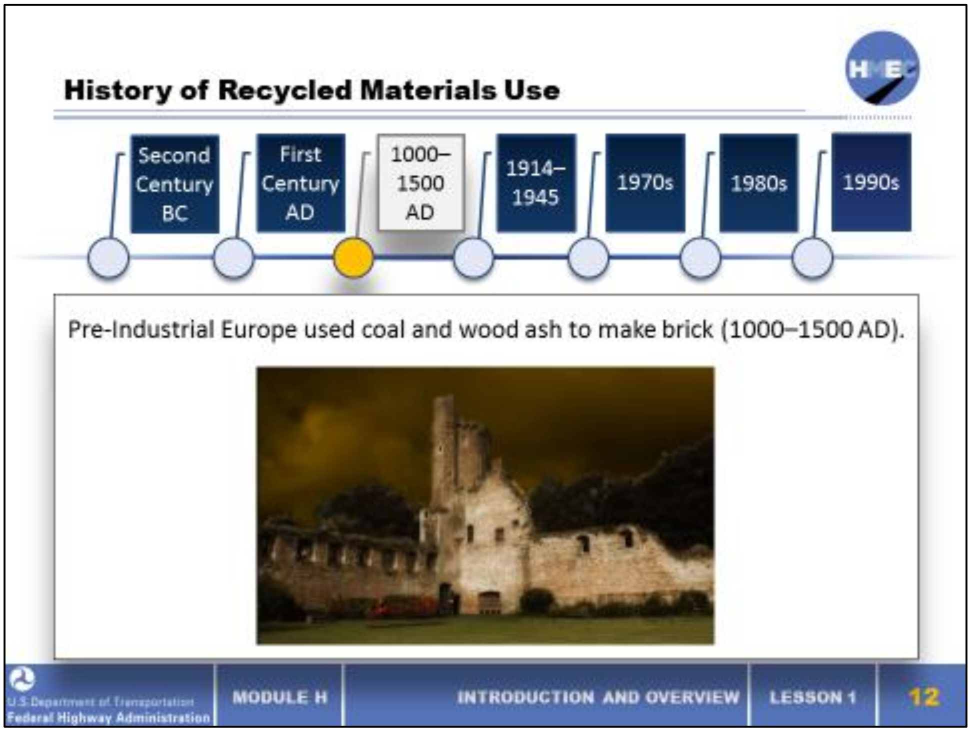

Recycled materials have been used for approximately 2,000 years. For example, the use of ash dates back to the ancient Roman Empire and some structures still exist. Steel and other metals recycling were critical factors during WWII, giving the United States a supply of materials to recycle into ships, tanks, and other items critical to support the war. Recycled paper products are used in the production of mulch and tackifiers for seeding operations to retain moisture that supports plant and grass cover. Slag and mine tailings produced in the 1940s are currently being used as granular fills and other uses depending on quality. Construction and demolition debris is being reclaimed and turned into other uses dramatically reducing demand on landfills and the need to find other waste disposal areas. Recycled glass is commonly used in the production of high-quality glass beads in pavement markings, and most asphalt pavements placed contain 15–40% Reclaimed Asphalt Pavement (RAP), along with reclaimed shingles in some States.

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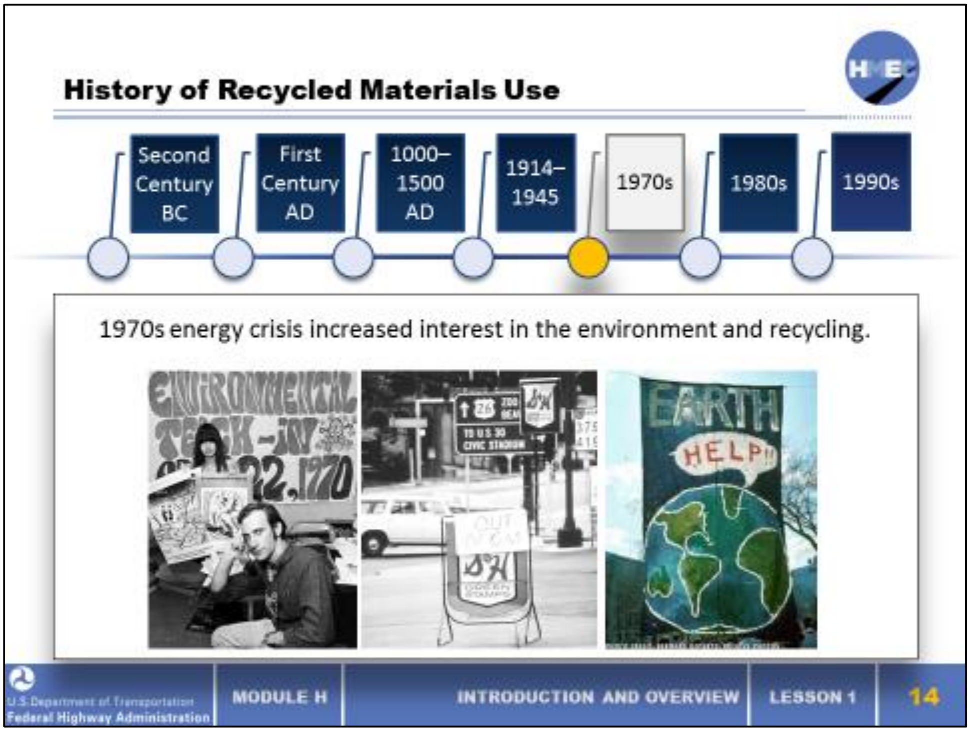
Slide 13

Steel and other metals recycling were critical factors during WWII, giving the United States a supply of materials to recycle into ships, tanks, and other items critical to support the war.

Slide 14



In the '70s, recycled glass was commonly used in the production of high-quality glass beads in pavement markings. Although the first reported use of Reclaimed Asphalt Pavement (RAP) was in 1915, the interest in using RAP began in the late 1970s and peaked during the 1980s.

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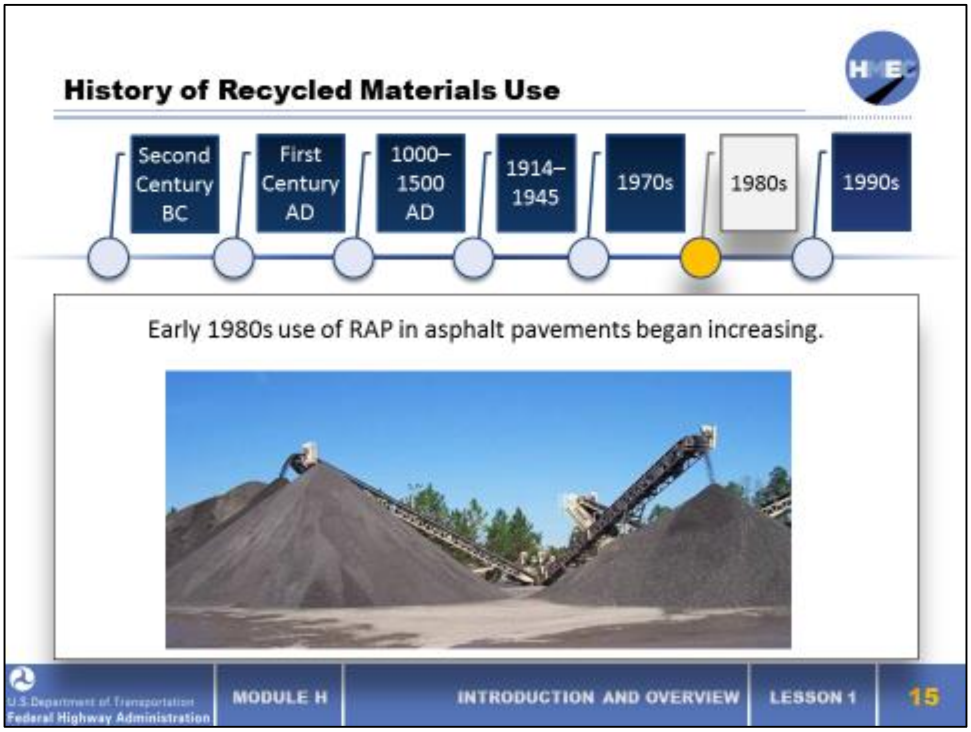
History of Recycled Materials Use
Second Century BC
First Century AD
1000–1500 AD
1914–1945
1970s
1980s
1990s
Early 1980s use of RAP in asphalt pavements began increasing.
U.S. Department of Transportation
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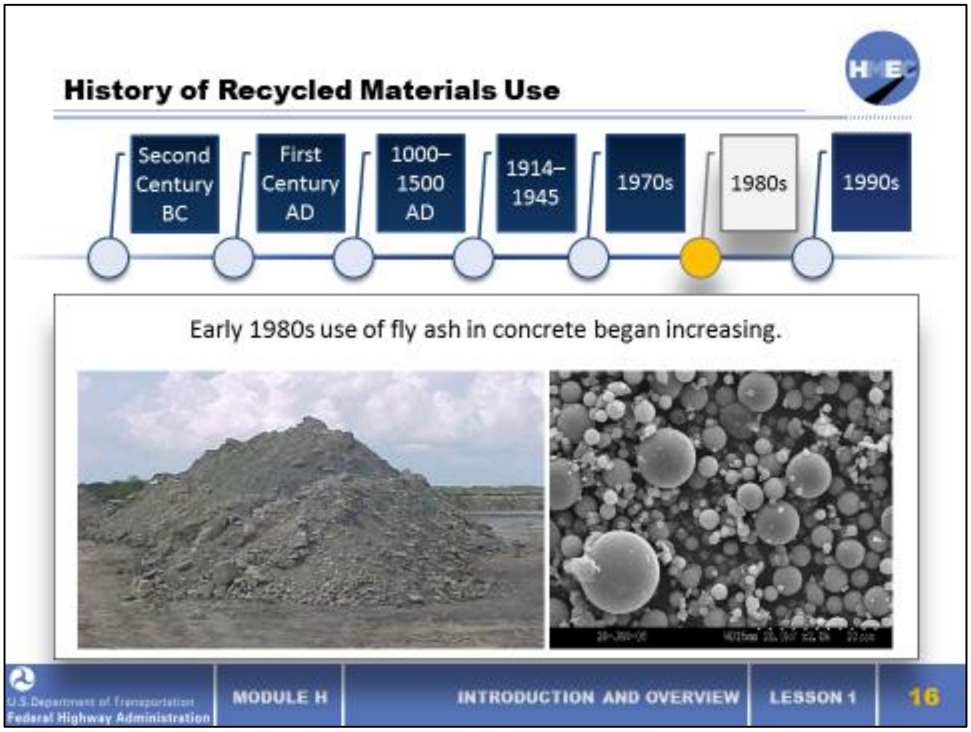
History of Recycled Materials Use
Second Century BC
First Century AD
1000–1500 AD
1914–1945
1970s
1980s
1990s
Early 1980s use of fly ash in concrete began increasing.
U.S. Department of Transportation
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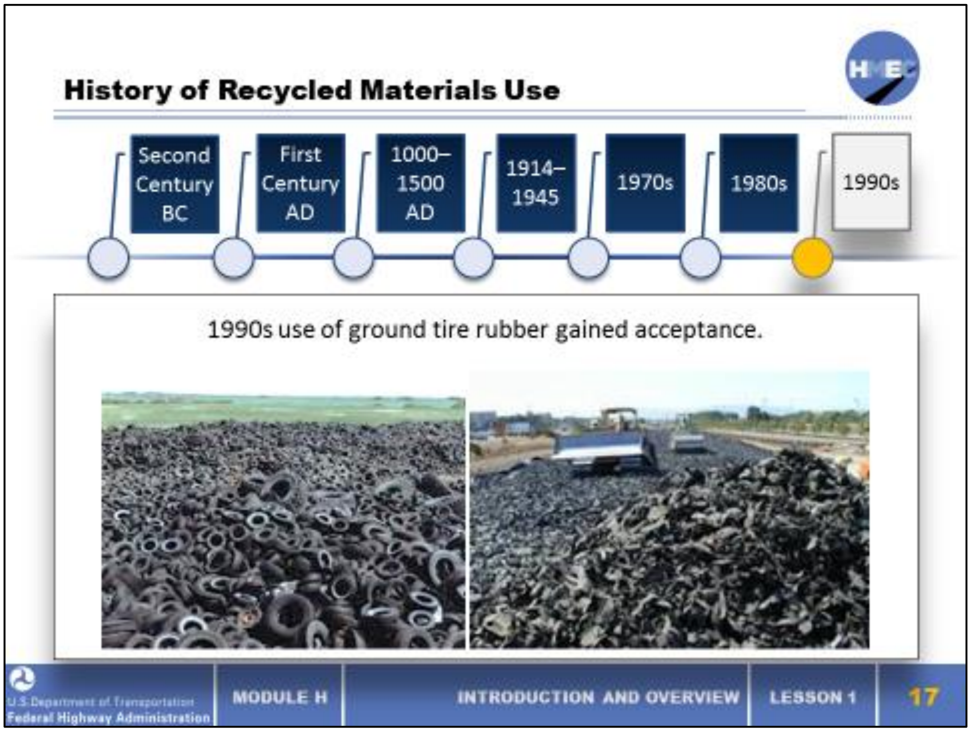

Construction and demolition debris is being reclaimed and recycled, dramatically reducing demand on landfills and the need to find other waste disposal areas.

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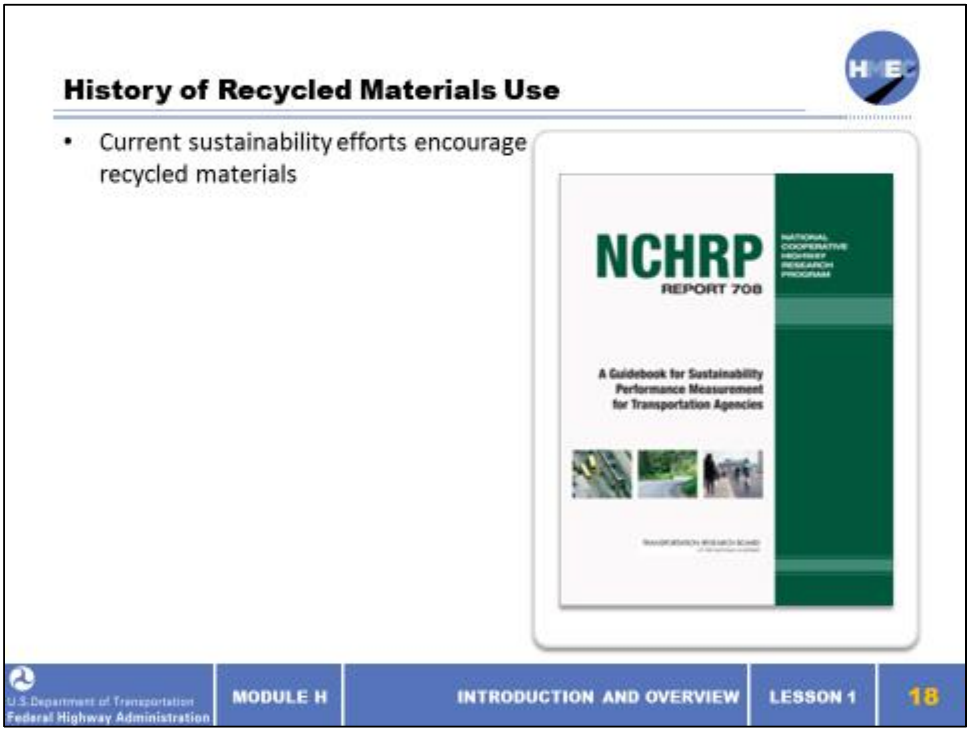

FHWA encourages the use of recycled materials in pavement.

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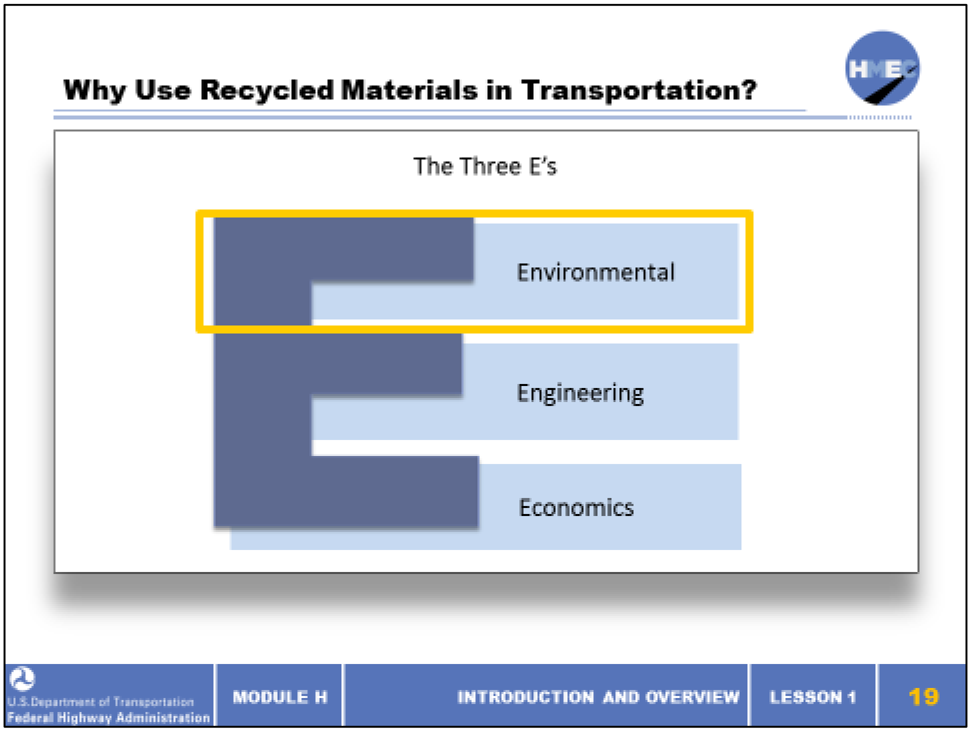

Identify benefits: the three E's (Phrase coined by Cecil Jones, not found in literature other than past presentations). Develop thoughts about the benefits of recycling and the considerations involved in the decision to allow recycled material. The primary areas that should be considered when evaluating whether it is appropriate to use a recycled material are environmental, engineering, and economics.

We'll discuss the environmental perspective first. The environmental perspective must be considered. Some materials may fulfill a need in transportation construction, but if they leach into groundwater, or damage vegetation, the environmental damage would not warrant using the material.

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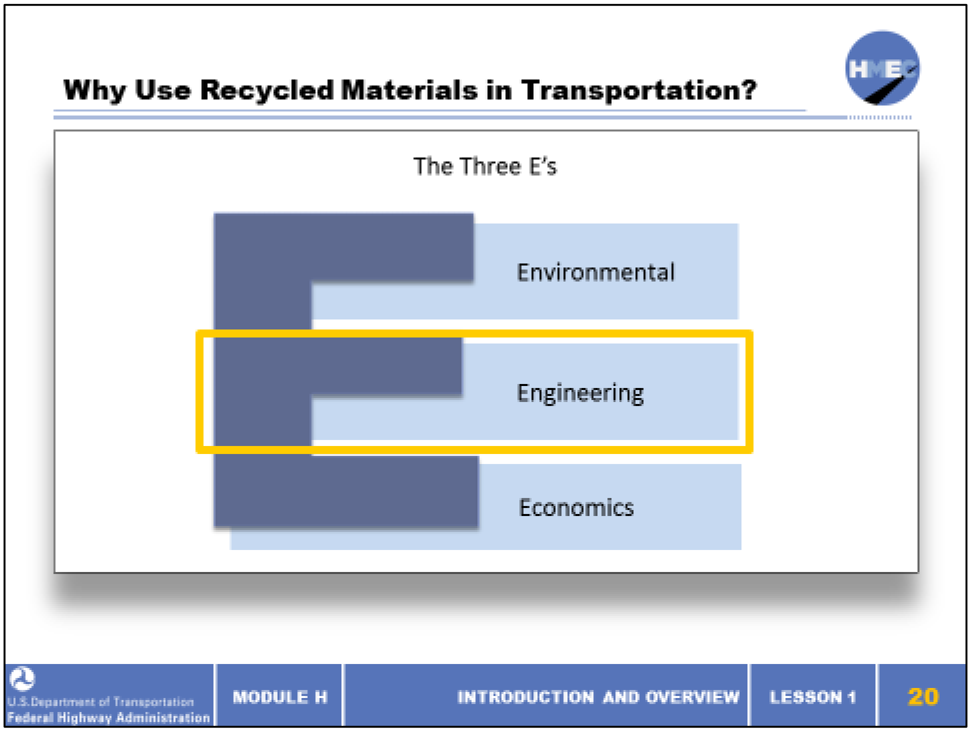

The engineering perspective is a critical consideration. Engineers should not be tempted to build linear landfills under pavements, or devise a way to produce "trashcrete." The engineering need must be met when recycled materials are used, just as they are when virgin materials are used.

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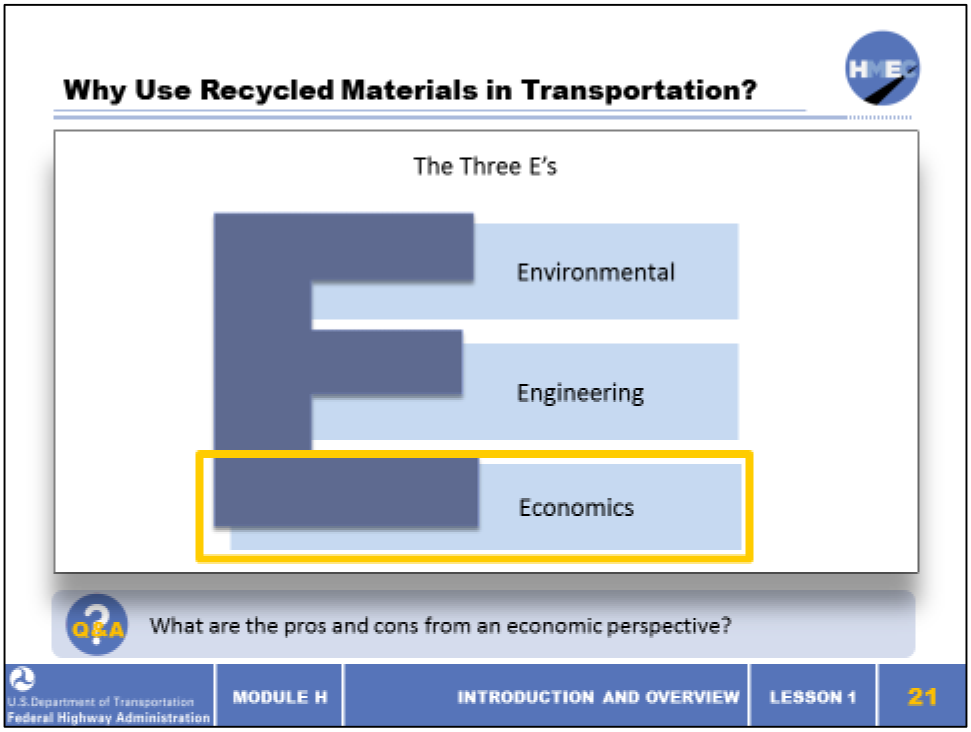

As State agency budgets continue to be challenged, economics must be considered and evaluated, both short term and long term.

Expand the discussion beyond traditionally acceptable recycled materials such as RAP, recycled asphalt shingles (RAS), fly ash, recycled concrete aggregate (RCA), glass beads in traffic markings, etc., and encourage innovation in seeking and being willing to consider other possibilities.

Some of the previously mentioned uses of recycled materials are now commonplace and many do not even think of them as being recycled. Hot mix asphalt (HMA) is the most recycled material in the world, followed by recycled concrete, but many people, even those within State transportation agencies, are not aware of this. Transportation agencies should take steps to educate the public about the extensive use of recycled materials with the nation's transportation network. Subsequent slides contain images about three asphalt pavements. One is a virgin mix (which was hard to find), another using RAP, and another using both RAP and RAS. They look the same, and their performance characteristics are also the same, other than the fact that the RAS provides a stiffer residual binder.

The use of recycled materials in asphalt pavements is a classic case of using a readily available and valuable resource to produce new pavements that meet the economic, environmental, and engineering desires of agencies.

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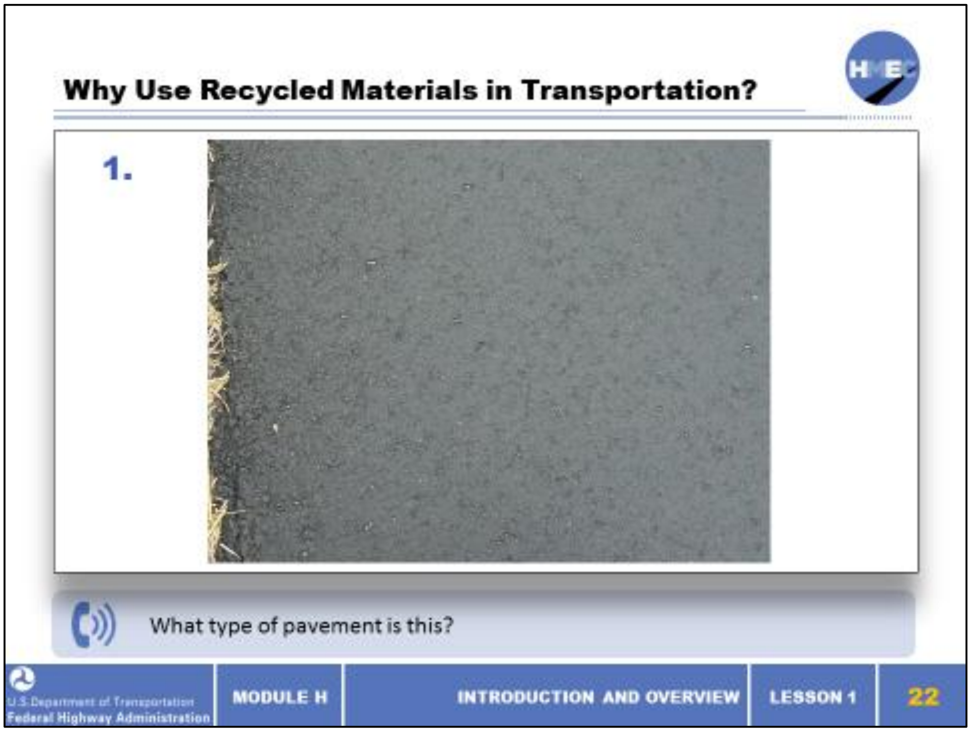
Why Use Recycled Materials in Transportation?
1.
What type of pavement is this?
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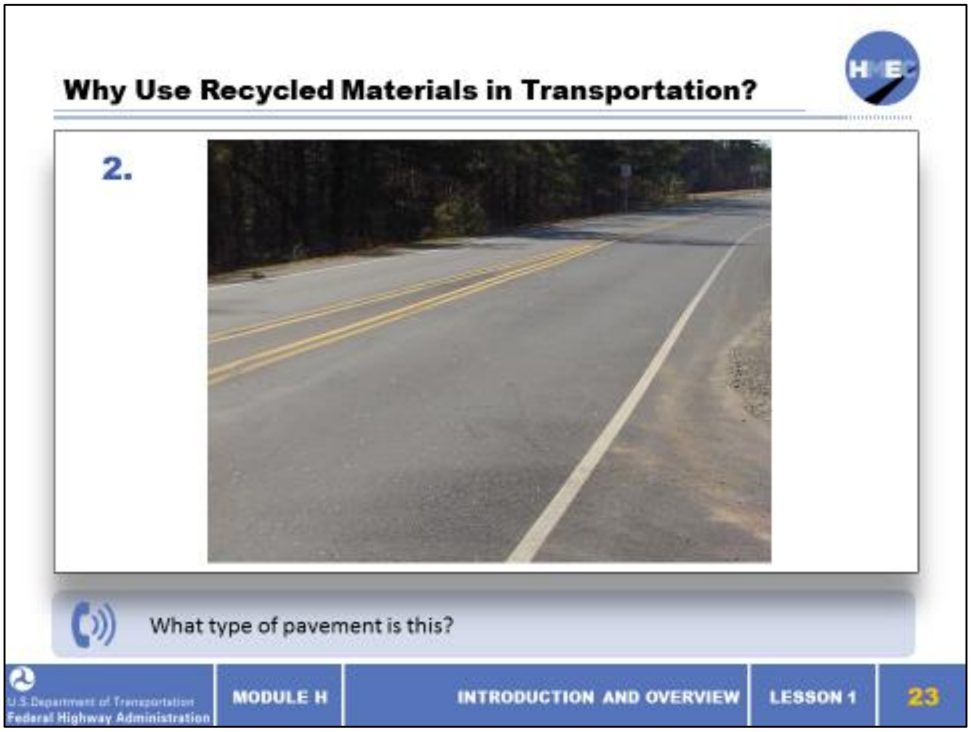
Why Use Recycled Materials in Transportation?
2.
What type of pavement is this?
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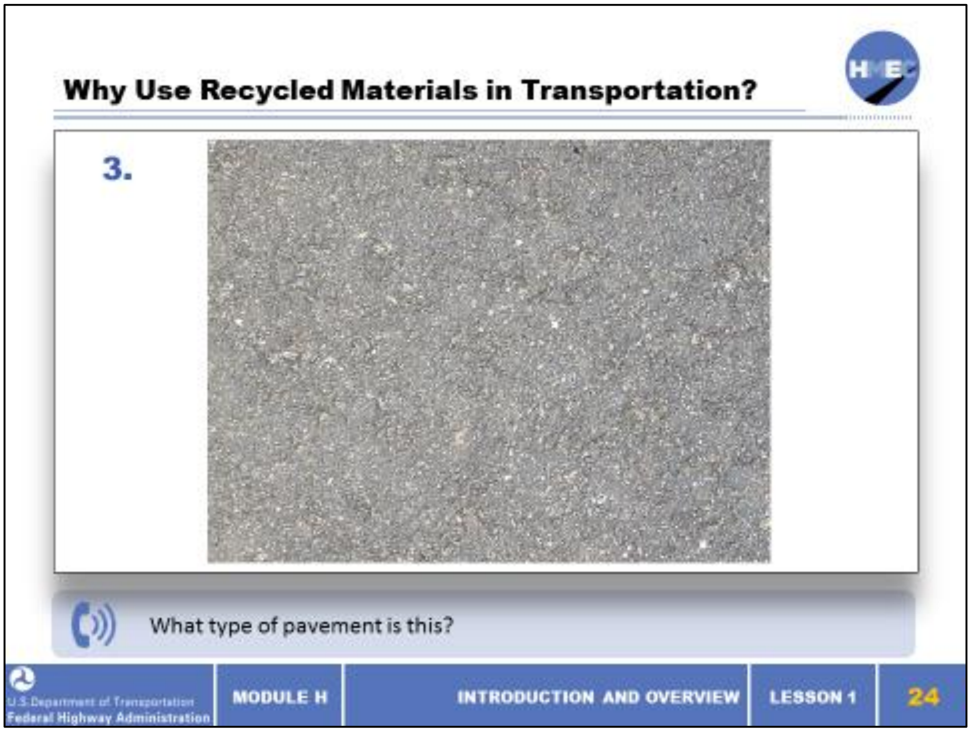
Why Use Recycled Materials in Transportation?
3.
What type of pavement is this?
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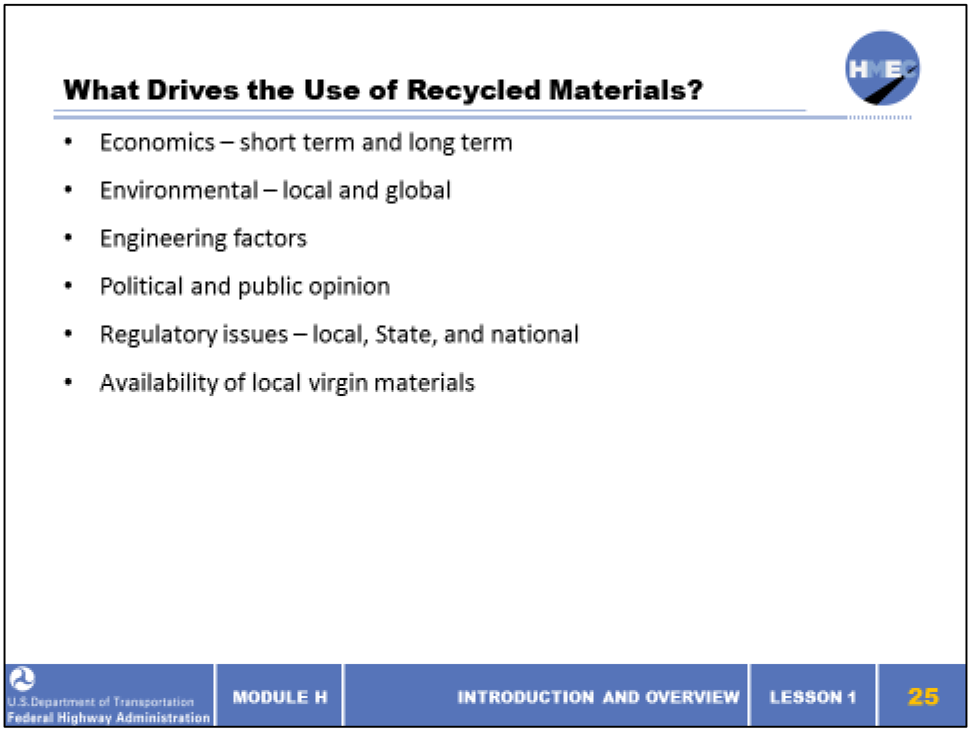

Various factors enter into the resultant use of recycled materials. Let's take an initial look at what drives agencies to make the decision to use recycled materials. The three E's come into play: economics (both short term and long term), environmental issues (both local and global), engineering factors, and political and public opinion, regulatory issues at all governmental levels (local, State, and national), and the availability of local virgin materials.

We need to consider the micro and macro view when considering each of these topics.

For example, with economics, if an initial cost savings is realized by using a particular material that reduces the service life of the product, the long-term cost rises, which may not warrant its use. Likewise, if using a reclaimed material has a higher initial cost and the service life of the product is extended, the higher initial cost might be warranted. When considering environmental issues, we must consider both local considerations on the project site as well as the environmental impact on a more global scale (such as reducing greenhouse gasses). Political and/or public opinion can influence the decision to use recycled materials either in favor of or in opposition to their use beyond the engineering feasibility; this must be built into the decision process. Both local and national regulations, and interpretation of those regulations, must be navigated when considering new uses, and they can at times be in conflict with each other (dueling agencies syndrome). Also, if only a small quantity of a recycled material is available, or if an adequate supply of virgin materials do not exist, the move towards the use of a recycled material varies.

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Economic Drivers for Recycling
What are some factors that influence economics?
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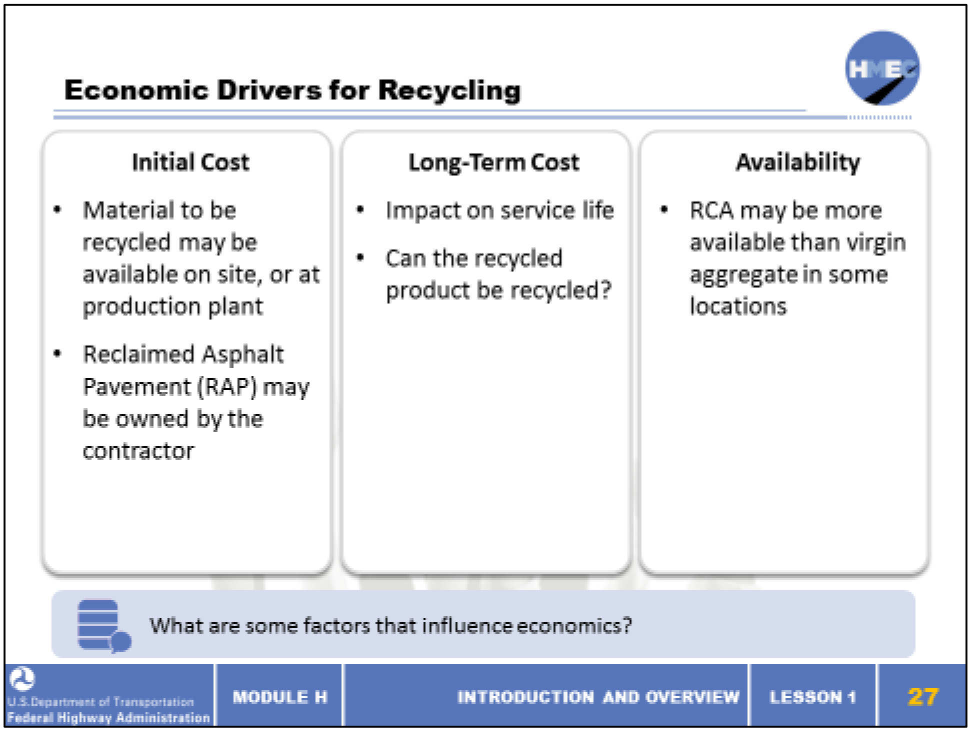

Emphasize the economic considerations, both short term and long term, of using a potential material. Consider if it is available within a reasonable distance and cost. Long transportation distances may rule out the use, as will only having a limited supply of materials to be recycled. Give an example of a producer having limited supply of foundry sand available (approximately 6 tons per year). Because that is less than one truckload annually, it is not economical for a contractor to modify his process in any way for such a low volume.

The impact on service life needs to be given consideration. If a recycled material influences the service life of the final product, it can swing the economics in either direction and influence the decision to use. In the case of fly ash in concrete, it both reduces the initial cost and increases the service life of the concrete, making it a win-win on the economic front. Another point to consider is if the recycled product can be recycled at the end of its service life. Asphalt pavements containing RAP can be recycled again once it has reached the end of its service life, thereby continuing the economic benefits initially realized. (Note that this was a big question in the early days of using RAP and some States were reluctant to move forward with the use of RAP until research and field performance proved the long-term benefit). This may not be true with all recycled materials, but it needs to be considered.

Point out that in some areas of the country, quality aggregates are not readily available, making recycled aggregates the only, or at least the most economical, option. Examples include parts of Florida, Texas, and large metropolitan areas such as New York City.

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Slide 28

Recycling reduces the demand for natural materials, such as virgin aggregates, potentially reducing the energy required in their production. Using recycled materials, such as foundry sand in concrete, can encapsulate heavy metals and preclude leaching potential. The use of RAP, RAS, and RCA have resulted in significant reduction in the amount of quality materials being buried on project sites or taken to landfills.

Give an example of a discussion with a roofing contractor prior to PCR shingles being allowed for use in asphalt pavements. When asking the contractor about what he was doing with the shingles removed from the roof, he advised they were going to the landfill and his price obviously included the tipping fee for doing so. I asked him if he would be willing to separate shingles from other waste if there was a market to reuse and the response was yes. Now they are allowed, so the volume of shingles going to the landfill has reduced.

The image on the slide is the process of removing, crushing, and sizing an old concrete pavement to produce RCA that meets the specifications for a base course material. Transportation costs are eliminated and quality aggregates are produced for the base course.

Both local and global environmental impacts must be considered and evaluated. A short-term impact on the project, such as increased setting time of concrete with fly ash, does raise an initial issue but each ton of fly ash used in lieu of cement reduces the carbon footprint an approximately equal amount. In some instances, these short-term impacts can be mitigated, such as using admixtures to overcome the increased setting time of concrete with fly ash.

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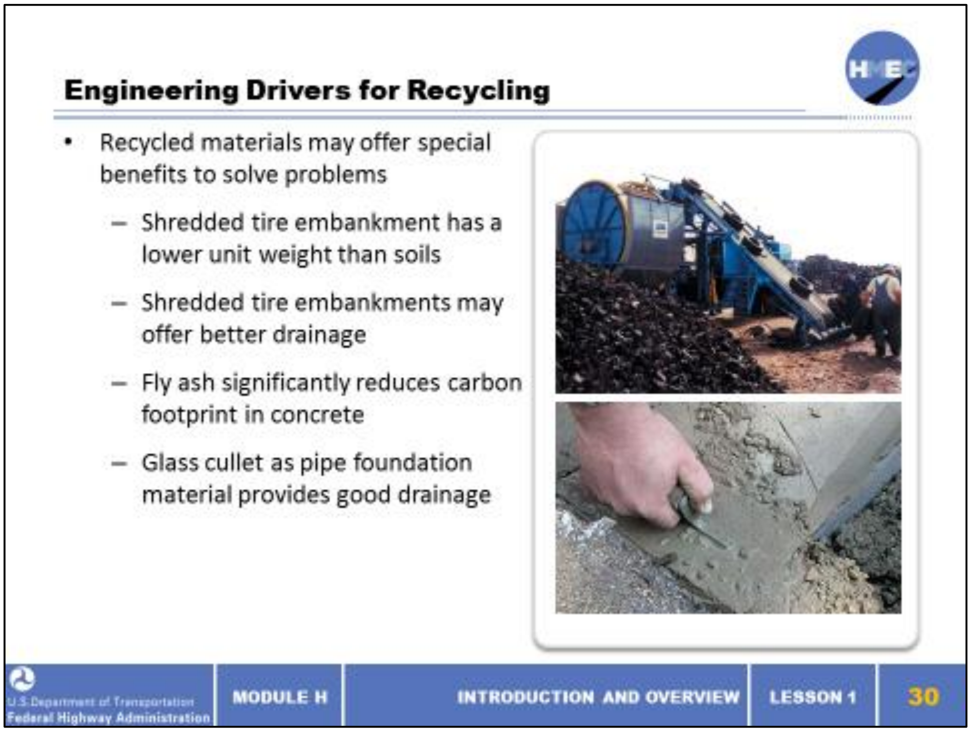
Slide 29

The perception may exist in some areas that using recycled materials somehow results in a lesser-quality finished product and that their use negatively impacts the service life of the final product. Recycled materials should perform equal to, or better than, virgin materials. Many examples exist, such as the use of pozzolans in concrete that can improve permeability, mitigate alkali-silica reactivity (ASR), and reduce the corrosion potential of embedded reinforcing steel. In addition, significant reduction in greenhouse gasses is associated with the replacement of cement with fly ash in a concrete mixture.

RCA as an aggregate produces a higher strength base course material. FHWA has issued a report on RCA that acknowledges that the angularity of RCA does help increase the structural strength in the base, resulting in improved load-carrying capacity. RCA is a good crushed material with excellent interlock between particles. This report also acknowledges that research from two States that found the residual cementitious materials in RCA provide improved strength.

Slide 30



The solution to a performance or design issue may be able to be resolved by the use of recycled materials. Using shredded tires in a properly constructed embankment has a lower unit weight than most soils, which can benefit some situations. One example was on a widening project with a high fill and a culvert needed to be extended to accommodate the widening. The initial culvert design had thinner sections at the ends under the slope and the widening project would require the end portions of the culvert to be removed and replaced to support the weight of the widened embankment. A lightweight embankment using shredded tires allowed the existing culvert sections to remain in place, resulting in a reduction in both cost and construction time. Shredded tire embankments may also offer better drainage characteristics. As noted previously, the use of fly ash in concrete has a significant impact on durability and reduces the carbon footprint of the concrete.

Slide 31

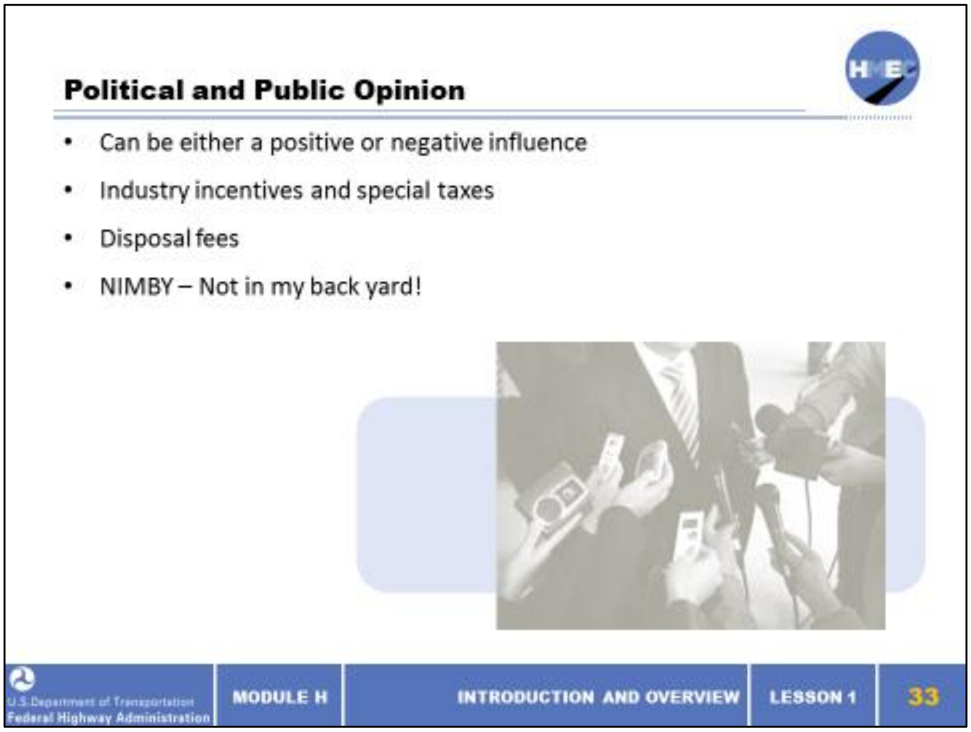
The addition of pozzolans to concrete allow the agency to design the concrete mixture to meet the durability requirements of the member being designed and constructed. For instance, concrete in harsh coastal environments or in areas with a high use of deicing salts can be designed to be more resistant to the penetration of chlorine ion migration, thereby reducing the corrosion potential of the reinforcing steel. The result is a longer lasting and better performing structure. This is not a one-size-fits-all solution as different exposure conditions may warrant different mix designs to meet the performance requirements of the member.

Reinforce the thought that the act of recycling a material, such as asphalt pavements or concrete elements does not impact the quality of the aggregates. Good aggregates remain good aggregates in most cases, and given the difficulty in permitting or even expanding existing quarries, the recycled aggregates may be better and more readily available.

Slide 32

This is an example of a project on I-95 in South Carolina that recycled an existing concrete pavement back into the base and the concrete mixture itself when widened from four lanes to a six-lane facility. Can you tell which is the recycled concrete lane? The pavement is approximately 10 years old now and is still performing well with no noticeable quality differential.

Slide 33



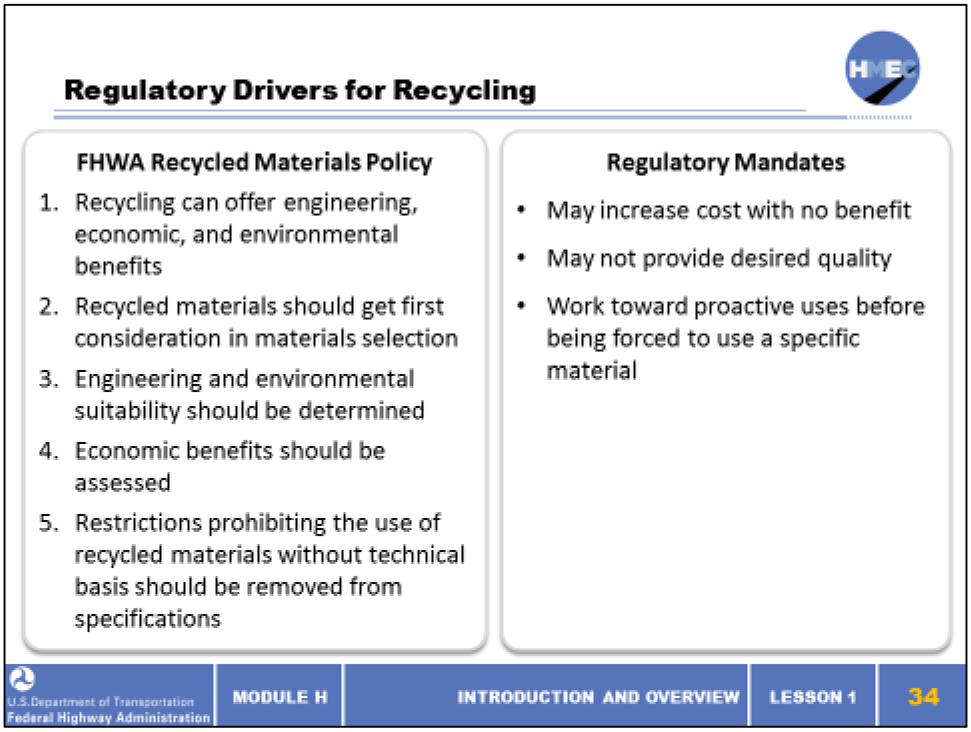
Perception, both positive and negative, can influence whether recycled materials are used in a particular area. Local industries may receive incentives from local governing bodies to support employment, resulting in “strong encouragement” to assist that industry in utilizing byproducts—whether or not they meet the three E’s. How should transportation agencies respond? One example is a Christmas tree ornament manufacturer in a small rural town had considerable waste from broken ornaments after coating the inside with chromium. DOT was encouraged to find a way to use the thin, broken shards. Ultimately DOT was unable to use them because of heavy metal leaching possibility and bonding issues with the glass if put into a pavement.

Another example with a different, and more positive end result, was a State levying a tax on the purchase of new tires. The funds were used to clean up stockpiles of used tires and were ultimately reused as tire-derived aggregates.

Municipally owned landfills charge tipping fees that are not realized if a significant portion of the waste stream is diverted because of a new use for a considerable quantity of materials.

NIMBY mentality, whether realistic or not, can become a factor when some recycled materials are used. Unfortunately, fly ash use in concrete is getting attention currently because of several recent ash pond spills that contaminated waterways when failures in the storage facilities occurred.

Slide 34



State the FHWA recycling policy and discuss its facets. The policy is proactive and encourages agencies to give recycled materials first consideration provided that the engineering and environmental suitability are appropriate. The policy also encourages agencies to remove restrictions, prohibiting the use of recycled materials.

Sometimes regulations may mandate the use of a material due to “external influencing factors” without due consideration of the three E’s. This can possibly increase costs with no performance benefit and possibly a reduction in quality. Agencies should work toward a proactive approach to the use of recycled materials before being forced to use specific materials through legislation.

Discuss the benefits of being proactive and seeking uses of recycled materials after evaluating the three E’s. Give the example of the early 1990s when legislative bodies mandated the use of certain materials without good science with mixed success (legislation subsequently removed). Challenge participants to be active and seek proactive ways to effectively use recycled materials rather than waiting for mandates.

Regulatory influences on recycling can be either positive or negative. Positive guidance like the FHWA Recycled Materials Policy (February 7, 2002) encourages the appropriate use of recycled materials considering the environmental, engineering, and economic potential of the materials being considered. Other types of restrictions or mandates take the evaluation aspect out of the hands of the transportation agency. Such restrictions and mandates prevent agency engineers from being allowed to make sound engineering decisions about what is best for their transportation network.

Link to FHWA Recycled Materials Policy:
http://www.fhwa.dot.gov/legsregs/directives/policy/recmatmemo.htm

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Slide 35

Special funds to clean up waste may result in available recycled materials to meet an engineering need. DOT may not benefit from the collection of fees in the aforementioned tire example, but may benefit in having an available supply of lightweight fill material. A location with a large foundry may benefit from the locally available foundry sand to meet specific needs that may result in a cost savings to both DOT and the community due to the material not being wasted or sent to a landfill.

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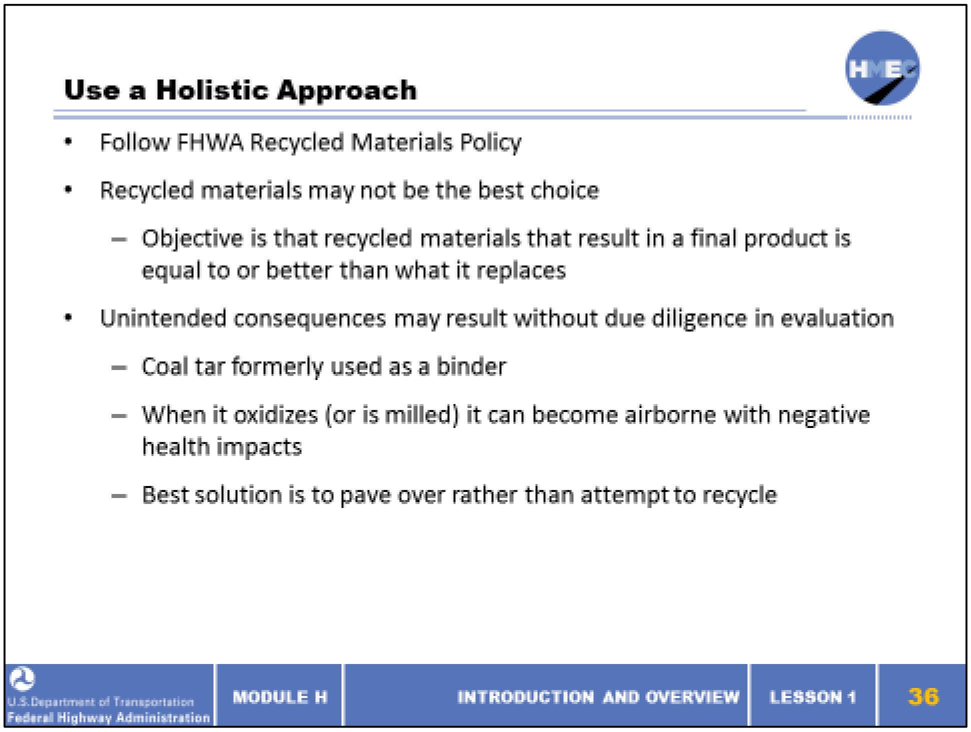
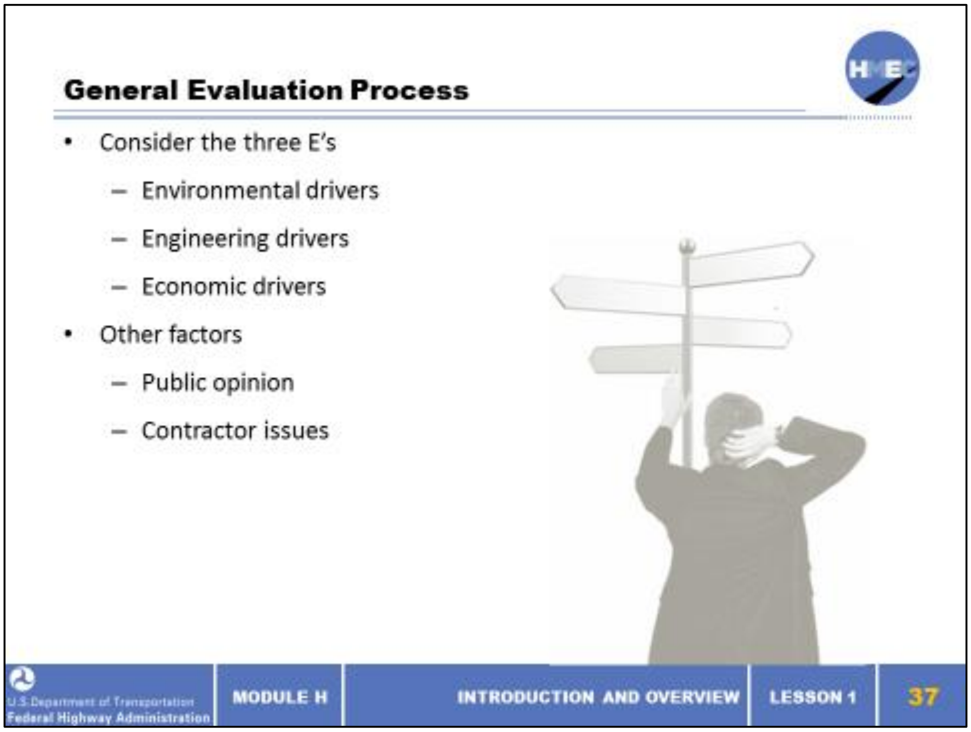
Slide 36



Back to the points of the FHWA Recycled Materials Policy, consider the three E's when evaluating recycled materials. Consider the "big picture" when evaluating potential materials and uses. Use the FHWA Recycled Materials Policy as a guide, remembering that the goal is to have recycled materials that result in a final product equal to or better than what it replaces.

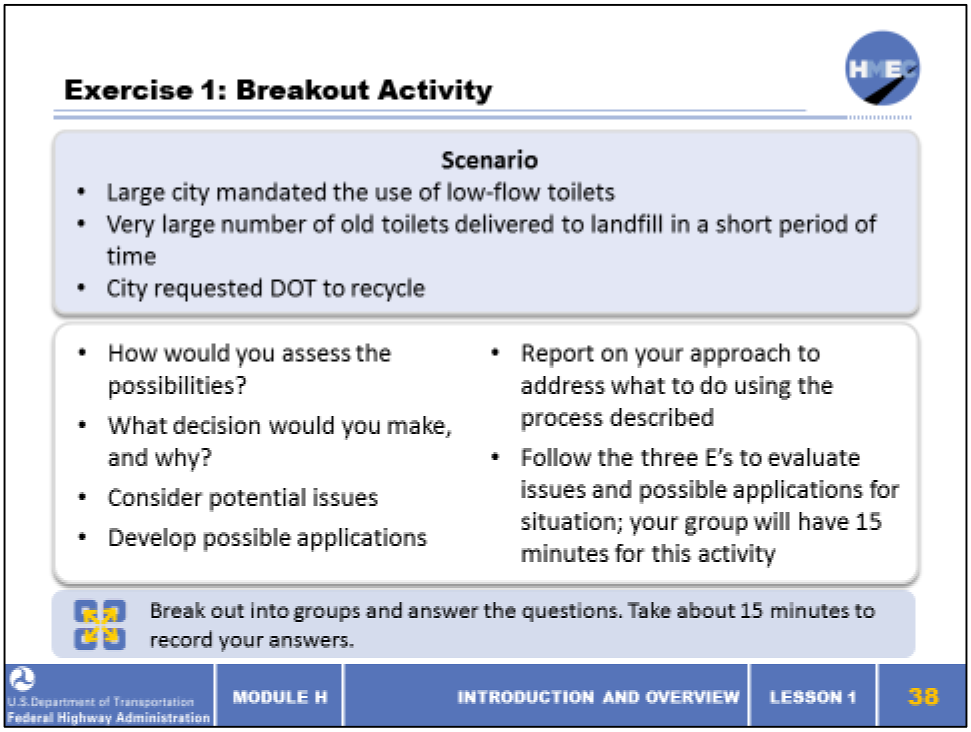
Recycled materials are not always the best choice and evaluation should consider both short-term and long-term performance. For instance, at the end of its service life, how does it need to be treated? Ideally it can be recycled again, but if it has to be covered or removed and wasted it may be better not to have used initially. This was the case on the use of coal tar being used as a binder in some areas. Because of issues related to the potential for airborne contamination, milling and reusing is not a viable solution.

Slide 37



Reinforce the discussions from the last series of slides and the range of perspectives to be taken into account when considering the use of a recycled material. Summarize the environmental, engineering, and economic considerations along with the public perception and regulatory issues impacting the proposed use that are needed to reach a decision.

Slide 38



Scenario: In New York City, a mandate was set for low-flow toilets, so millions of toilets were sent to a landfill in a short period of time. A request was made by the city to DOT to use these toilets in highway applications. How would you assess the possibilities? What decision do you think was made, and why?

In your assigned breakout room, use the note pod to capture your ideas and possible applications in response to the questions.

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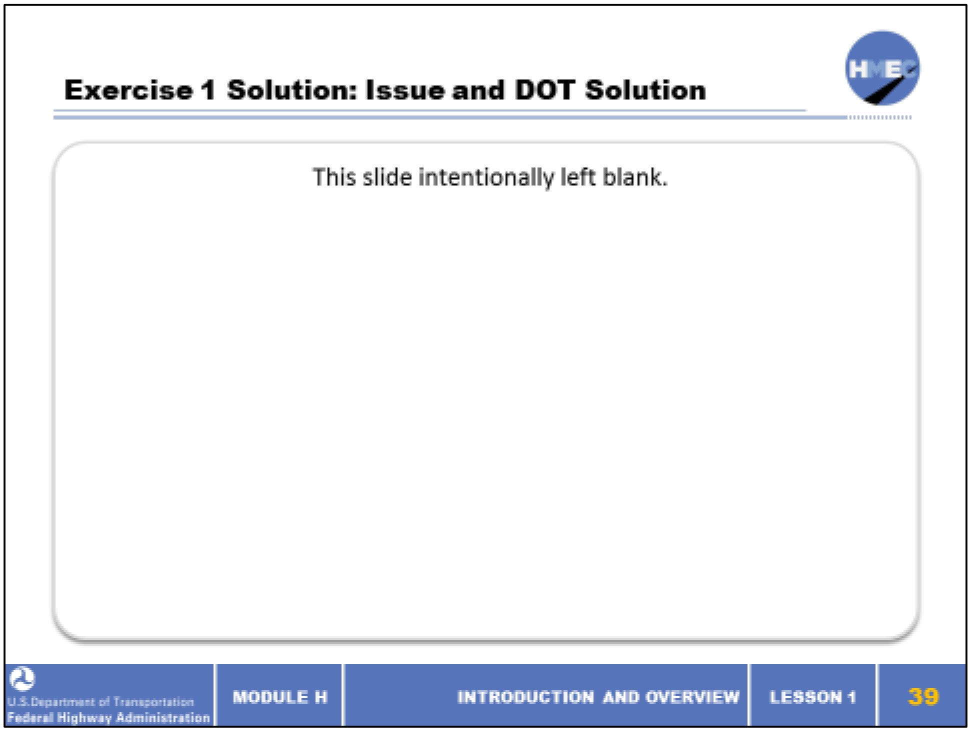
Slide 39


Exercise 1 Solution: Issue and DOT Solution
HMEC
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U.S. Department of Transportation
Federal Highway Administration
MODULE H
INTRODUCTION AND OVERVIEW
LESSON 1
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Slide 40


Common Recycled Materials in Transportation
Identify the top 10 materials recycled in your area of responsibility.
U.S. Department of Transportation
Federal Highway Administration
MODULE H
INTRODUCTION AND OVERVIEW
LESSON 1
40

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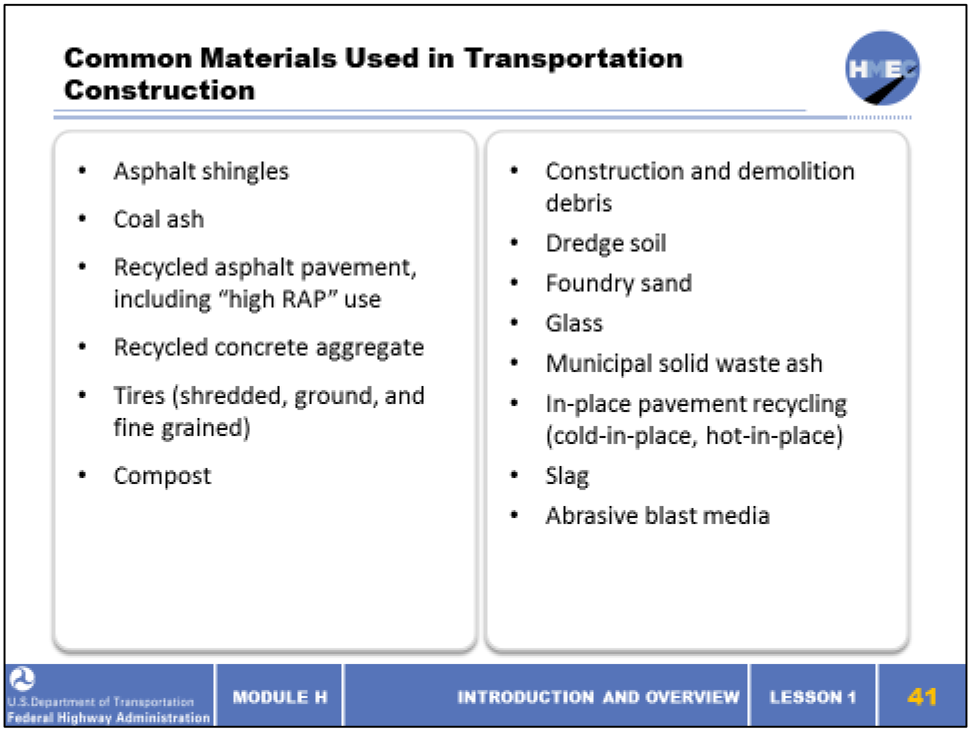
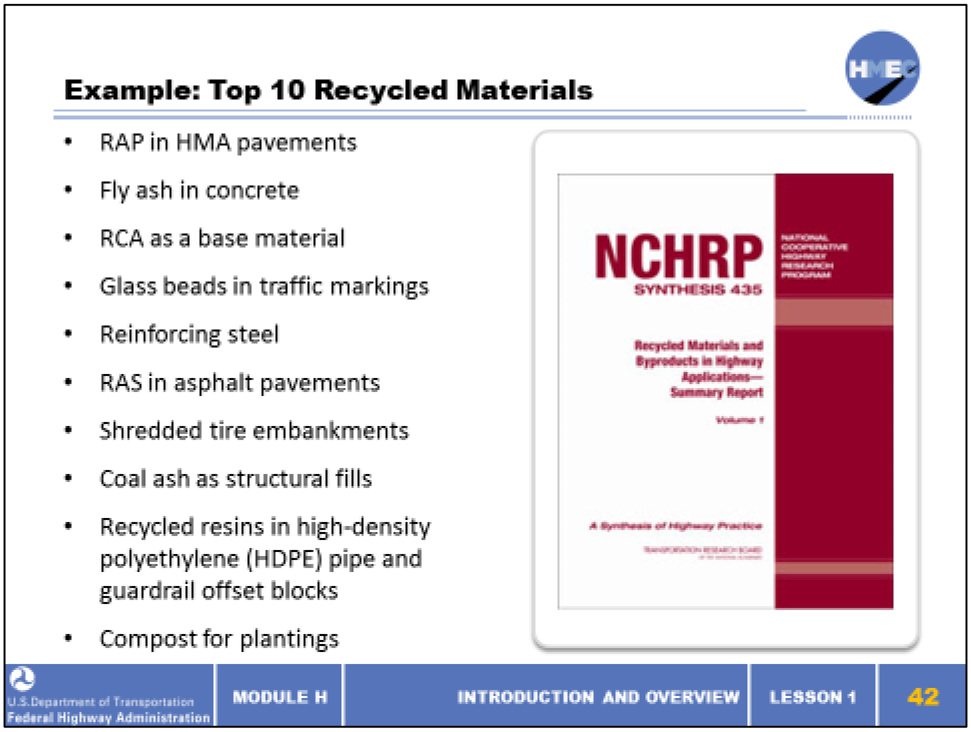
Slide 41



Refer to NCHRP Synthesis 435 and the variety of materials reported being used by States.

Slide 42


Example: Top 10 Recycled Materials
- RAP in HMA pavements
- Fly ash in concrete
- RCA as a base material
- Glass beads in traffic markings
- Reinforcing steel
- RAS in asphalt pavements
- Shredded tire embankments
- Coal ash as structural fills
- Recycled resins in high-density polyethylene (HDPE) pipe and guardrail offset blocks
- Compost for plantings
NCHRP
SYNTHESIS 435
Recycled Materials and Byproducts in Highway Applications— Summary Report
Volume 1
A Synthesis of Highway Practice
U.S. Department of Transportation
Federal Highway Administration
MODULE H
INTRODUCTION AND OVERVIEW
LESSON 1
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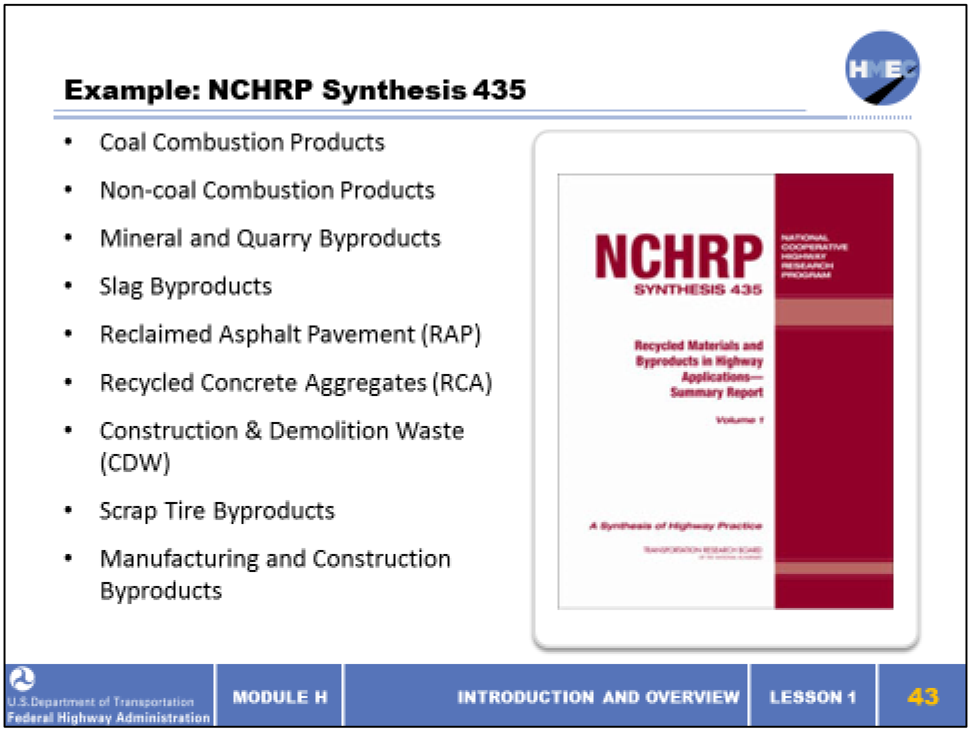
Slide 43



Introduce and discuss the contents of this 8 volume document that is included in their resource materials. Review how the synthesis is organized with Volume 1 providing general background information about each category, including how it is produced, how the materials are being used, basic performance information, advantages and challenges related to using the materials, and future research needs. Volumes 2 – 8 provides detailed information about the various materials including physical and chemical properties, usage and production, literature reviews, specifications, survey results about how state highway agencies have used the materials and lessons learned from agency uses. This synthesis should be included in the reference materials and is available at http://www.trb.org/Publications/NCHRPSyn435.aspx.

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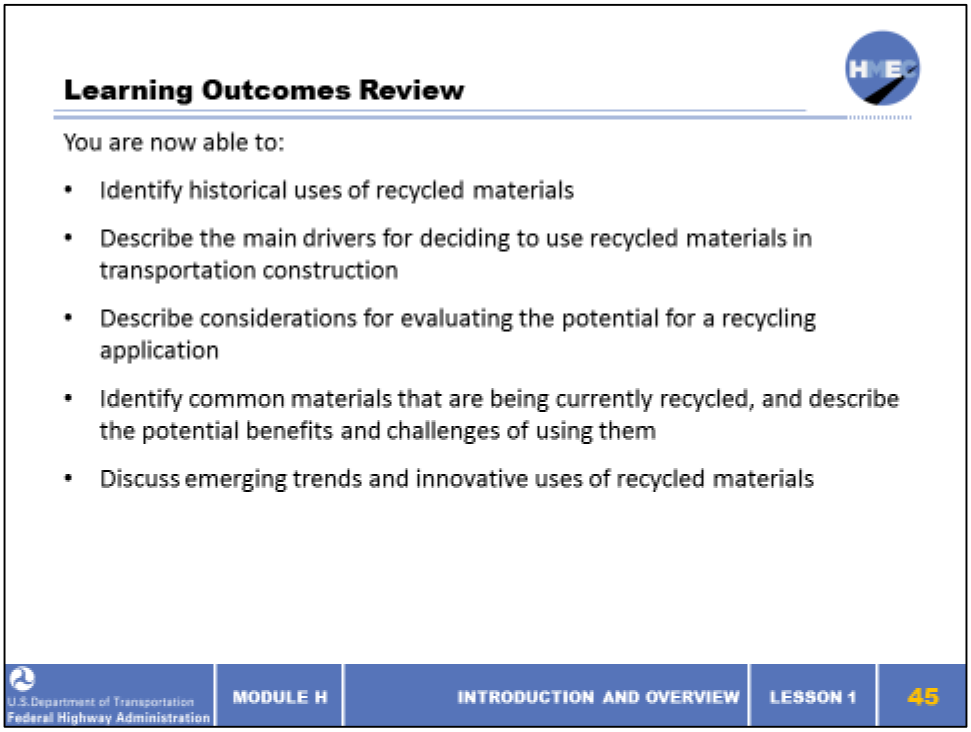
Slide 44

Discuss details of zero-waste projects where nothing is removed from the site and the challenges that it offers. The contractor must have all suppliers on board to make this a success. The state of Maryland has developed a “Zero Waste Maryland” plan to recycle, reuse, and recycle nearly all waste generated in the state by 2040 and this plan includes highway construction. Information is available at http://www.mde.state.md.us/programs/Marylander/Documents/Zero_Waste_Plan_Draft_12.15.14.pdf

Two-lift concrete pavements allow for a lower quality and lower strength concrete (maybe using RCA having quality issues) topped by a higher quality concrete to provide the durability required for the wearing surface. Information available at http://www.cptechcenter.org/research/research-initiatives/two-lift/

Some States utilize showcase projects to require a wide range of recycled materials and publicize the features involved, and others offer special incentives for contractors who bring innovative ideas related to the use of recycled materials. One such incentive involves the use of a value engineering type program that shares cost savings with contractors.

Slide 45


HMEC
Learning Outcomes Review
You are now able to:
• Identify historical uses of recycled materials
• Describe the main drivers for deciding to use recycled materials in transportation construction
• Describe considerations for evaluating the potential for a recycling application
• Identify common materials that are being currently recycled, and describe the potential benefits and challenges of using them
• Discuss emerging trends and innovative uses of recycled materials
U.S. Department of Transportation
Federal Highway Administration
MODULE H
INTRODUCTION AND OVERVIEW
LESSON 1
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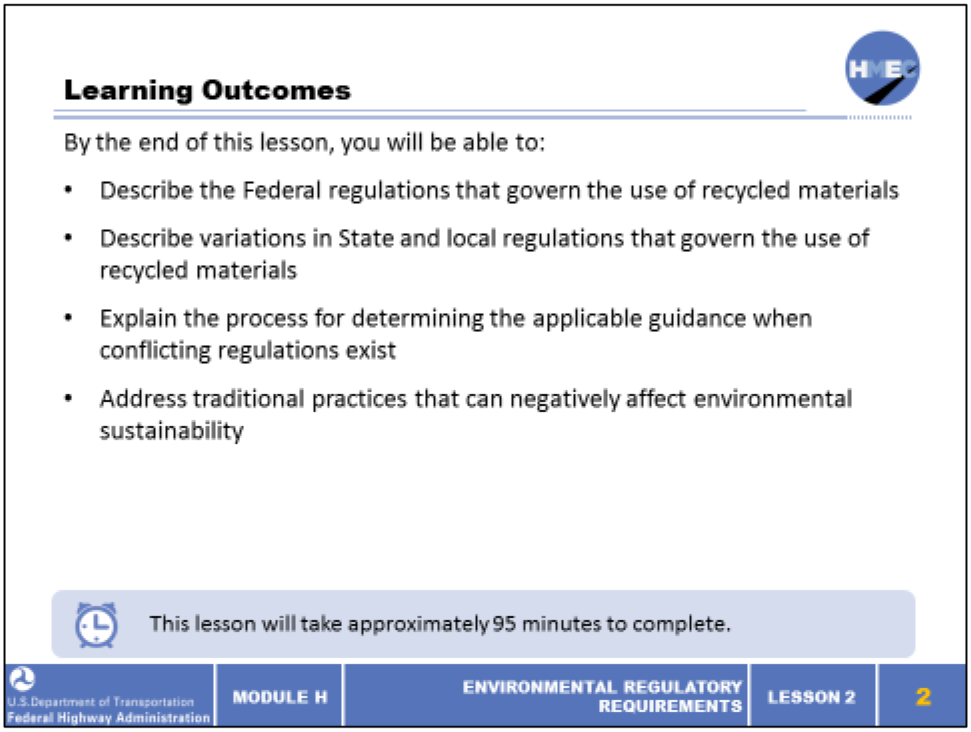
Slide 1


WCT
HMEC
Highway Materials Engineering Course
Lesson 2: Environmental Regulatory Requirements
Evaluating Recycled Materials for Beneficial Uses in Transportation Construction
U.S.Department of Transportation
Federal Highway Administration
MODULE
H

Slide 2


Learning Outcomes
By the end of this lesson, you will be able to:
• Describe the Federal regulations that govern the use of recycled materials
• Describe variations in State and local regulations that govern the use of recycled materials
• Explain the process for determining the applicable guidance when conflicting regulations exist
• Address traditional practices that can negatively affect environmental sustainability
This lesson will take approximately 95 minutes to complete.
U.S. Department of Transportation
Federal Highway Administration
MODULE H
ENVIRONMENTAL REGULATORY REQUIREMENTS
LESSON 2
2

Slide 3

Federal regulations govern the use of recycled materials and how various regulating bodies interrelate with each other.

Slide 4

Regulations may impact a State DOT from both directions. Federal regulations flow to the State from legislation through the interpretation and policy statements from EPA and FHWA. These requirements also flow to the municipal and local agencies if included in the work being proposed. Municipal and local agencies may also have more stringent requirements. Those requirements may flow upward to the State DOT, adding more requirements for the work being performed. If the State, municipal, or local agency regulations pre-dated the Federal regulation, they may still be in place and possibly more stringent.

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Slide 5


Federal Regulations and Recycled Materials
HMEC
State Agency
City Agency
State DOT
Local Agency
DEQ
VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY
RICHMOND
VIRGINIA
VDOT
Regulations go in both directions
In your area, which agency has the most stringent regulations regarding recycled materials?
U.S. Department of Transportation
Federal Highway Administration
MODULE H
ENVIRONMENTAL REGULATORY REQUIREMENTS
LESSON 2
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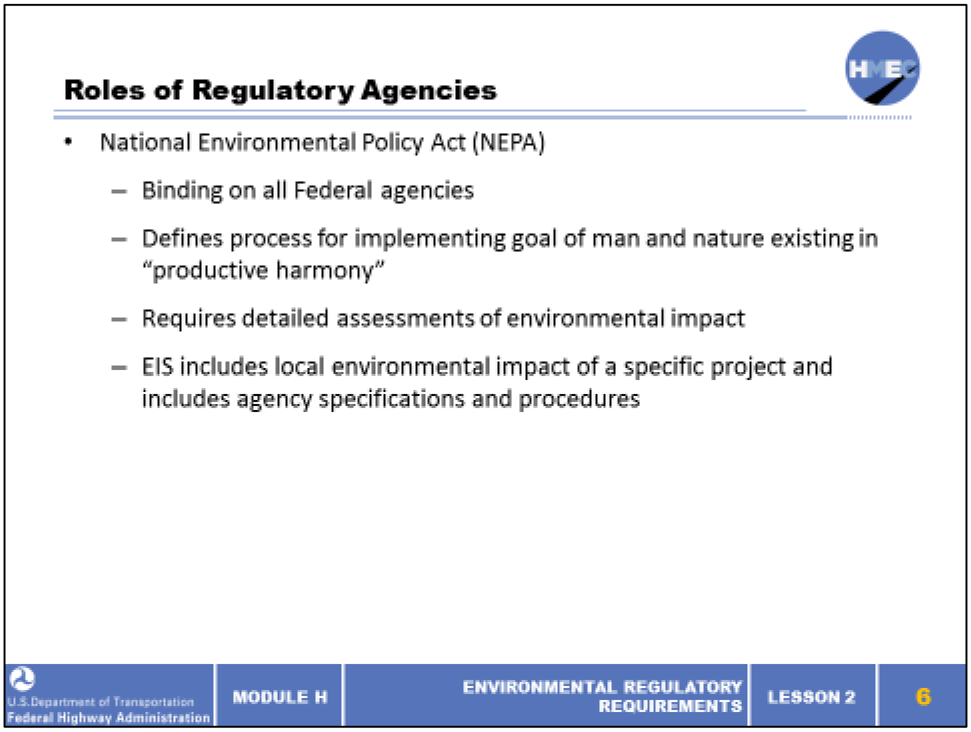
Slide 6


Roles of Regulatory Agencies
HMEC
• National Environmental Policy Act (NEPA)
– Binding on all Federal agencies
– Defines process for implementing goal of man and nature existing in "productive harmony"
– Requires detailed assessments of environmental impact
– EIS includes local environmental impact of a specific project and includes agency specifications and procedures
U.S. Department of Transportation
Federal Highway Administration
MODULE H
ENVIRONMENTAL REGULATORY REQUIREMENTS
LESSON 2
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Slide 7


Roles of Regulatory Agencies
HMEC
• Resource Conservation and Recovery Act (RCRA)
– Goal of reducing waste through source reduction and recycling
– Established "cradle to grave" management of hazardous waste
– Established a Comprehensive Procurement Guideline (CPG) program
– Addresses interstate transportation considerations
– Many States have been delegated the authority to manage waste by EPA
U.S. Department of Transportation
Federal Highway Administration
MODULE H
ENVIRONMENTAL REGULATORY REQUIREMENTS
LESSON 2
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Slide 8


Roles of Regulatory Agencies
• Environmental Protection Agency
– Responsible for operational duties associated with the administrative aspects of the EIS filing process
– Charged with reviewing EIS and commenting
– Interprets legislation and offers guidance
UNITED STATES
ENVIRONMENTAL
PROTECTION AGENCY
U.S. Department of Transportation
Federal Highway Administration
MODULE H
ENVIRONMENTAL REGULATORY REQUIREMENTS
LESSON 2
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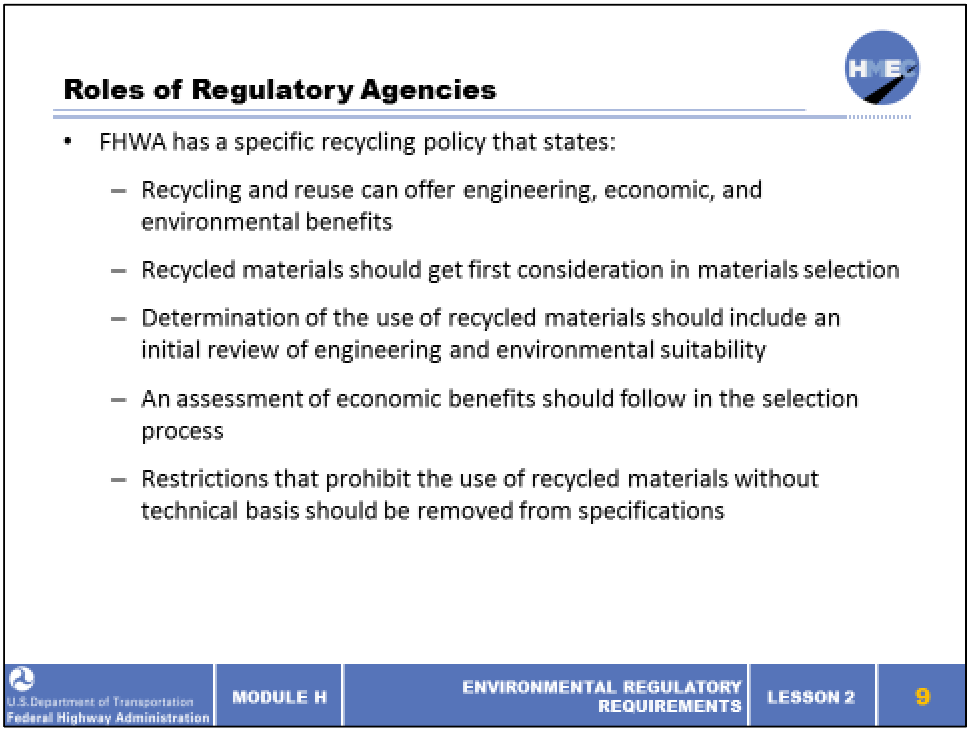
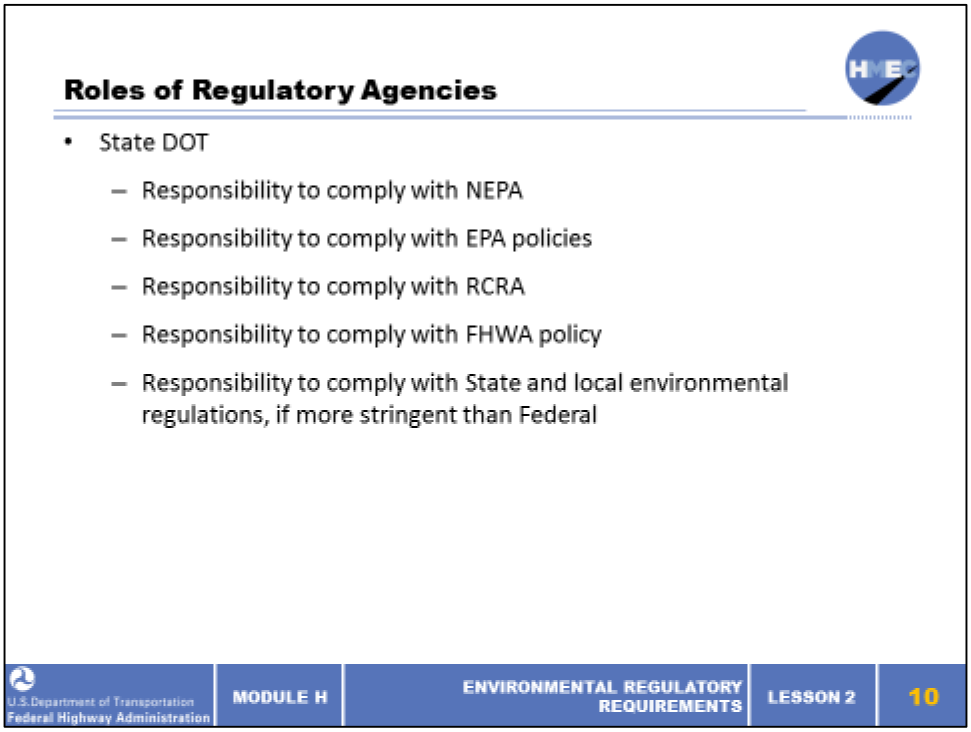
Slide 9



Federal agencies, such as FHWA, add requirements and guidance specifically related to transportation projects and have a policy to coordinate the environmental document, consider alternative courses of action during the process, include public involvement during the process for proposed projects, and address measures necessary to mitigate any adverse impacts that are incorporated into the proposed project.

Slide 10


Roles of Regulatory Agencies
HMEC
• State DOT
– Responsibility to comply with NEPA
– Responsibility to comply with EPA policies
– Responsibility to comply with RCRA
– Responsibility to comply with FHWA policy
– Responsibility to comply with State and local environmental regulations, if more stringent than Federal
U.S. Department of Transportation
Federal Highway Administration
MODULE H
ENVIRONMENTAL REGULATORY REQUIREMENTS
LESSON 2
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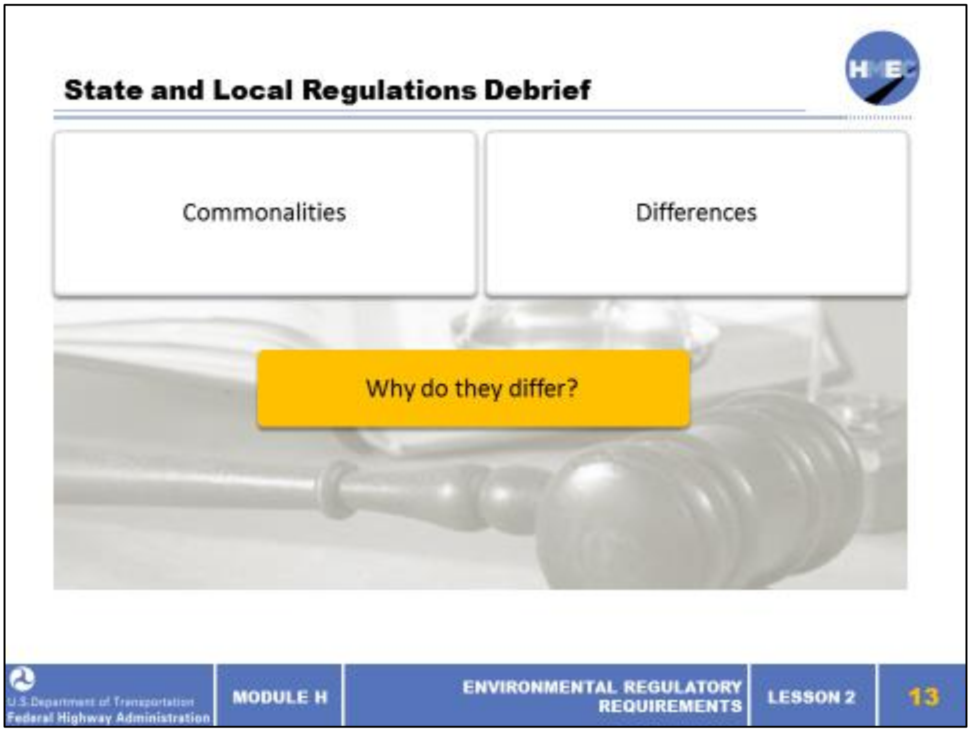
Slide 11

State and local regulations may differ significantly between States, or between a State and a municipality within that State.

Slide 12

Although State and local mandates exist, in some cases the mandates may not be successful because of other issues. One such example involves a State legislative mandate to use fly ash as a fill material, but because of local resistance from both citizens and elected officials when attempts to use it in their local areas, the material was not used

Slide 13


State and Local Regulations Debrief
Commonalities
Differences
Why do they differ?
U.S. Department of Transportation
Federal Highway Administration
MODULE H
ENVIRONMENTAL REGULATORY REQUIREMENTS
LESSON 2
13

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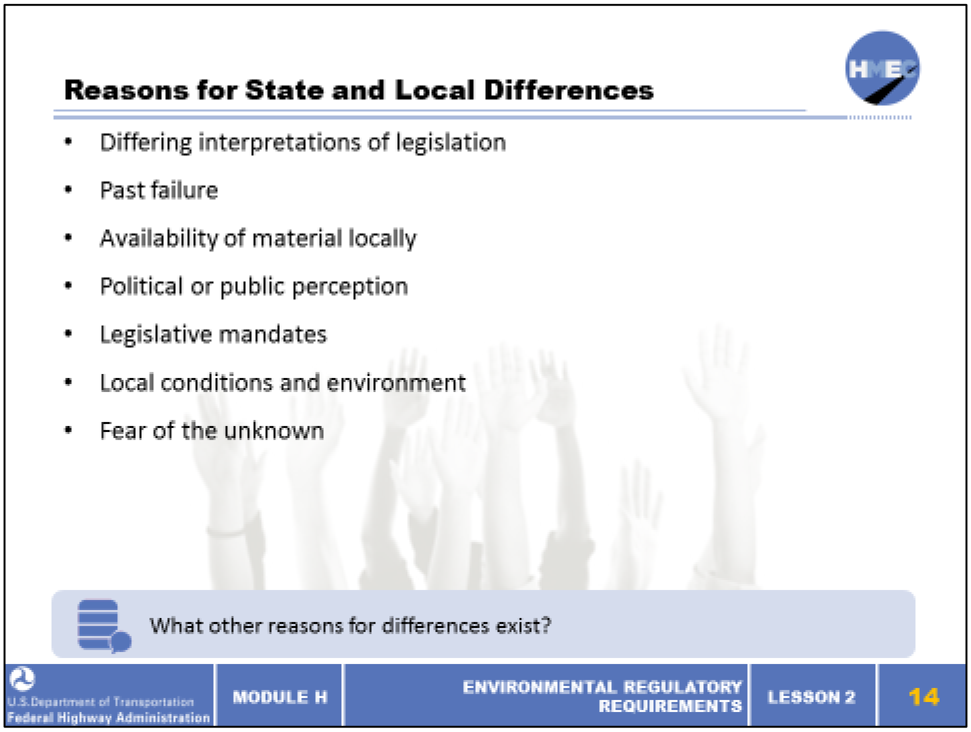
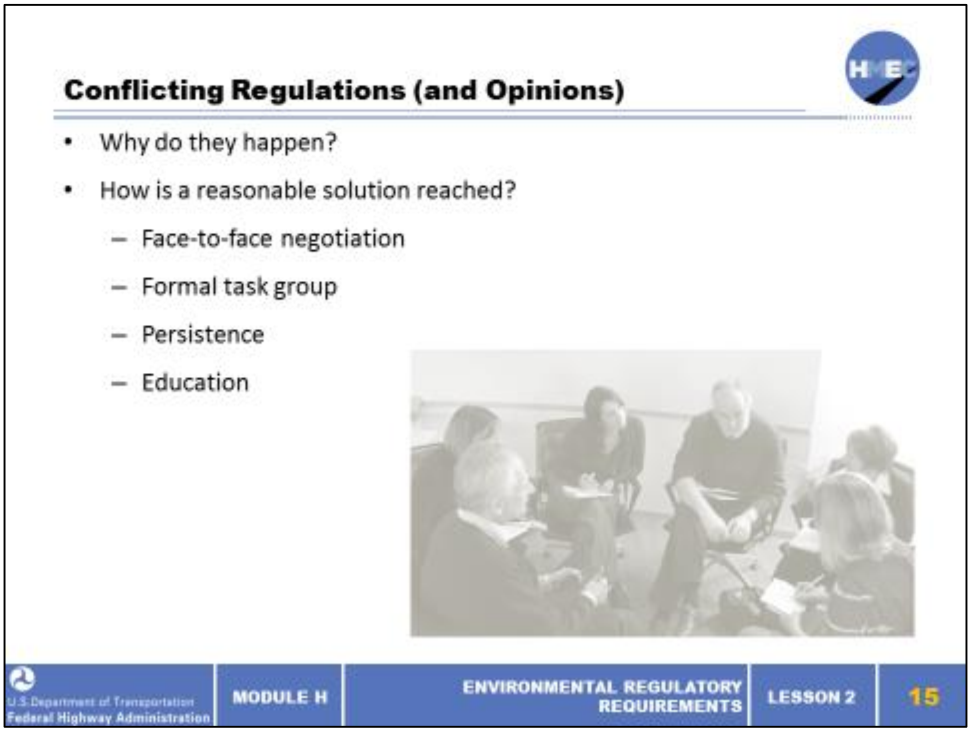
Slide 14

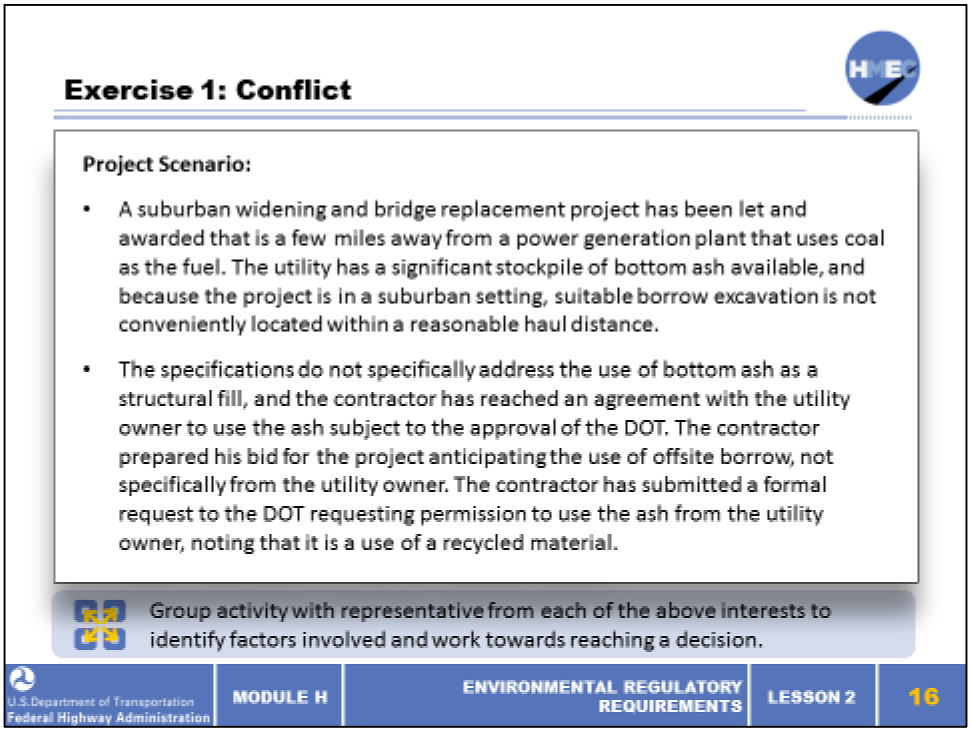

Reasons for State and Local Differences
HMEC
Differing interpretations of legislation
Past failure
Availability of material locally
Political or public perception
Legislative mandates
Local conditions and environment
Fear of the unknown
What other reasons for differences exist?
U.S. Department of Transportation
Federal Highway Administration
MODULE H
ENVIRONMENTAL REGULATORY REQUIREMENTS
LESSON 2
14

Slide 15



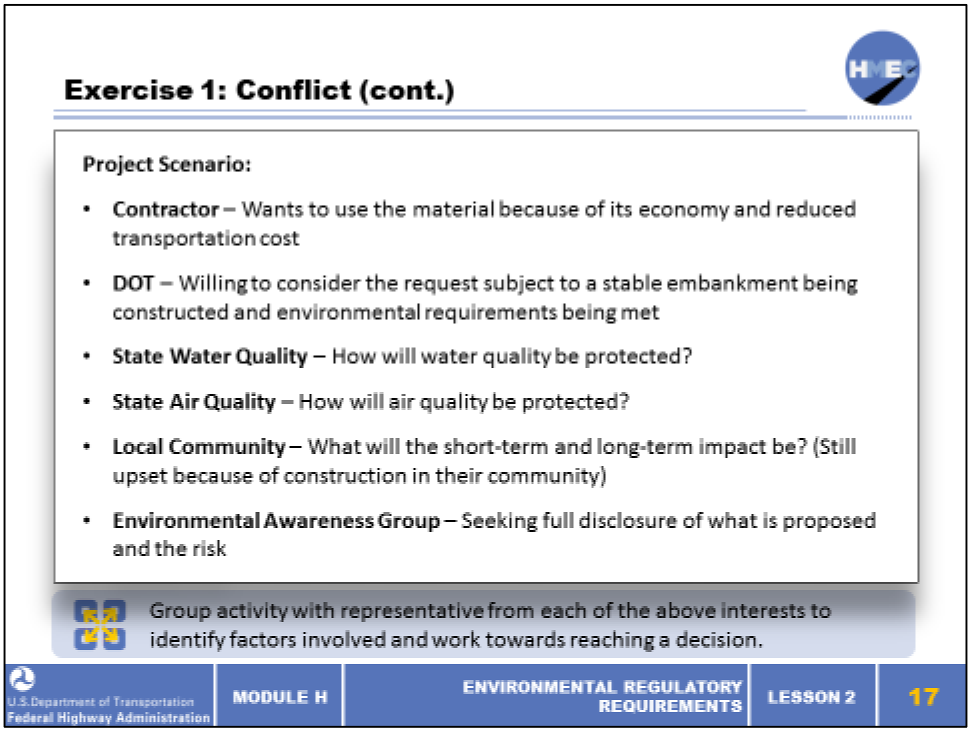
What happens when you encounter conflicting regulations?

Slide 16



How can differences be resolved?

Slide 17


Exercise 1: Conflict (cont.)
HMEC
Project Scenario:
• Contractor – Wants to use the material because of its economy and reduced transportation cost
• DOT – Willing to consider the request subject to a stable embankment being constructed and environmental requirements being met
• State Water Quality – How will water quality be protected?
• State Air Quality – How will air quality be protected?
• Local Community – What will the short-term and long-term impact be? (Still upset because of construction in their community)
• Environmental Awareness Group – Seeking full disclosure of what is proposed and the risk
Group activity with representative from each of the above interests to identify factors involved and work towards reaching a decision.
U.S. Department of Transportation Federal Highway Administration
MODULE H
ENVIRONMENTAL REGULATORY REQUIREMENTS
LESSON 2
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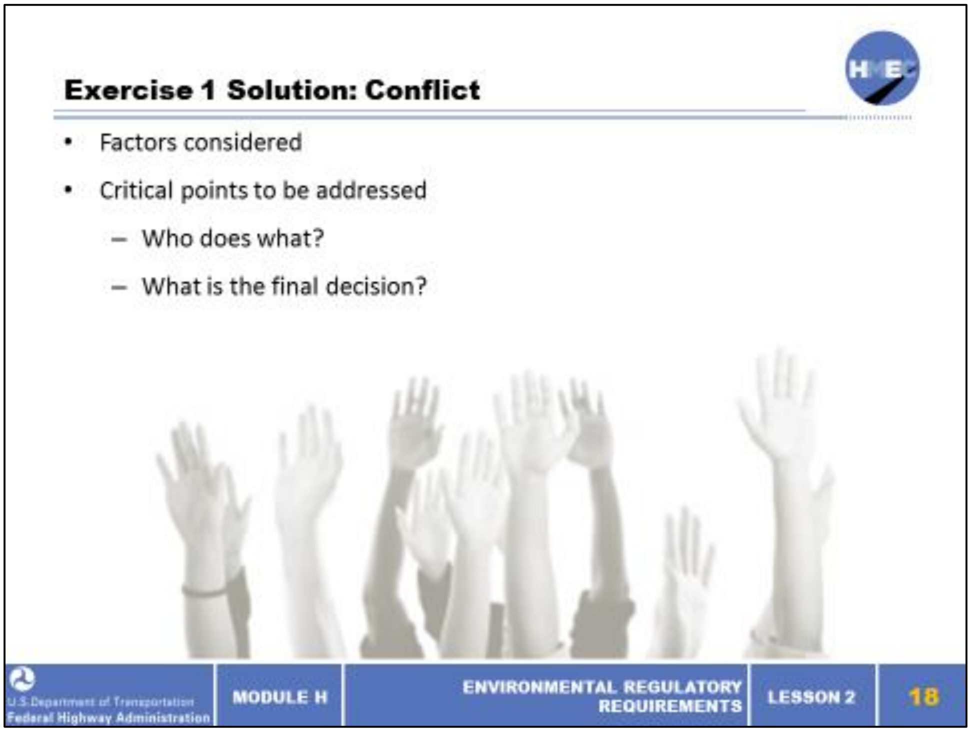
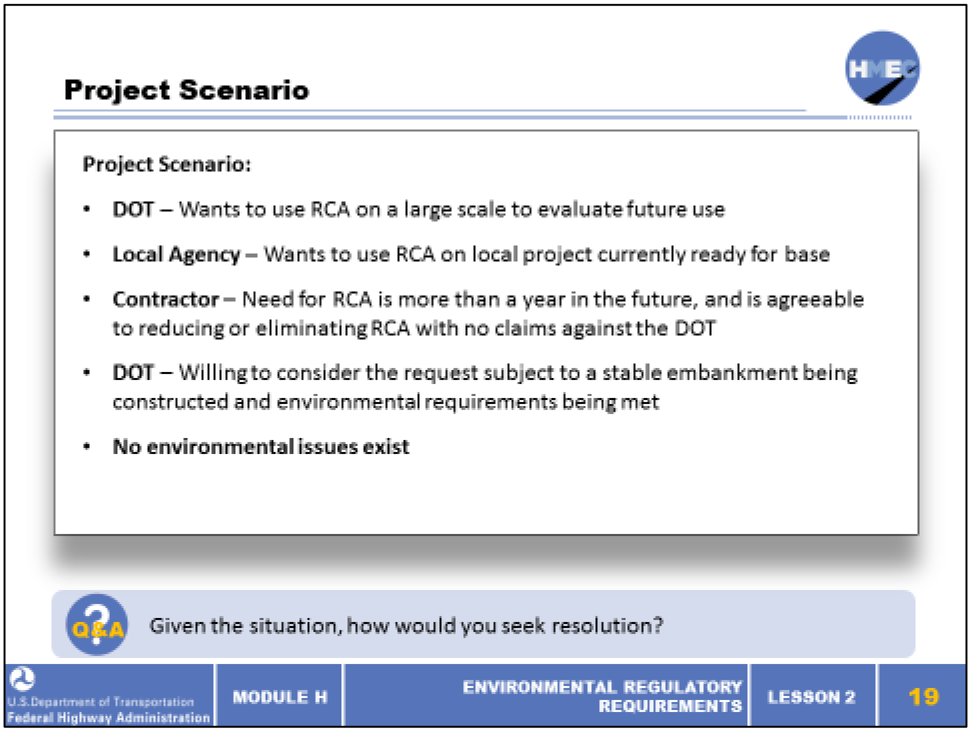
Slide 18



What have we learned about how to resolve differences?

Slide 19


Project Scenario
Project Scenario:
DOT – Wants to use RCA on a large scale to evaluate future use
Local Agency – Wants to use RCA on local project currently ready for base
Contractor – Need for RCA is more than a year in the future, and is agreeable to reducing or eliminating RCA with no claims against the DOT
DOT – Willing to consider the request subject to a stable embankment being constructed and environmental requirements being met
No environmental issues exist
Q&A
Given the situation, how would you seek resolution?
U.S. Department of Transportation
Federal Highway Administration
MODULE H
ENVIRONMENTAL REGULATORY REQUIREMENTS
LESSON 2
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Slide 20

What are some traditional practices that can negatively affect environmental sustainability?

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Slide 21

Negative Impacts on Sustainability

- What uses could "break the chain" of sustainability in the future?
  - Unencapsulated lead paint
  - Asbestos
  - Burning clearing debris
  - Others?

U.S. Department of Transportation Federal Highway Administration | MODULE H | ENVIRONMENTAL REGULATORY REQUIREMENTS | LESSON 2 | 21

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Negative Impacts on Sustainability Debrief
• Examples of items that impact future sustainability
• Evaluation phase must consider potential future impacts
U.S. Department of Transportation
Federal Highway Administration
MODULE H
ENVIRONMENTAL REGULATORY REQUIREMENTS
LESSON 2
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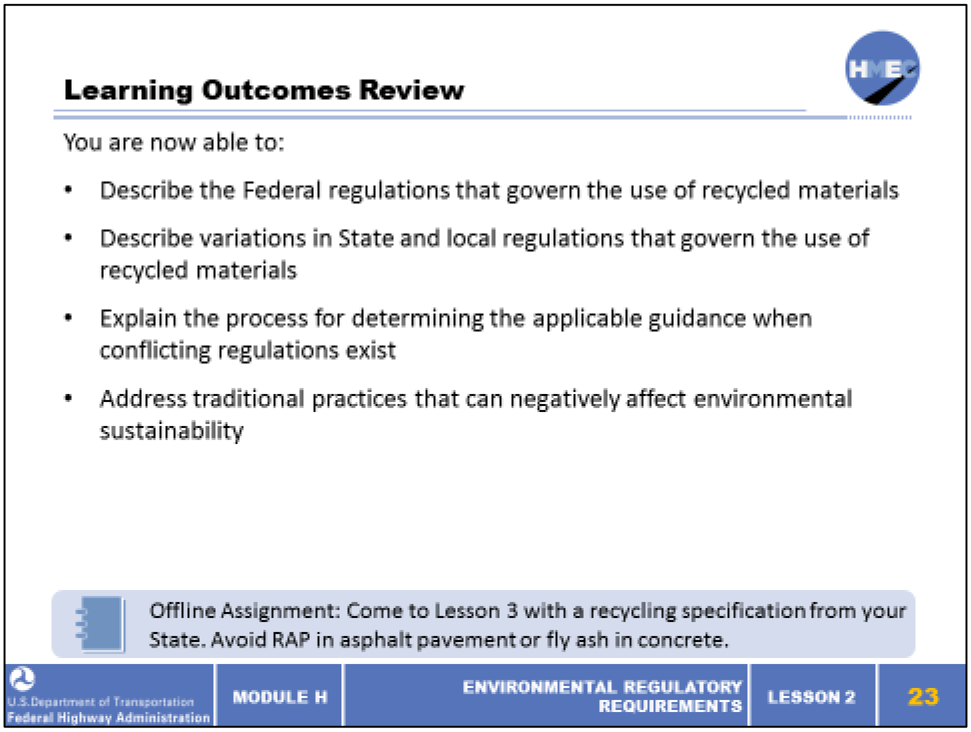
Slide 23



Offline Assignment: Come to Lesson 3 with a recycling specification from your State. Avoid RAP in asphalt pavement or fly ash in concrete.

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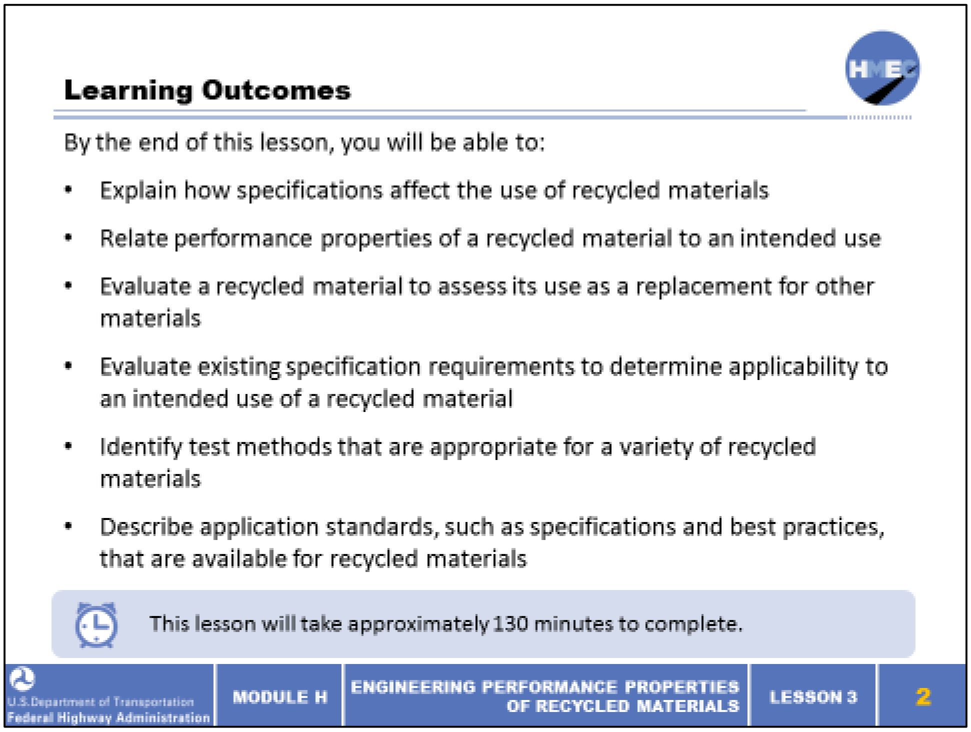
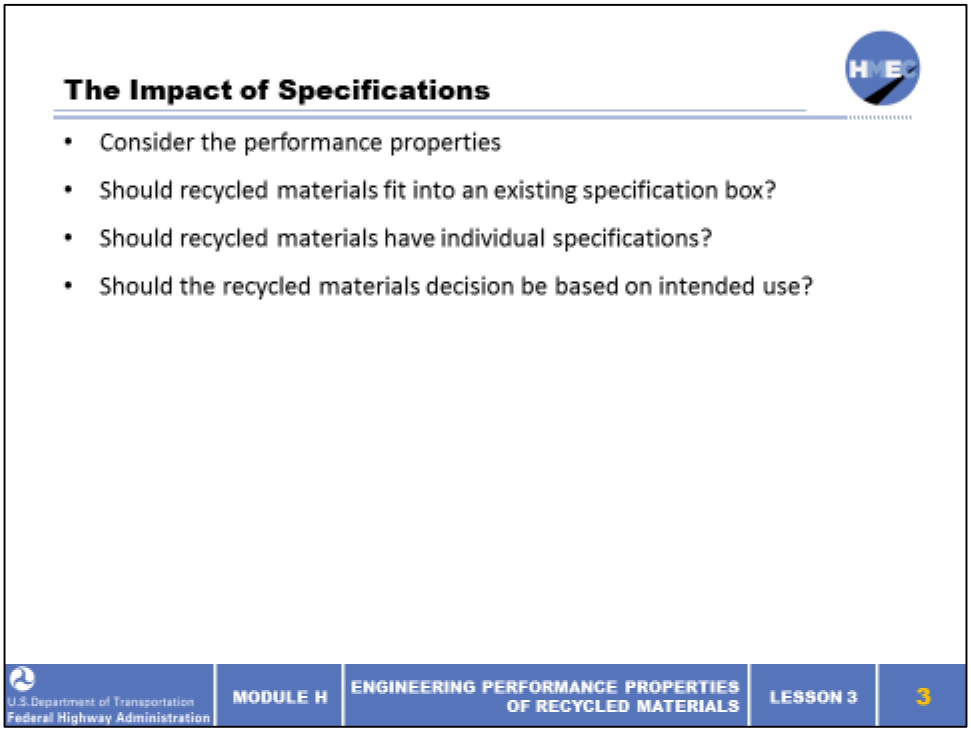
Slide 1


HMEC
Highway Materials Engineering Course
Lesson 3: Engineering Performance Properties of Recycled Materials
Evaluating Recycled Materials
for Beneficial Uses in
Transportation Construction
U.S.Department of Transportation
Federal Highway Administration
MODULE
H

Slide 2


Learning Outcomes
HMEC
By the end of this lesson, you will be able to:
Explain how specifications affect the use of recycled materials
Relate performance properties of a recycled material to an intended use
Evaluate a recycled material to assess its use as a replacement for other materials
Evaluate existing specification requirements to determine applicability to an intended use of a recycled material
Identify test methods that are appropriate for a variety of recycled materials
Describe application standards, such as specifications and best practices, that are available for recycled materials
This lesson will take approximately 130 minutes to complete.
U.S. Department of Transportation
Federal Highway Administration
MODULE H
ENGINEERING PERFORMANCE PROPERTIES OF RECYCLED MATERIALS
LESSON 3
2

Slide 3



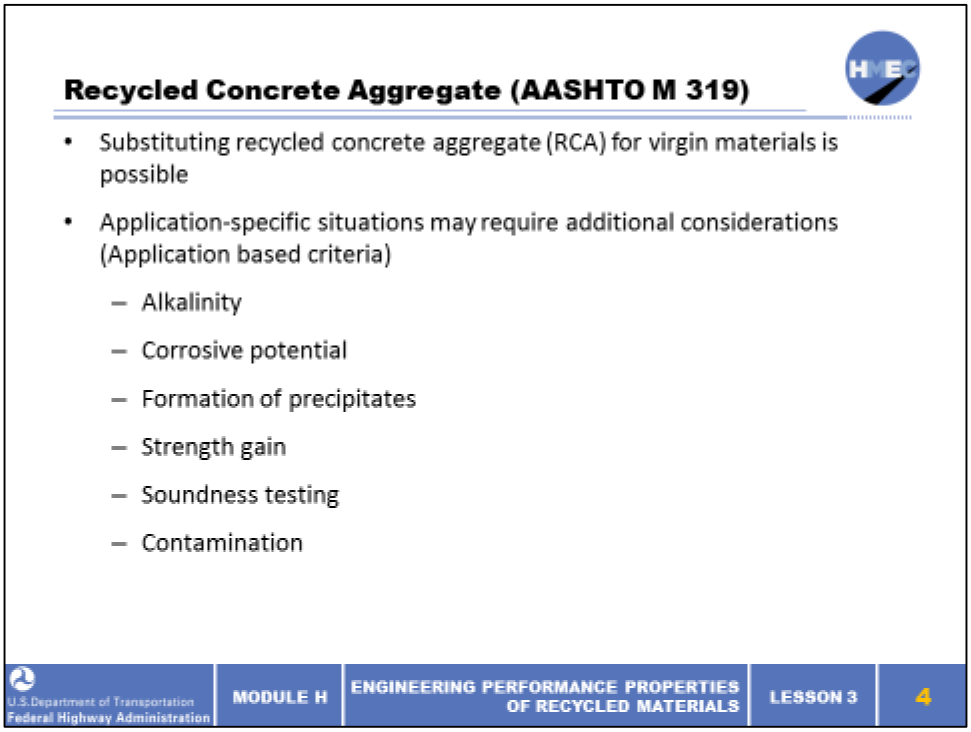
How do specifications affect the use of recycled materials?

A primary question to answer should be: What properties are required for the use of a given recycled material? Although the goal is for the final product including recycled materials to perform equal to or better than what it replaces, an important factor is what the performance characteristics are that are critical for the intended use. For example, actions to retard the migration of chlorides through a concrete member is an important characteristic for a bridge deck. The use of fly ash, or other pozzolans, enhance the permeability characteristics of concrete, thereby making the use of a recycled material desirable.

Shifting specifications toward a performance-related model should result in a longer life than simply following a prescriptive specification, but it should also allow for creativity and innovation to find other solutions to meet the intended purpose. This may open the avenue for the use of recycled materials in some areas, and in others it could limit the use of certain materials, both virgin and recycled.

Should recycled materials always fit into an existing specification box? At times they do and at other times a separate specification might be required to address properties unique to the recycled material. A simple example is the case of reinforcing steel. The specifications do not address whether the steel is virgin or recycled as long as the metallurgic and strength parameters are met. The use of an industrial byproduct as an embankment material will likely have its own specification to address leachate characteristics as well as the engineering performance characteristics.

Slide 4



While it is entirely possible that RCA can be dropped into an existing specification, the particular application might warrant additional considerations. Look at AASHTO M 319 and the notes in Section 1.3, which address situations that may require additional actions over and above what might be taken for virgin materials.

Specifically:
• Because of high alkalinity, you may need to consider limits about proximity to the water table and surface water.
• Corrosive potential because of the high alkalinity is aggressive on zinc coatings and aluminum culverts.
• The possibility of precipitate formation could impact fabric-wrapped subdrain systems, and appendix X2 discusses how to evaluate or mitigate the impact.
• The strength of base with RCA will likely increase with time and could therefore reduce in permeability. If the base is intended as a drainage course, the fines should be removed from the RCA prior to use.
• Soundness tests may reveal higher loss than what actually exists because of chemicals involved with the test method. Section 6.3 and appendix X3 discuss alternative test approaches.

• The potential for the RCA to have contaminates exists and should be addressed in the specification.

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Specification Shout Out
What are other examples of how specifications impact the use of recycled materials?
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An example of an application-based criteria could be hot mix asphalt (HMA). Typical specifications include requirements for binder content and volumetric requirements (VMA, total voids, gradation), and the use of reclaimed asphalt pavement (RAP) is acceptable if these final requirements can be met (in most States). While this is not necessarily a “drop in” substitution, the final application is to have a pavement meeting the same requirements. Most specifications still have requirements for the constituent materials whether they are virgin or recycled. For instance, most States require the virgin aggregates to meet specific gradation targets before blending, and certain requirements of the RAP may also be required.

A true performance specification only identifies the final performance measures, and leaves the details up to the contractor. Very few States have totally performance-based specifications, but an application-based specification moves in that direction with additional guidance about the components of the final product.

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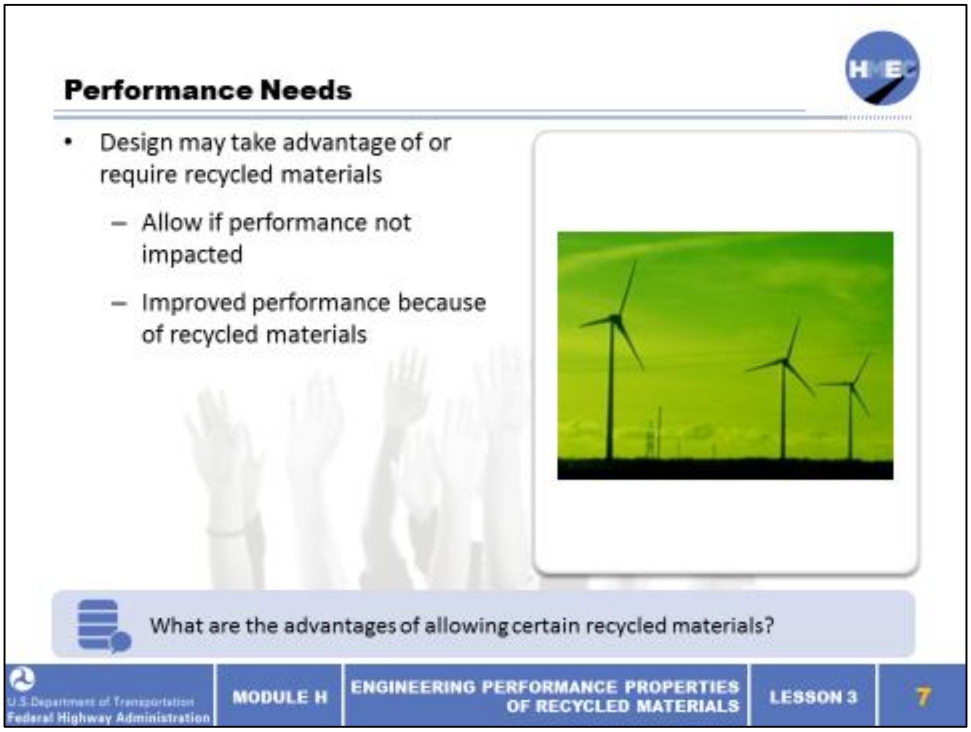

What consequences does using a recycled material have on performance?

The specifications may allow contractors to take advantage of recycled materials if desired, or may require the use of a recycled material to improve the performance characteristics. If performance is not negatively impacted, RAP is allowed in most States (although the specifications typically include additional requirements for the use of RAP). The use of RAP provides an economic advantage and if there is no quality degradation, most contractors choose to use it.

Examples of where the performance characteristics of the final product might be improved by the use of a recycled material is the use of fly ash in concrete to improve the durability and the use of recycled asphalt shingles (RAS) to produce a stiffer and possibly more rut-resistant asphalt pavement. The use of RCA in an unbound base has been shown to increase the strength due to the angularity and cementious effect due to the existence of unhydrated cement.

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Slide 8

Are special accommodations required when recycled materials are used?

Some materials may necessitate additional accommodations to facilitate their use. While not necessarily a specification issue, the use of shredded tires in an embankment may require the use of special equipment on the project and may puncture truck tires on the site.

RAP may need to be broken down into different sizes (fractionated), especially at higher percentages of use, to assure the final gradation meets specification requirements. Although this may be considered a special accommodation, it is very similar to how virgin aggregates are treated. The various sizes of virgin aggregates that are used in the mix are typically stored in separate bins and have individual gradation requirements to be approved for use.

Fly ash needs to be protected from moisture because it can clump or harden if it gets too wet. On the other hand, fly ash can become airborne if it is too dry so it needs to be covered or otherwise contained during transportation and storage.

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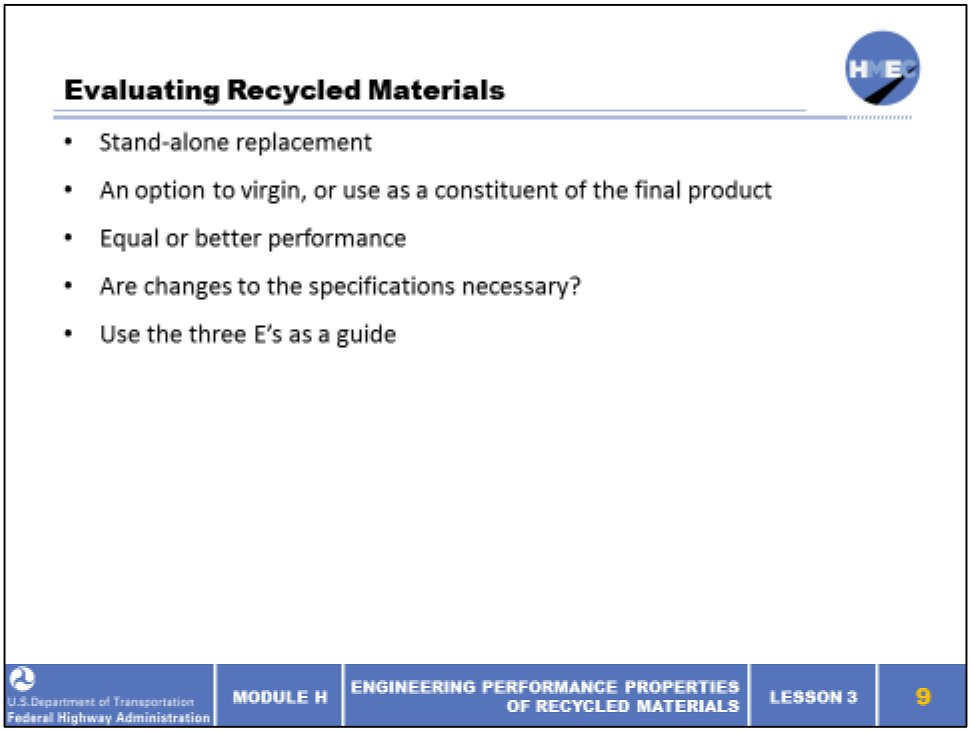

How do we go about evaluating the quality characteristics of a recycled material to determine if specification changes are necessary?

Considerations for evaluating the quality characteristics of a recycled material include:
- Can it be used as a stand-alone replacement?
- Can it be an option to virgin, or included as a constituent of the final product?
- Is the performance equal to, or better than, virgin?
- Will using the recycled material require changes to existing specifications or processes?
- Follow the three E's (environmental, engineering and economics) in the evaluation.

The type of specification influences the responses to the first four questions. True performance specifications would allow for innovation to come into play, subject to environmental and other regulatory issues. Prescriptive method specifications may not allow the incorporation of recycled materials without some type of contract modification. Some specifications specifically prohibit the use of recycled materials in direct conflict with the FHWA Recycled Materials Policy.

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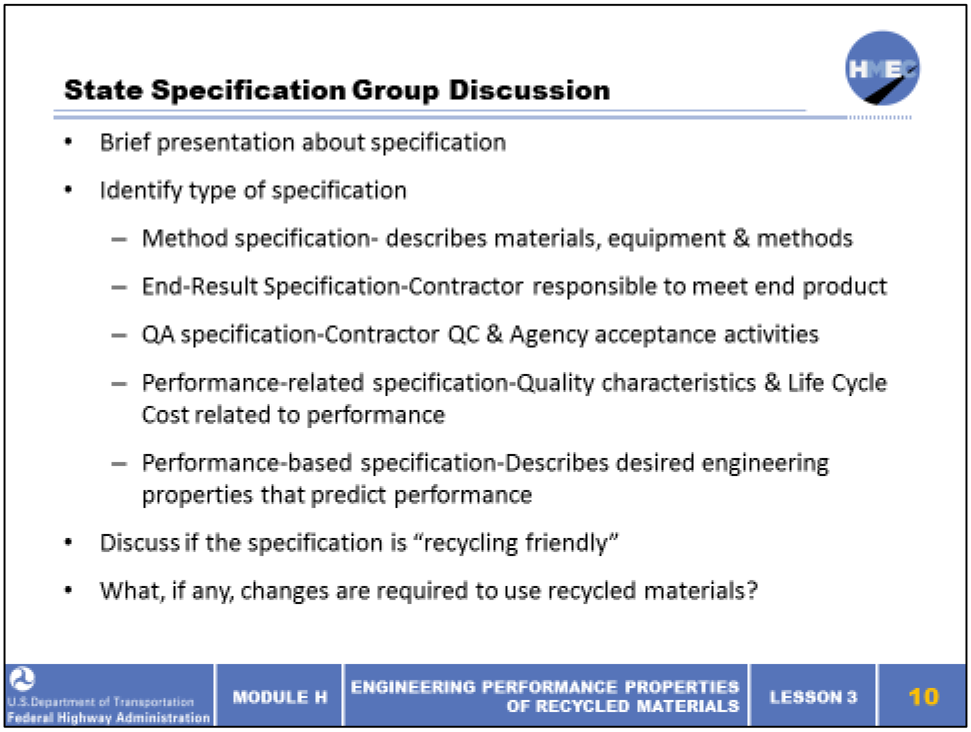

Compare your State specifications relative to how the type of specification relates to the use of recycled materials.

Expanded definitions of specification types are available at: http://www.fhwa.dot.gov/construction/specstoc.cfm

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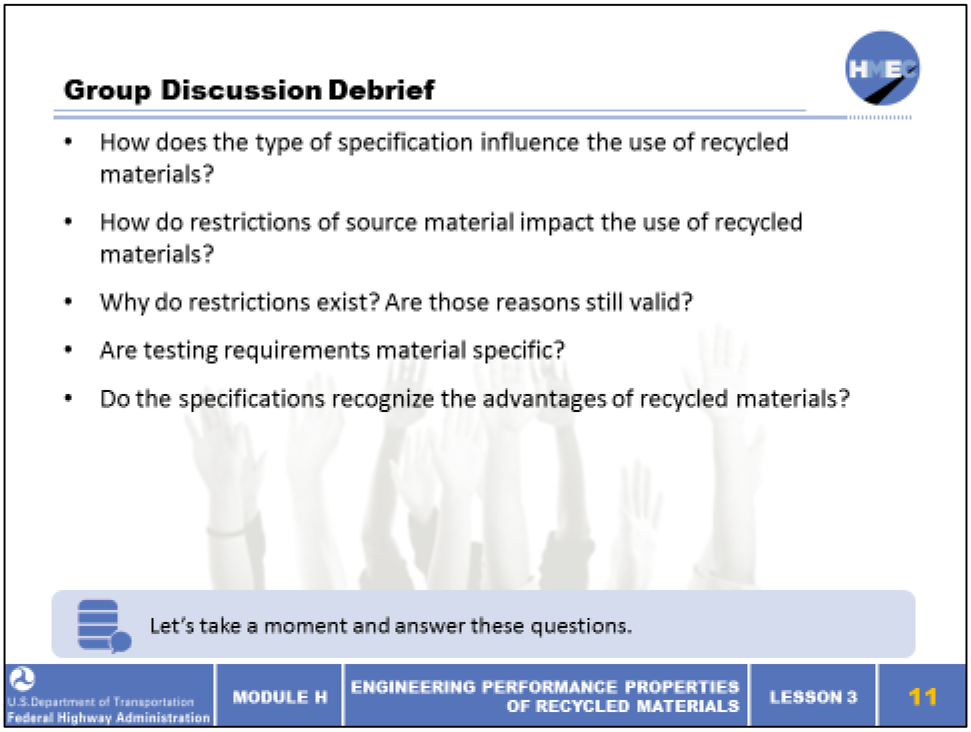
Group Discussion Debrief
HMEC
How does the type of specification influence the use of recycled materials?
How do restrictions of source material impact the use of recycled materials?
Why do restrictions exist? Are those reasons still valid?
Are testing requirements material specific?
Do the specifications recognize the advantages of recycled materials?
Let's take a moment and answer these questions.
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Federal Highway Administration
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ENGINEERING PERFORMANCE PROPERTIES OF RECYCLED MATERIALS
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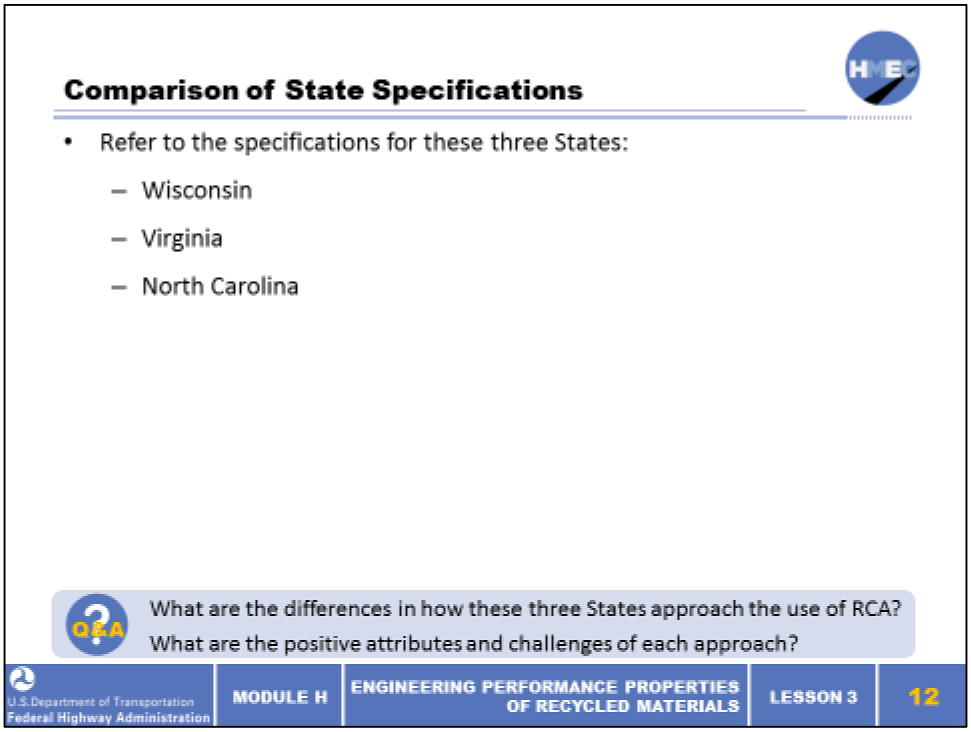
HMEC
Comparison of State Specifications
• Refer to the specifications for these three States:
– Wisconsin
– Virginia
– North Carolina
Q&A
What are the differences in how these three States approach the use of RCA?
What are the positive attributes and challenges of each approach?
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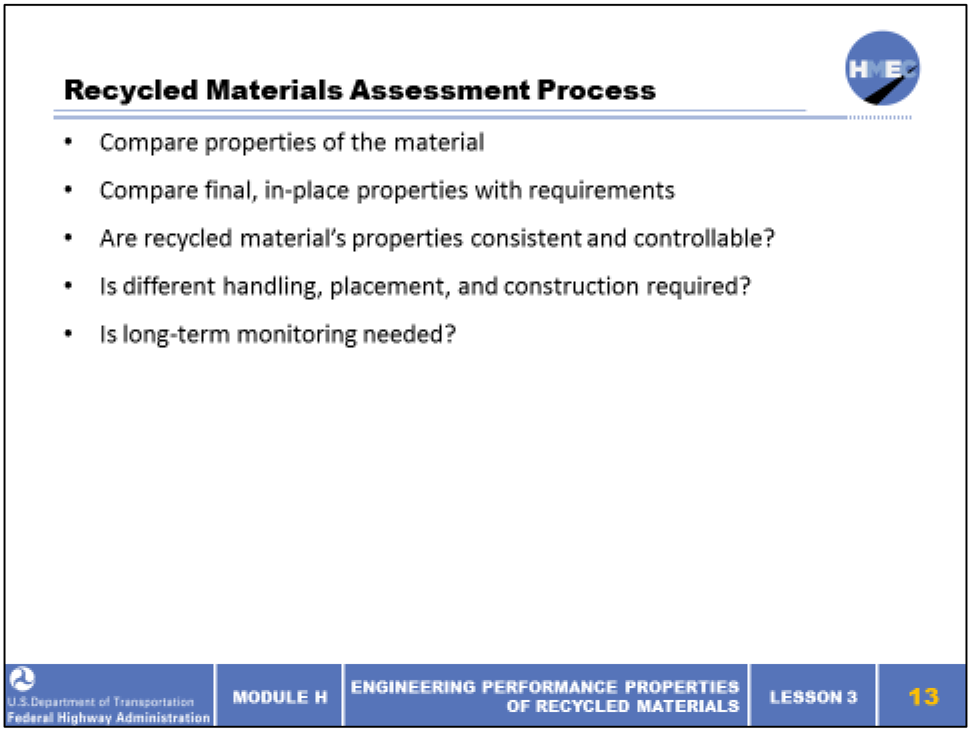

Do existing specifications apply to the use of recycled materials?

Slide 14

A wide variety of test methods exist that are appropriate across a wide variety of recycled materials. They exist in national standards bodies such as AASHTO, ASTM, and American Concrete Institute (ACI), and also exist within individual State specifications and procedures. These methods can be searched individually through the respective Web sites of these national organizations, or through various publications. For instance, Volume 2 of NCHRP Synthesis 435 lists 25 nationally recognized test methods in Table 45 that are used to evaluate coal combustion byproducts in highway applications. Some of these methods are specific to fly ash, while others are standard methods used for any material being evaluated for a specific use.

Standard developing organizations typically include committees or groups focusing on developing and maintaining standards with a focus on the evaluation of recycled materials.

States may also modify existing methods, or develop different test methods to evaluate recycled materials if deemed appropriate based upon local conditions. Prior to such modifications, it is desirable to first determine if an established national standard can meet the need, and if not, individuals can approach the standard developing body about the issues and work cooperatively to make modifications to the national standard.

Standards are readily available that can be used to determine the characteristics of materials, both virgin and recycled. The range of test methods varies from particle size analysis that can easily apply to both virgin and recycled materials, to very specific requirements such as the characteristics of recycled resins used in high-density polyethylene (HDPE) pipe.

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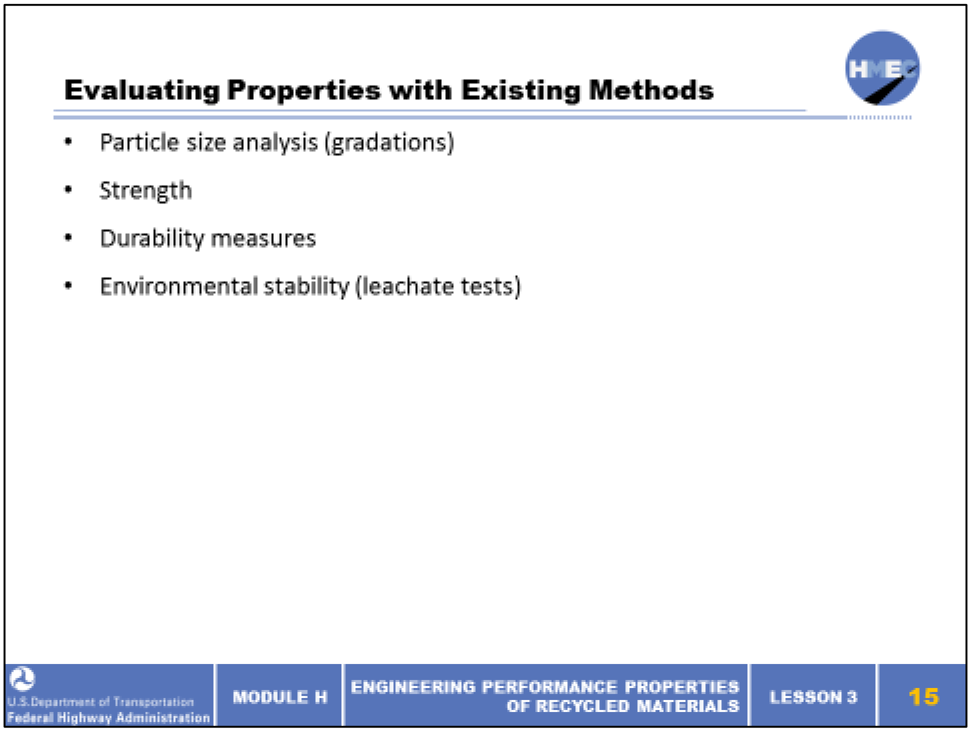

Many properties of recycled materials can be evaluated using existing test methods.

Consider the ignition test for fly ash (loss-on ignition, or LOI). The test method exhibits the amount of carbon in the fly ash and impacts how it is classified. This is an appropriate test method because the carbon amount has an impact on how concrete performs, particularly related to the compatibility with air entraining agents and other admixtures.

Examples of properties that can be determined using existing tests methods for materials incorporating recycled materials include:

- Particle size analysis (gradation for RCA and other products);
- Strength (concrete, soils, base courses);
- Durability measures (permeability, scaling, abrasion resistance, freeze/thaw, etc.); and
- Environmental stability (leaching, oxidation, etc.).

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Standards for Recycled Materials
Shout out some standards used in your State that are appropriate for use with recycled materials.
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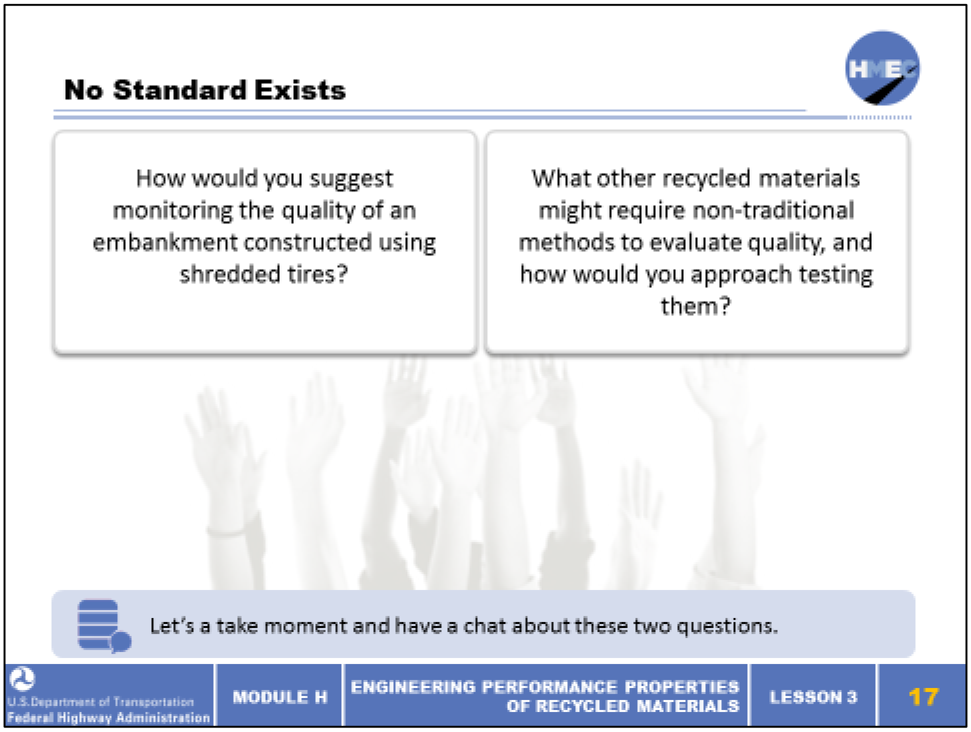
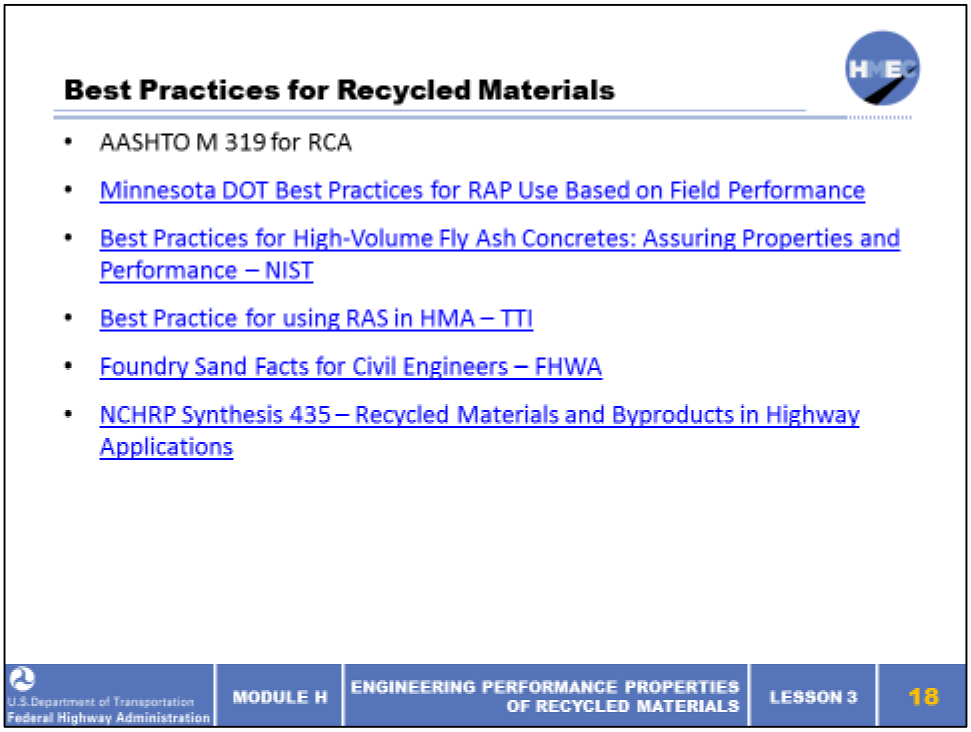
Slide 17



What happens if no standard exists for the recycled material proposed? When no standard exists, how will the quality be evaluated? For example, how is density evaluated on an embankment using shredded tires? The material will not fit into a proctor mold, and the shredded tires will not accommodate the use of a sand cone or nuclear gauge. How would you suggest proceeding?

Slide 18



Numerous standards and best practices guides are available for a wide variety of recycled materials including:

- AASHTO M 319 for RCA
- Minnesota DOT Best Practices for RAP use Based on Field Performance (http://www.dot.state.mn.us/mnroad/projects/RAP/Reports/LRRB%20826%20report%20200915.pdf)
- Best Practices Guide for High-Volume Fly Ash Concretes: Assuring Properties and Performance (http://concrete.nist.gov/~bentz/NIST.TN.1812.pdf)
- Best Practice for Using RAS in HMA – TTI (http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/0-6614-1.pdf)
- Foundry Sand Facts for Civil Engineers (http://isddc.dot.gov/OLPFiles/FHWA/011435.pdf)
- NCHRP Synthesis 435 – Recycled Materials and Byproducts in Highway Applications (http://www.trb.org/Publications/NCHRPSyn435.aspx)

Many resources are available for guidance and standards related to the use of recycled materials in transportation applications. These are available through FHWA, NCHRP, State agency research sections, industry groups and associations, and independent sources. These best practices typically include reference case studies, research efforts, guide specifications, and testing protocols.

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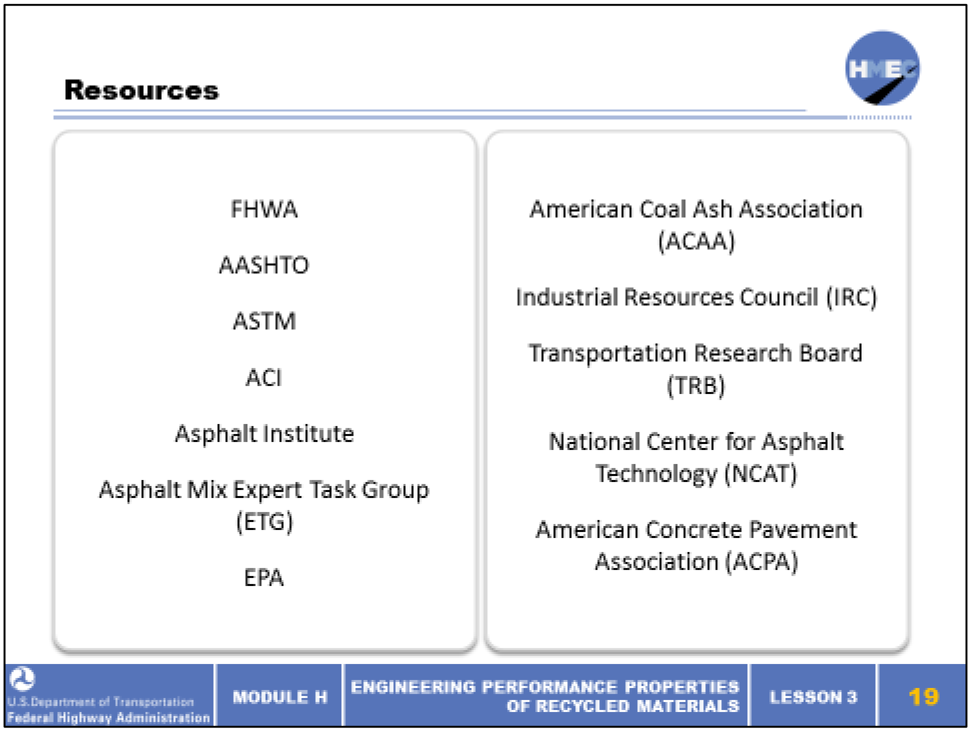

A partial listing of organizations with available resources are shown.

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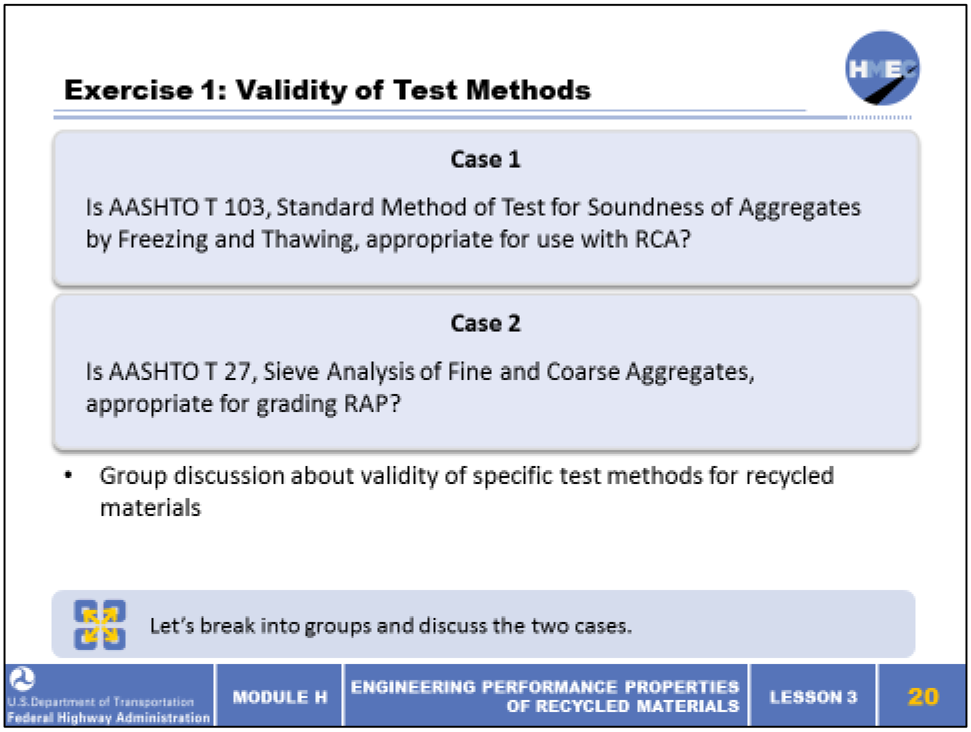
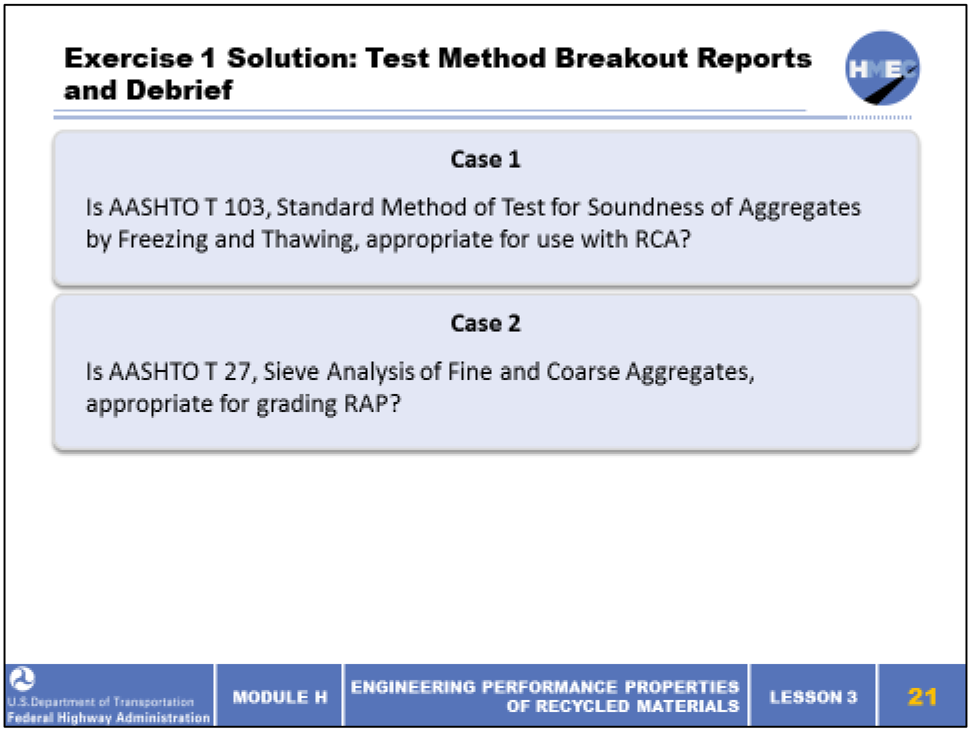


Are existing test methods always appropriate for use with recycled materials?

Slide 21


Exercise 1 Solution: Test Method Breakout Reports and Debrief
HMEC
Case 1
Is AASHTO T 103, Standard Method of Test for Soundness of Aggregates by Freezing and Thawing, appropriate for use with RCA?
Case 2
Is AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregates, appropriate for grading RAP?
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Learning Outcomes Review

You are now able to:

- Explain how specifications affect the use of recycled materials
- Relate performance properties of a recycled material to an intended use
- Evaluate a recycled material to assess its use as a replacement for other materials
- Evaluate existing specification requirements to determine applicability to an intended use of a recycled material
- Identify test methods that are appropriate for a variety of recycled materials
- Describe application standards, such as specifications and best practices, that are available for recycled materials

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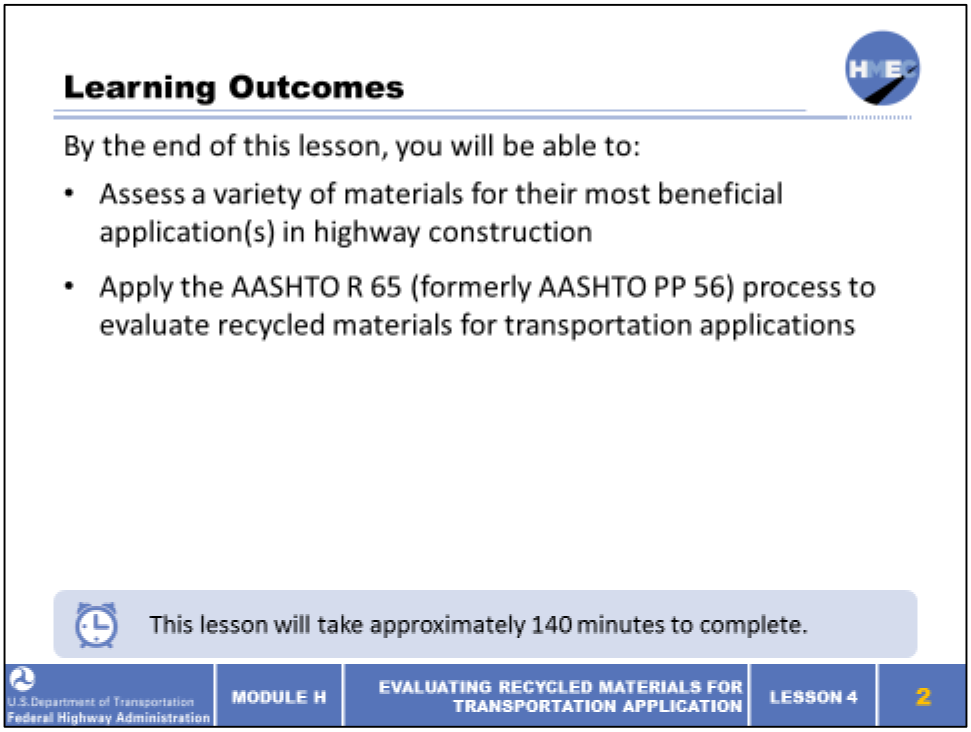
WCT
HMEC
Highway Materials Engineering Course
Lesson 4: Evaluating Recycled Materials for Transportation Application
Evaluating Recycled Materials for Beneficial Uses in Transportation Construction
U.S.Department of Transportation
Federal Highway Administration
MODULE
H

Slide 2


Learning Outcomes
HMEC
By the end of this lesson, you will be able to:
• Assess a variety of materials for their most beneficial application(s) in highway construction
• Apply the AASHTO R 65 (formerly AASHTO PP 56) process to evaluate recycled materials for transportation applications
This lesson will take approximately 140 minutes to complete.
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EVALUATING RECYCLED MATERIALS FOR TRANSPORTATION APPLICATION
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How do we go about assessing materials for their most beneficial use in transportation projects?

Example: Tire shreds. During the early uses of this recycled material, unanticipated failures occurred in a few locations, and rather than stop the use of the material, the failures were thoroughly evaluated and understood. Because of the understanding of the causes, the use of the material has continued to this day.

During the mid-1990s, the construction of embankments using tire shreds was becoming more common across the country. Three separate incidents involving the observation of steam escaping from cracks in the embankments, and ultimately the observation of flames, caused significant concern about the ability to continue this practice.

Although many embankments had been constructed across the country, two projects in the State of Washington, and one project in Colorado experienced an exothermic reaction and began emitting steam and visible flames after installation. Dr. Dana Humphrey conducted an investigation for FHWA and the report was published in March 1996 describing the results of his work.

Link to report: http://www.rma.org/download/scrap-tires/Civil%20Engineering/CIV-091-Investigation%20of%20Exothermic%20Reaction%20in%20Tire%20Shred%20Fill.pdf

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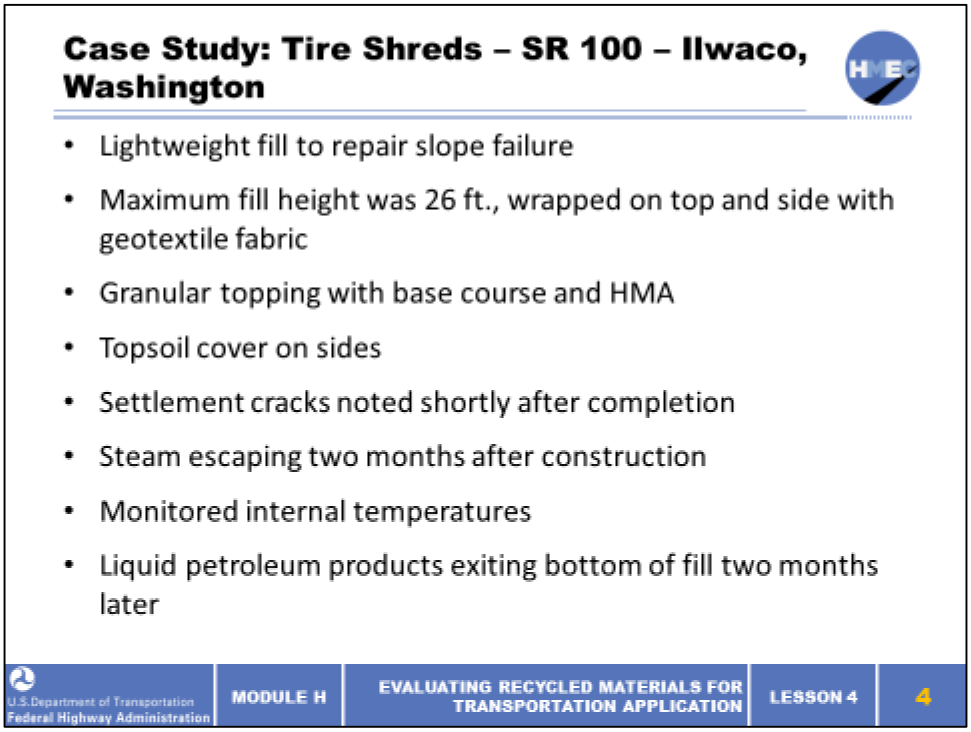

This is a case study for Ilwaco, Washington.

Tire shreds were used as a lightweight fill to repair a slide area on SR 100 in Ilwaco, Washington. The design used a 4-ft. thick blanket of stone at the bottom of the slide area, daylighting at the toe of the fill. The maximum thickness of the tire shred fill was 26 ft., and a geotextile was placed on the top and sides of the tire fill. Four ft. of granular fill was placed on the top, followed by an aggregate base course and a hot mix asphalt (HMA) pavement surface. The sides were covered with 2 ft. of topsoil.

The tire shreds were placed in 1–3-ft. lifts and compacted with passes of a 70,000-lb. bulldozer. A heavy rain was reported during the construction of the tire shred fill. The fill was completed in October 1995, and a crack in the pavement was noted in late December 1995. On January 3, 1996, steam was observed escaping through cracks and several weeks later, internal temperatures were recorded varying from 130–160 °F. In March 1996, liquid petroleum products were exiting the base of the fill.

The initial thoughts about what was happening was an exothermic reaction within the tire shreds.

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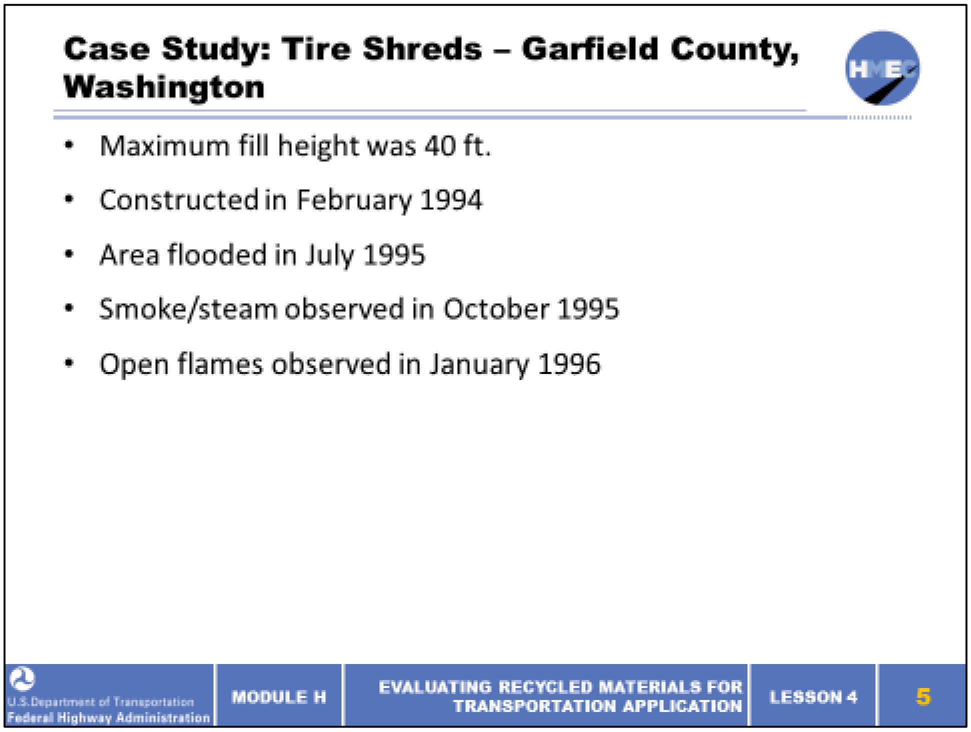

Second case study in Garfield County, Washington.

In Garfield County, Washington, another tire shred fill was constructed in February 1994 that had a 40-ft. maximum height. A flood was experienced in July 1995, and in October of that same year, smoke was reported venting through cracks in the fill. Steam venting continued and open flames were observed in January 1996.

Construction details were similar to the SR 100 project, although there were some variations.

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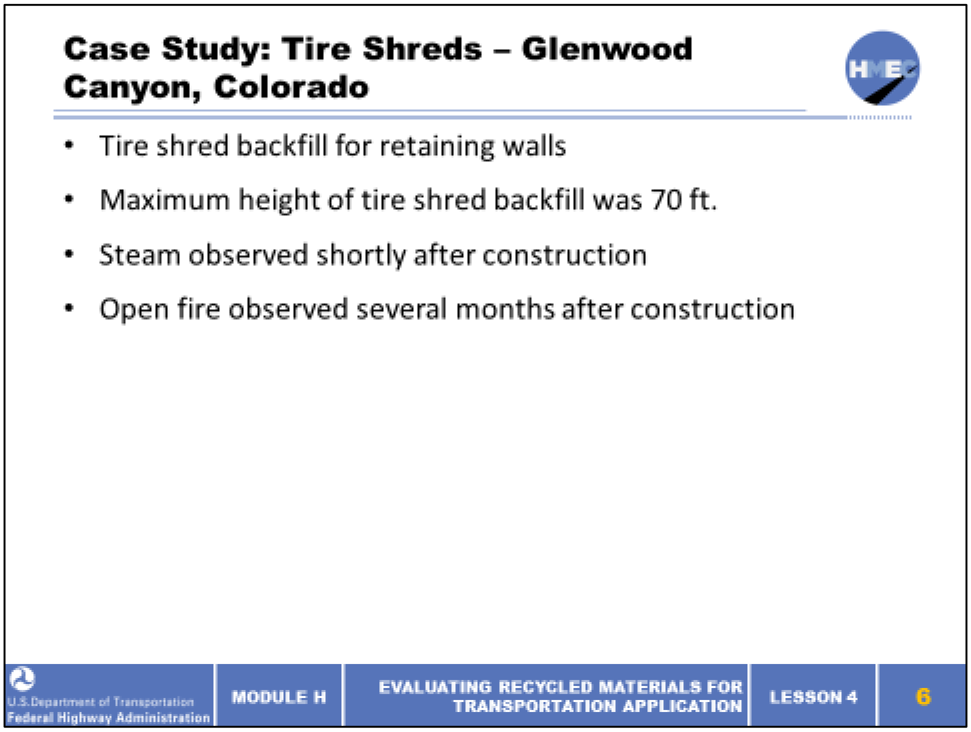

Third case study in Glenwood Canyon, Colorado.

Tire shreds were used as backfill for retaining walls, up to 70 ft. high. The walls and backfill were constructed during the middle of 1995. Steam was first observed during the summer of 1995, and on October 30, 1995, an open fire was observed in one location.

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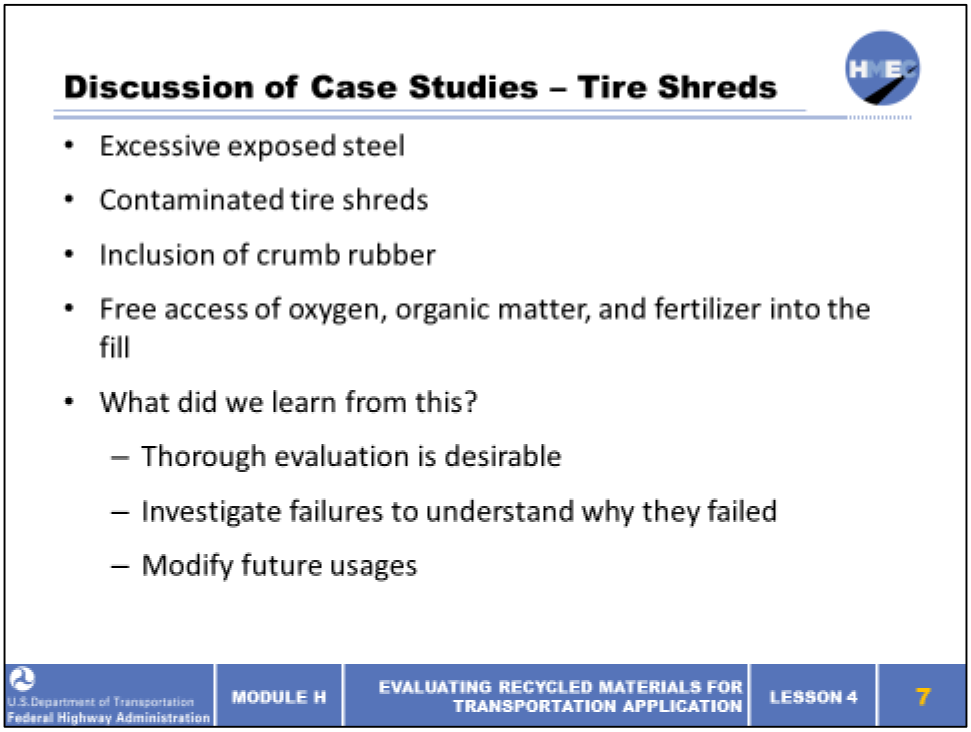

What happened in these case studies?

These incidents obviously created interest and concern for others using tire shreds in embankments across the nation; however, many embankments have been constructed before and after these incidents. The exact cause of the exothermic reaction in these tire shred fills remains unknown, but possible factors include:

- Excessive exposed steel;
- Tire shreds contaminated by liquid petroleum products;
- Inclusion of crumb rubber with the shreds; and/or
- Embankment design allowed free access of oxygen into the fill, along with organic matter and fertilizer.

Subsequent designs typically blend soil and tire shreds and no additional exothermic reactions have occurred.

What did we learn from the case studies? We need to make sure due diligence is followed during the evaluation stages. Even so, failures may occur and we should learn from them. Tire shred fills continue to be used today successfully. The existence of a failure should not necessarily lead to the conclusion to disallow the particular material again. Rather, the failure should be investigated and the allowable use modified to preclude similar failures in the future.

In North Carolina, we were concerned about the ability to compact pure tire shred layers, so we experimented in the laboratory with a blend of soil and shreds that we felt would allow the voids to be filled and the layer compacted to a reasonable degree. We also felt doing this would limit settlement and the intrusion of water. Although not a sophisticated analysis, we were lucky and never had significant issues with tire shred embankments. After the events in the case studies happened, we did monitor internal temperatures for several years and found no problems.

Other ways to minimize the possibility of exothermic reactions include:

- Limiting the thickness of lifts to minimize heating
- Screening out fines or other contaminates that could accelerate the reactions
- Taking action to keep out oxygen

Key take-away points from these case studies include:

- Maximum height of tire fill should be limited to about 10 feet. If the fill needs to go higher, then a soil buffer zone should be constructed tire lifts.
- Particle size of tire derived aggregate needs to be controlled.

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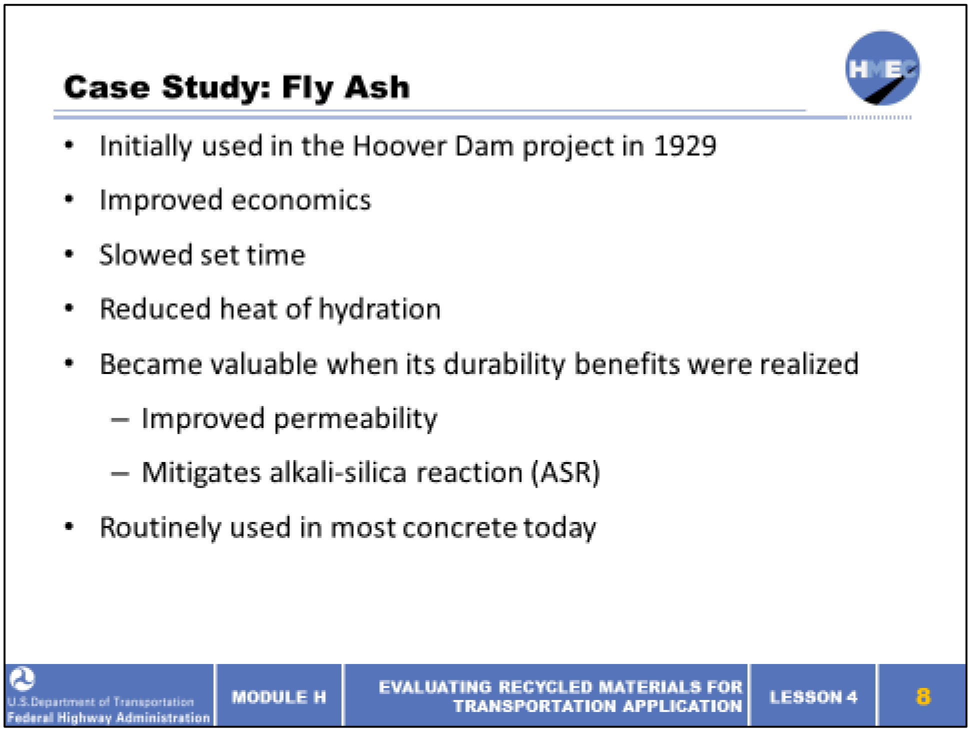

Although the Romans used ash in the production of ancient concrete, the first use in this country was at the Hoover Dam construction in 1929. It helped reduce the heat of hydration in mass concrete, therefore it was beneficial in that project. It was initially sometimes considered to be a way to reduce the cost of concrete by replacing some amount of cement with what was seen as a waste product.

The benefits of fly ash in concrete has been realized to be extremely beneficial over the past 30 years, and is now seen as a critical aspect of quality concrete. The use of fly ash, and other pozzolans, provides durability to modern concrete through a reduction in permeability and mitigation of certain reactions between cement and aggregates.

The replacement of the I-35 bridge in Minneapolis is a current example of where the technology has advanced. A combination of coal combustion products were used in significant quantities on this high profile, fast track project that drew national attention because of the collapse of the existing structure in August 2007. Fly ash and other pozzolans were used in concrete throughout the structure to reduce the heat of hydration, provide improved resistance to chloride penetration into the concrete, and is one factor that improved the overall durability of the replacement structure. Although fly ash is viewed as slowing down the strength gain in concrete, this structure was opened to the public in mid-September of 2008, putting to rest the notion that fly ash cannot be used on fast track projects in cold climates.

Fly ash use has advanced to be an important factor in producing sustainable, longer-lasting, and more durable concrete.

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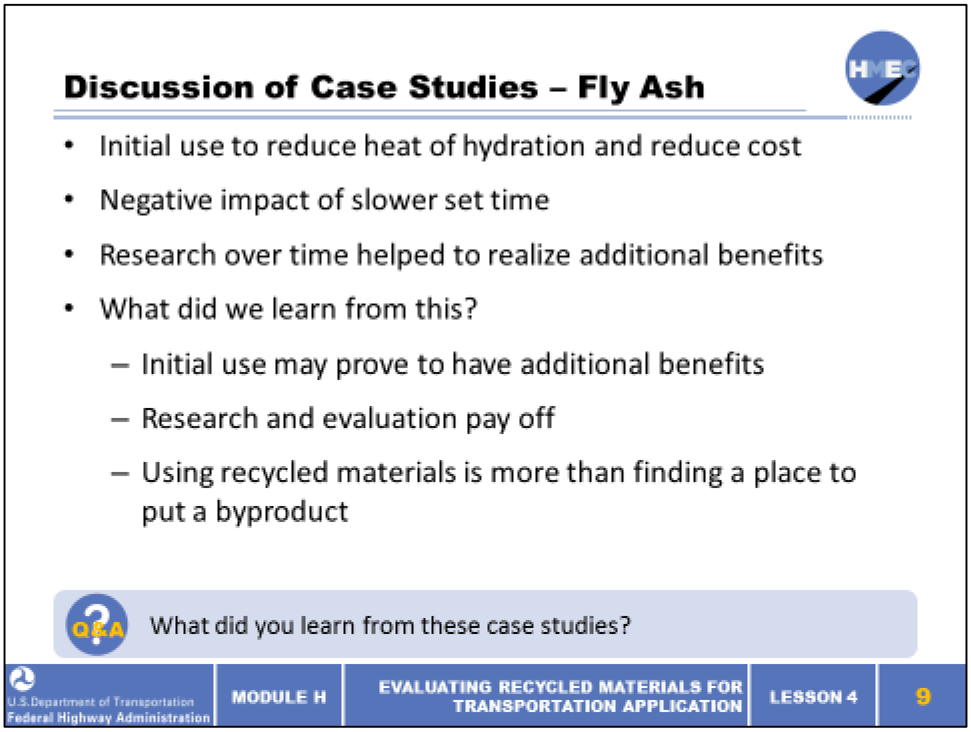

What happened in this case study?

The fly ash example exhibits a progression of the understanding of the true benefits about how ash contributes to the properties of the concrete. The early use in Hoover Dam was to reduce the heat of hydration and save costs. The increased set time was seen as a major drawback to its use.

Fly ash was not extensively used until the 70's other than for mass concrete. After that time, the added benefits of replacing some cement with fly ash were beginning to be better understood. Because of the size and shape of the fly ash particles, concrete mixtures were less permeable. Because of this, the intrusion of chlorides into the concrete is reduced which reduces the possibility of the chloride ions reaching reinforcing initiating corrosion and therefore cracking the concrete.

Through research, the reaction between the alkali in concrete and certain aggregates that caused severe durability issues with the concrete was better understood. Research also verified that the addition of fly ash could serve to mitigate these reactions and eliminate the cracking and subsequent degradation of the concrete. Continued research has expanded the knowledge base to understand that combinations of fly ash and other pozzolans can further enhance the quality and longevity of concrete.

Due to continued research and expanded use of coal combustion byproducts, the technology has evolved far beyond the early uses of reduction in the heat of hydration, accompanied by the nuisance of slow set times to being considered a valuable resource that significantly enhances the quality of concrete.

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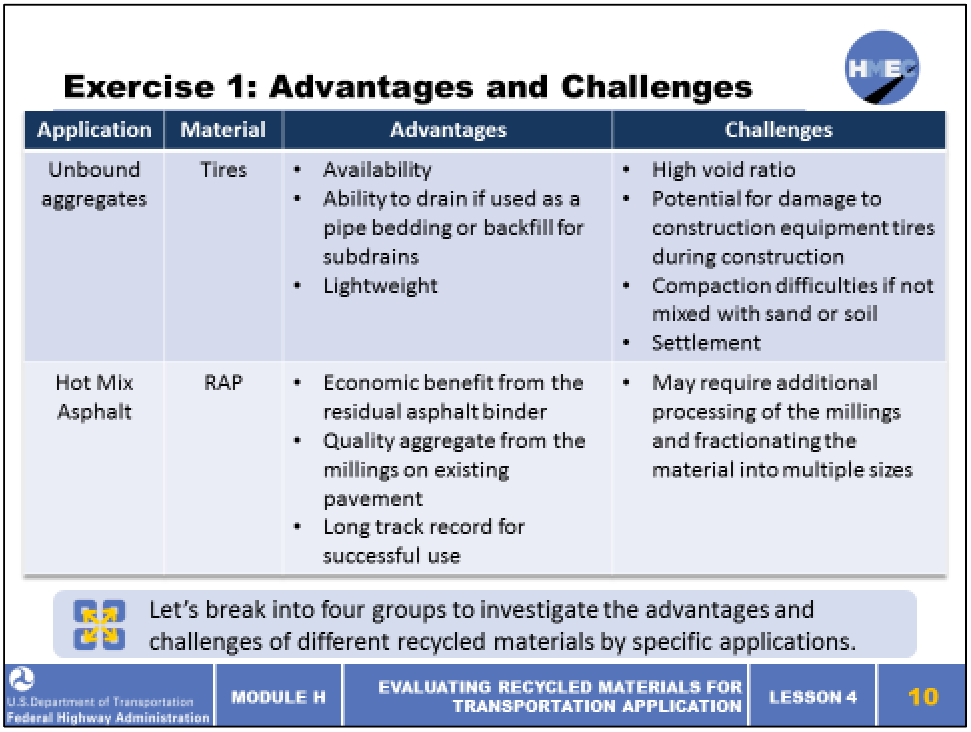

Application	Material	Advantages	Challenges
Unbound aggregates	Tires	• Availability • Ability to drain if used as a pipe bedding or backfill for subdrains • Lightweight	• High void ratio • Potential for damage to construction equipment tires during construction • Compaction difficulties if not mixed with sand or soil • Settlement
Hot Mix Asphalt	RAP	• Economic benefit from the residual asphalt binder • Quality aggregate from the millings on existing pavement • Long track record for successful use	• May require additional processing of the millings and fractionating the material into multiple sizes

Let's investigate the advantages and challenges of different recycled materials by specific applications.

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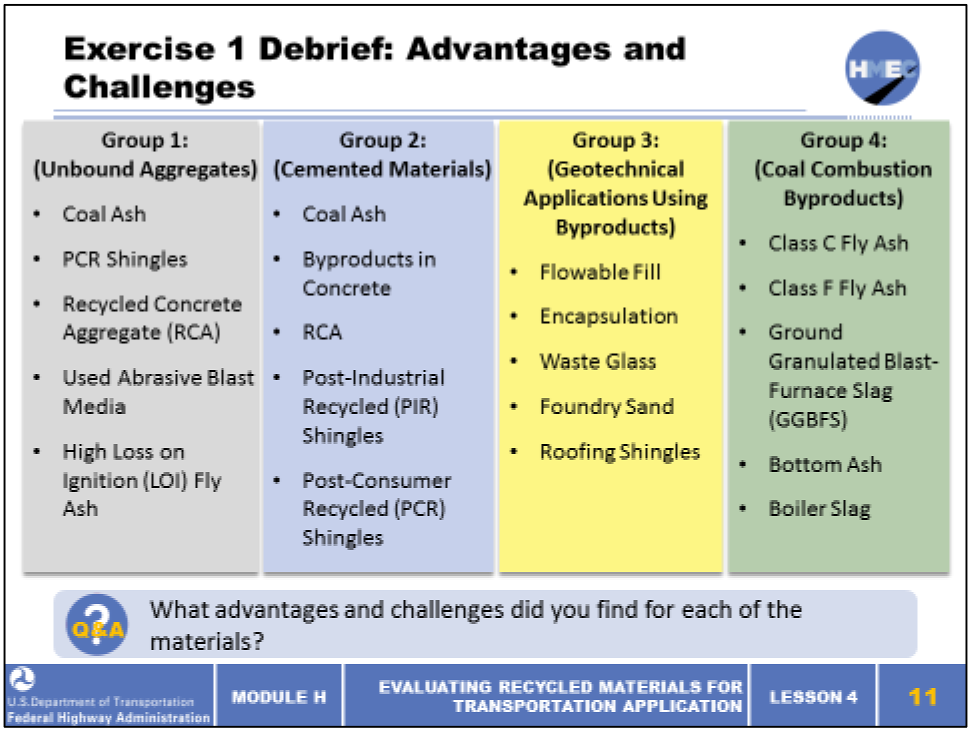
Application	Material	NCHRP Synthesis 435 Volume 1 Chapter Number	NCHRP Synthesis 435 Volume Number	Advantages	Challenges
Group 1:	Coal Ash	Chapters 3, 7 & 8	Volumes 2, 3, & 6		
Unbound	PCR Shingles				
Base Materials	RCA				
	Used Abrasive Blast Media				
	High LOA Fly Ash				
Group 2:	Coal Ash	Chapters 3, 7, & 9	Volumes 2, 6, 7, & 8		
Cemented	Byproducts in Concrete				
Materials	RCA				
	PIR Shingles				
	PCR Shingles				
Group 3:	Flowable Fill	Chapters 4, 7, & 9	Volumes 2, & 8		
Geotechnical	Encapsulation to prevent leaching				
Applications	Waste Glass				
Using	Foundry Sand				
Byproducts	Roofing Shingles				
Group 4:	Type C Fly Ash	Chapter 3	Volume 2		
Coal	Type F Fly Ash				
Combustion	GGBFS				
Byproducts	Bottom Ash				
	Boiler Slag				

Slide 11


Exercise 1 Debrief: Advantages and Challenges
HMEC
Group 1:
(Unbound Aggregates)
• Coal Ash
• PCR Shingles
• Recycled Concrete Aggregate (RCA)
• Used Abrasive Blast Media
• High Loss on Ignition (LOI) Fly Ash
Group 2:
(Cemented Materials)
• Coal Ash
• Byproducts in Concrete
• RCA
• Post-Industrial Recycled (PIR) Shingles
• Post-Consumer Recycled (PCR) Shingles
Group 3:
(Geotechnical Applications Using Byproducts)
• Flowable Fill
• Encapsulation
• Waste Glass
• Foundry Sand
• Roofing Shingles
Group 4:
(Coal Combustion Byproducts)
• Class C Fly Ash
• Class F Fly Ash
• Ground Granulated Blast-Furnace Slag (GGBFS)
• Bottom Ash
• Boiler Slag
Q&A
What advantages and challenges did you find for each of the materials?
U.S. Department of Transportation
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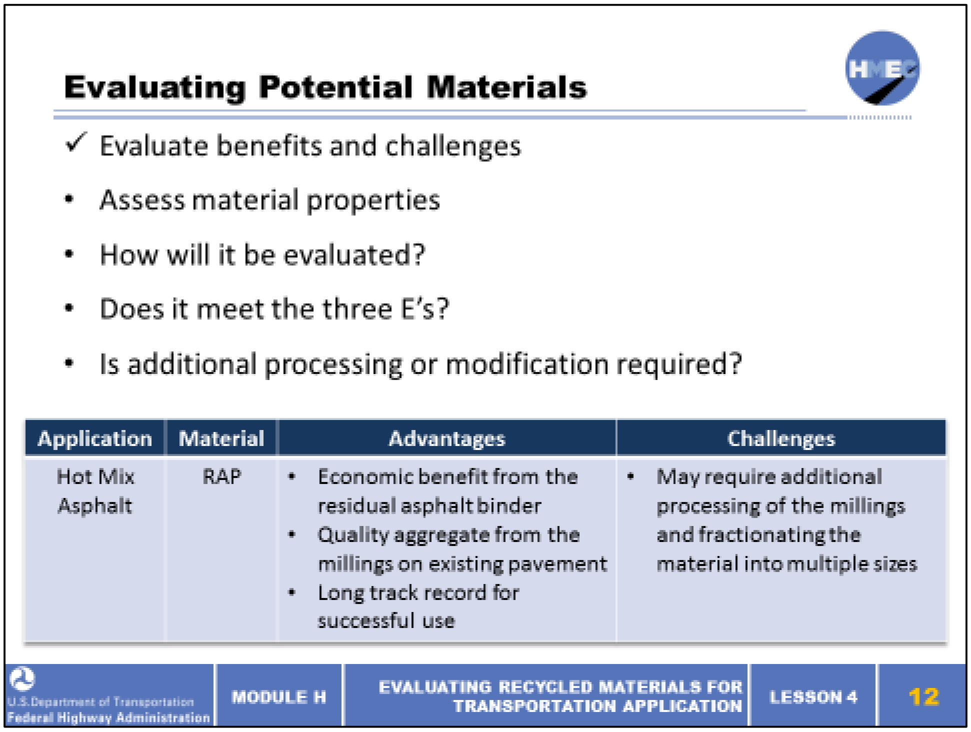
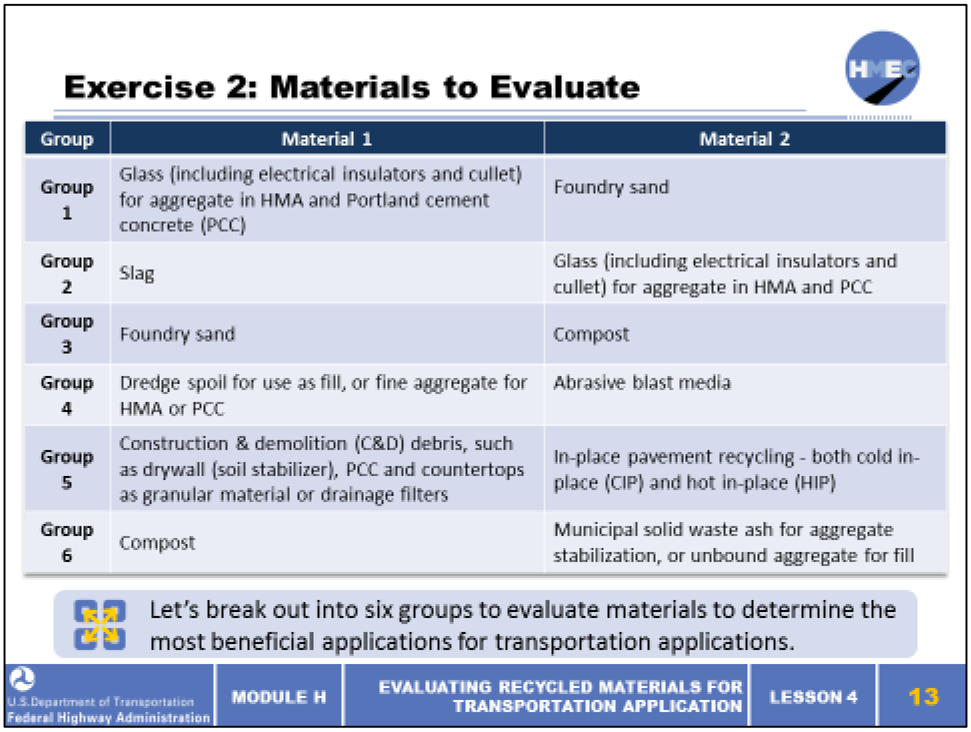
Slide 12



Developing a listing of advantages and challenges is a starting point toward evaluating the appropriateness of a recycled material for a proposed beneficial application. After weighing advantages (or benefits) and challenges of a particular material for a given application, the next steps include:

- Assessing the material properties;
- Determining how it will be evaluated (test methods or performance characteristics);
- Deciding if it makes environmental, economic, and engineering sense to proceed; and
- Figuring out if the material requires additional processing or modification prior to being approved.

Slide 13



Group	Material 1	Material 2
Group 1	Glass (including electrical insulators and cullet) for aggregate in HMA and Portland cement concrete (PCC)	Foundry sand
Group 2	Slag	Glass (including electrical insulators and cullet) for aggregate in HMA and PCC
Group 3	Foundry sand	Compost
Group 4	Dredge spoil for use as fill, or fine aggregate for HMA or PCC	Abrasive blast media
Group 5	Construction & demolition (C&D) debris, such as drywall (soil stabilizer), PCC and countertops as granular material or drainage filters	In-place pavement recycling - both cold in-place (CIP) and hot in-place (HIP)
Group 6	Compost	Municipal solid waste ash for aggregate stabilization, or unbound aggregate for fill

Putting these concepts to practice, evaluate materials to determine the most beneficial applications for transportation applications.

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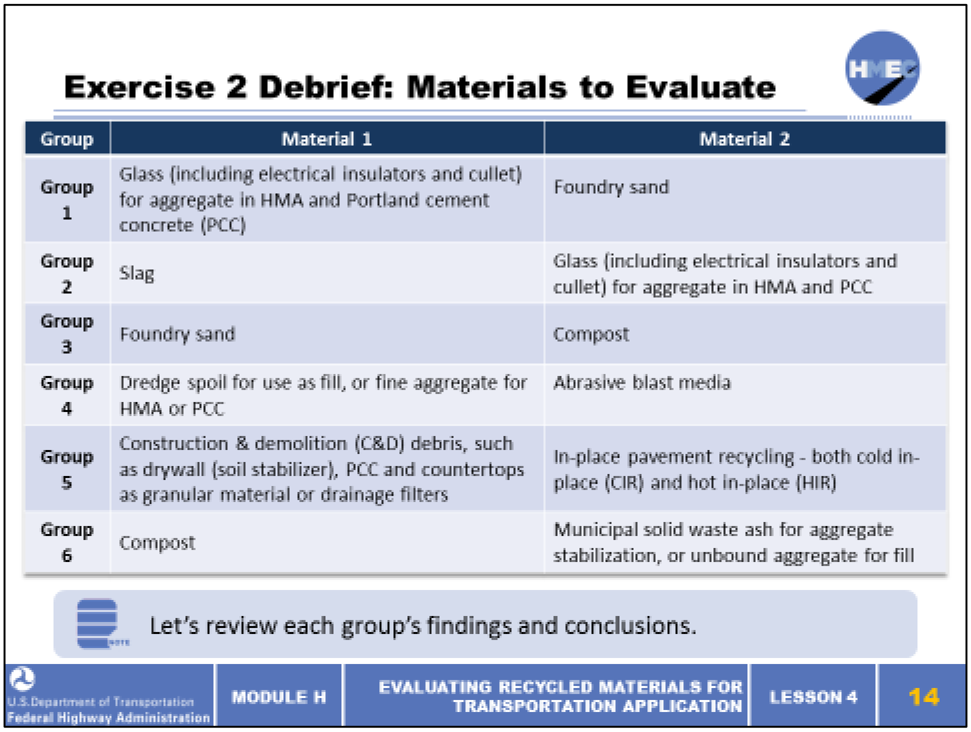
Slide 14


Exercise 2 Debrief: Materials to Evaluate

Group	Material 1	Material 2
Group 1	Glass (including electrical insulators and cullet) for aggregate in HMA and Portland cement concrete (PCC)	Foundry sand
Group 2	Slag	Glass (including electrical insulators and cullet) for aggregate in HMA and PCC
Group 3	Foundry sand	Compost
Group 4	Dredge spoil for use as fill, or fine aggregate for HMA or PCC	Abrasive blast media
Group 5	Construction & demolition (C&D) debris, such as drywall (soil stabilizer), PCC and countertops as granular material or drainage filters	In-place pavement recycling - both cold in-place (CIR) and hot in-place (HIR)
Group 6	Compost	Municipal solid waste ash for aggregate stabilization, or unbound aggregate for fill

Let's review each group's findings and conclusions.
U.S. Department of Transportation
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MODULE H
EVALUATING RECYCLED MATERIALS FOR TRANSPORTATION APPLICATION
LESSON 4
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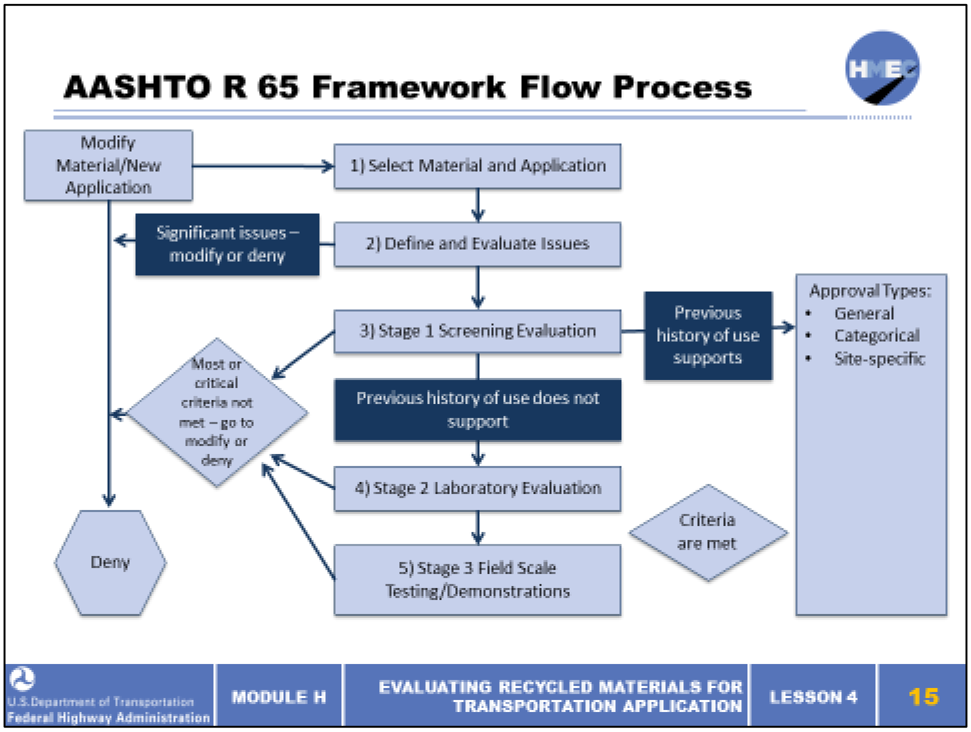
Slide 15



AASHTO has a standard practice that provides guidance for evaluating the engineering and environmental suitability of recycled materials, which is displayed on this slide.

AASHTO R 65 (formerly PP 56) is titled "Evaluating the Engineering and Environmental Suitability of Recycled Materials." The standard practice provides a five-step flowchart for the evaluation of recycled materials as well as detailed descriptions guiding users through the details of each step. The overall flowchart is shown as Figure 1.

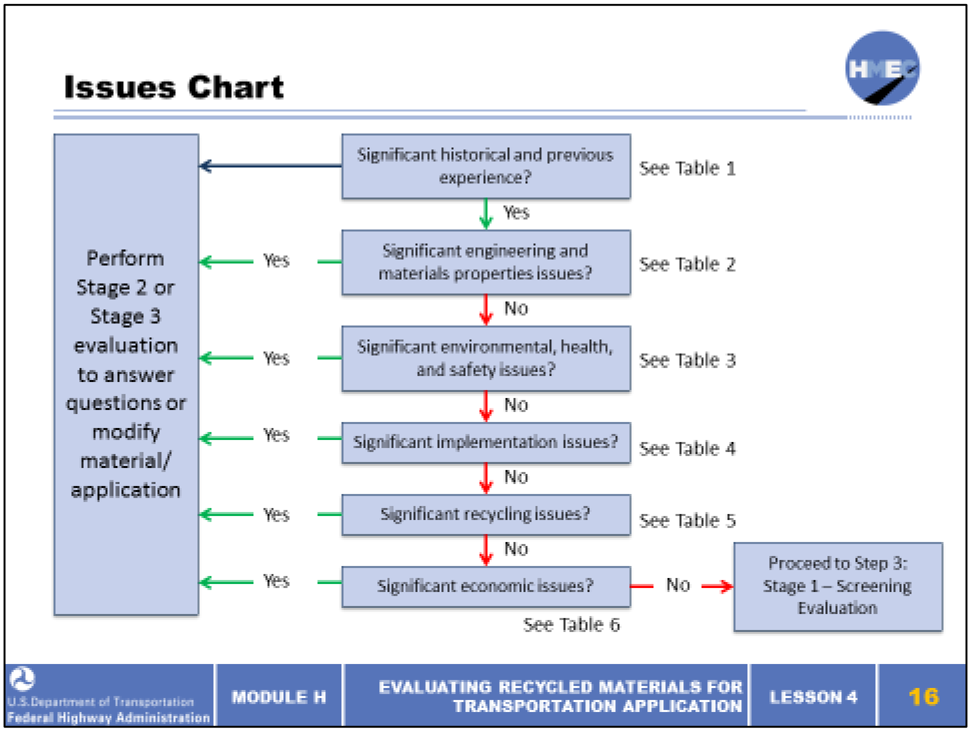
The overview of the AASHTO evaluation process is shown in this figure, and it is also included in the standard practice. It is a straightforward, five-step process as follows:

1. Select a material and a specific application;
2. Define and evaluate all issues that may warrant more detailed examination (benefits and challenges). Tables 1 through 6 in the standard practice provide more detailed guidance and checklists to ensure that proper information is collected;
3. Perform a Stage 1 screening to determine if the information collected in Step 2 is sufficient to justify acceptance (or rejection) of the proposed application without additional study;

4. Perform a Stage 2 laboratory evaluation if deemed warranted in Step 3 to better characterize the engineering and environmental properties of the material; and
5. Perform a Stage 3 field-scale testing or demonstration, if necessary.

Approval can occur at Stages 1, 2, or 3 of the evaluation process depending on the performance of the material from either known history or comparison with the criteria and the specification requirements for the material that it is replacing. Both technical evaluation and engineering judgment are used to make the decision about whether the material should be allowed. Following the steps in the standard practice does provide guidance that leads to a reasonable decision being made, although it is not without some level of risk.

Slide 16



AASHTO R 65 provides additional detail for the evaluation of Step 2 as shown here.

The standard practice gives more detail about evaluating the issues in Step 2 to assist in the decision making process. A series of steps guide the user towards a decision about whether additional screening evaluations are needed. These steps include the following issues:

1. Does significant historical and previous experience exist?
2. Are there significant engineering and materials properties?
3. Are there significant environmental, health, and safety issues?
4. Do significant implementation issues exist?
5. Are there significant recycling issues?
6. Do significant economic issues exist?

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Table 2—Engineering and Material Properties Questions

General Area	General Questions	
Engineering	1. Is information available about the engineering properties of the recycled material? This could include information about gradation, bulk density, durability, and compaction data. If so, collect the pertinent information.	Y N
	2. Is the recycled materials appropriately characterized with respect to time-dependent engineering properties? This could include time-dependent variation in gradation, bulk density, durability, and compaction. If so, collect the pertinent information.	Y N
	3. For the proposed application, are there appropriate engineering criteria for the product? This could include durability, grain size, and compaction requirements. If so, collect the pertinent information.	Y N
	4. Is engineering information available about important prior experiences (previous use, prior performance criteria, and similarity with other materials)? If so, assemble the pertinent information.	Y N
Materials Properties	1. Is information available about the material properties of the recycled material? This could include information about loss on ignition, mineralogy, and pozzolanic activity of the waste material. If so, summarize the data.	Y N
	2. Is the recycled material appropriately characterized with respect to time-dependent materials properties? If so, summarize the data.	Y N
	3. For the proposed application, are there appropriate material properties criteria for the product? If so, identify the criteria.	Y N

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Moving from the issues chart, a series of tables exist that probe into general questions and considerations as the evaluation continues. For instance, Table 2 helps look into the engineering and properties of the material being considered with a series of yes or no questions. Proceeding through the process will guide users towards a decision about whether or not to proceed evaluating the use of the material in question. The Appendix provides a detailed example of how to use this framework to evaluate the appropriateness of the material for use.

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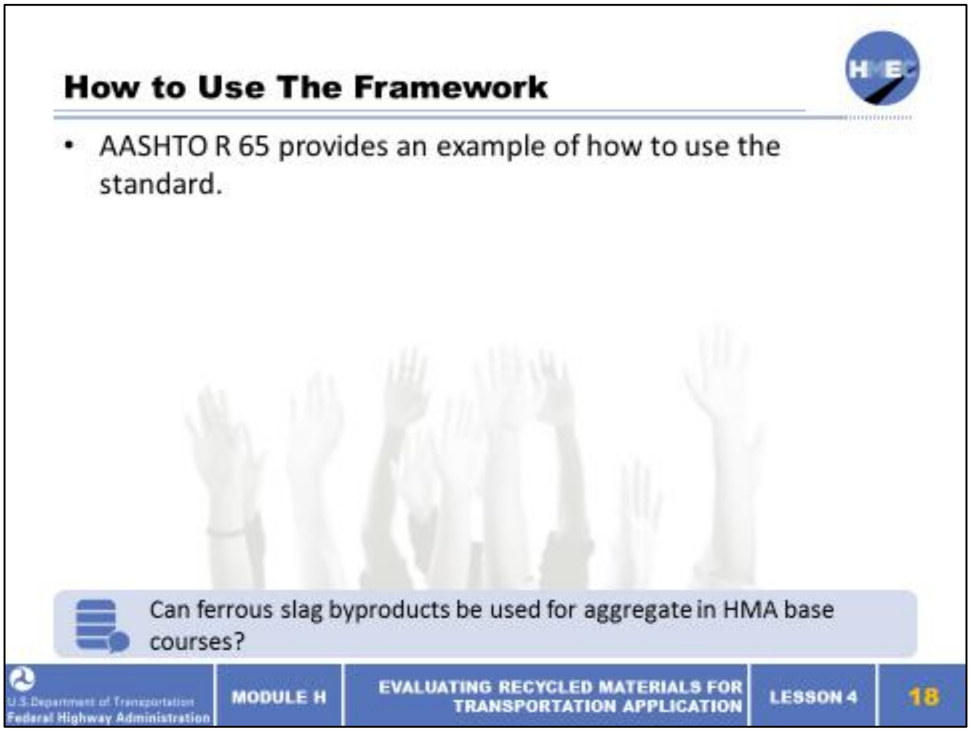
Slide 18


How to Use The Framework
AASHTO R 65 provides an example of how to use the standard.
Can ferrous slag byproducts be used for aggregate in HMA base courses?
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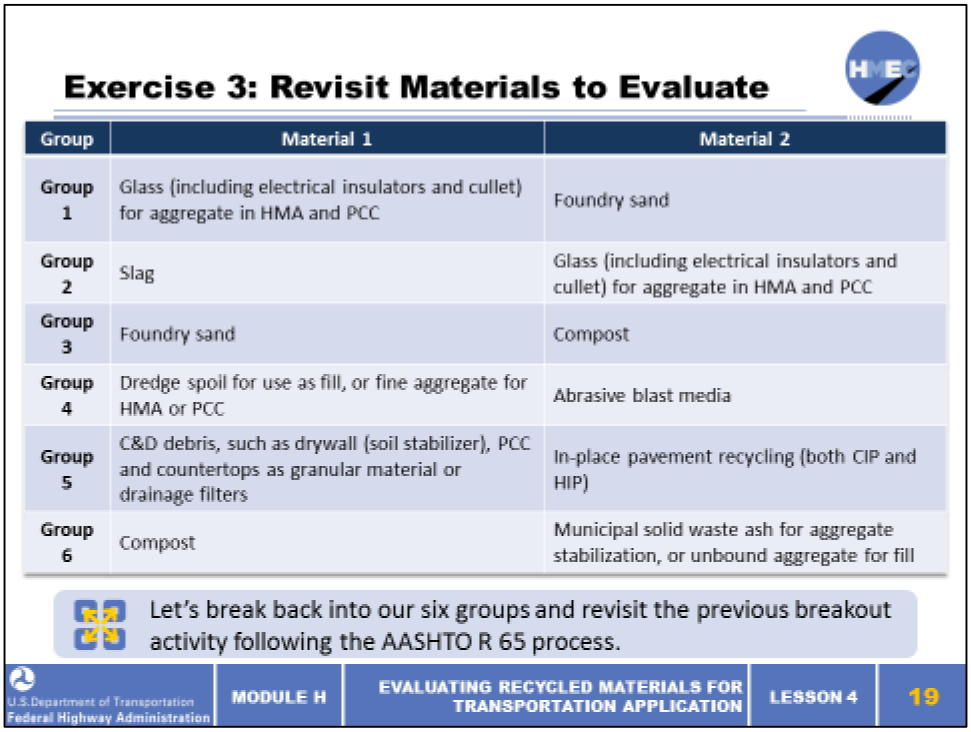
Slide 19



Exercise 3: Revisit Materials to Evaluate

Group	Material 1	Material 2
Group 1	Glass (including electrical insulators and cullet) for aggregate in HMA and PCC	Foundry sand
Group 2	Slag	Glass (including electrical insulators and cullet) for aggregate in HMA and PCC
Group 3	Foundry sand	Compost
Group 4	Dredge spoil for use as fill, or fine aggregate for HMA or PCC	Abrasive blast media
Group 5	C&D debris, such as drywall (soil stabilizer), PCC and countertops as granular material or drainage filters	In-place pavement recycling (both CIP and HIP)
Group 6	Compost	Municipal solid waste ash for aggregate stabilization, or unbound aggregate for fill

Let's break back into our six groups and revisit the previous breakout activity following the AASHTO R 65 process.

Slide 20

Exercise 3 Debrief: Revisit Materials to Evaluate

Group	Material 1	Material 2
Group 1	Glass (including electrical insulators and cullet) for aggregate in HMA and PCC	Foundry sand
Group 2	Slag	Glass (including electrical insulators and cullet) for aggregate in HMA and PCC
Group 3	Foundry sand	Compost
Group 4	Dredge spoil for use as fill, or fine aggregate for HMA or PCC	Abrasive blast media
Group 5	C&D debris, such as drywall (soil stabilizer), PCC and countertops as granular material or drainage filters	In-place pavement recycling (both CIP and HIP)
Group 6	Compost	Municipal solid waste ash for aggregate stabilization, or unbound aggregate for fill

Let's review your group's findings.

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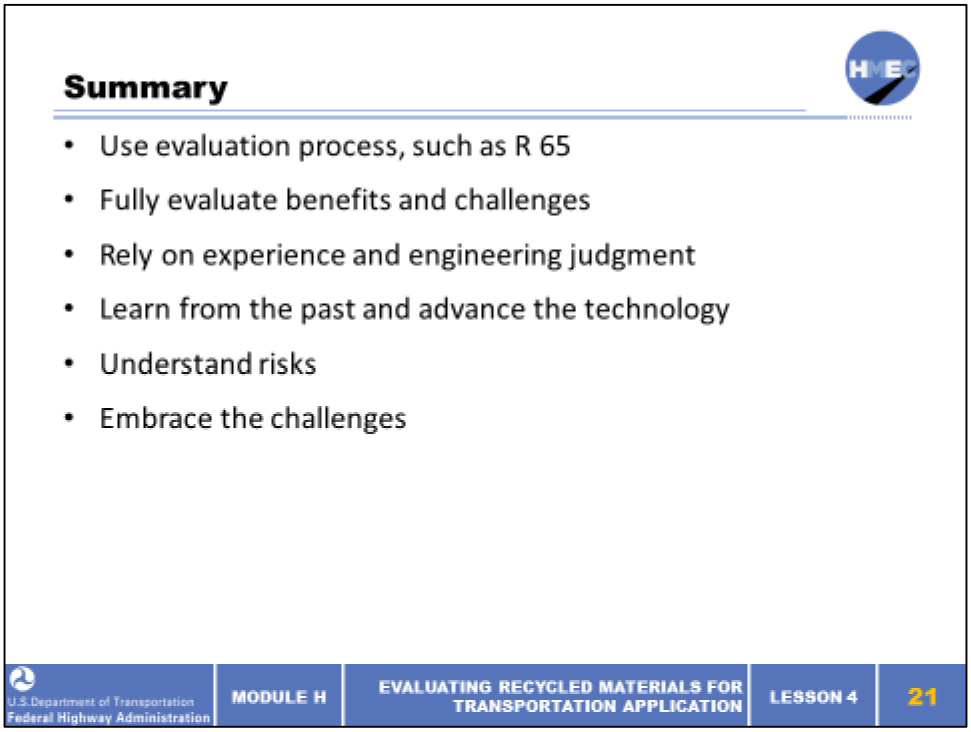
Slide 21



When considering proposed applications for recycled materials, a standard evaluation process is recommended to make attempts to fully assess all facets of the proposal. R 65 offers such a framework that when coupled with sound engineering judgment, can lead to sound decisions relative to appropriate uses. The details of an evaluation will differ by both proposed material and application, but the generic framework used should be adapted for the material being considered.

When considering the use of recycled materials, or any new material for that matter, you should be thorough and follow a logical path towards a decision. AASHTO R 65 provides such a pathway that can guide users to a reasonable decision about the appropriate use of a material for a particular application. Any process requires the use of engineering judgment in reaching the final decision, and is not without some element of risk. If an initial failure is experienced, that alone should not preclude further consideration. The example given about tire shred fills certainly supports this. Although the combination of high fills using tire shreds allowed oxygen, water, and other chemicals free access to the fill, many other successful tire shred embankments were installed prior to those events, and many more have been successfully installed subsequent to that date. A basic engineering premise is to learn from projects that did not go as planned, make future modifications, and continue to move forward.

The use of recycled materials has made tremendous advances since the early Roman times, and by the use of sound engineering and methodically evaluating new materials and uses for them will continue that advancement. Although challenges exist, we need to embrace the challenges and be a part of the movement towards a more sustainable future for transportation construction.

Slide 22

Learning Outcomes Review

You are now able to:

- Assess a variety of materials for their most beneficial application(s) in highway construction
- Apply the AASHTO R 65 process to evaluate recycled materials for transportation applications

Q&A Does anyone have any questions?

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HMEC
Highway Materials Engineering Course
Lesson 5: Addressing the Public Perception
MODULE
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Evaluating Recycled Materials for Beneficial Uses in Transportation Construction
U.S.Department of Transportation
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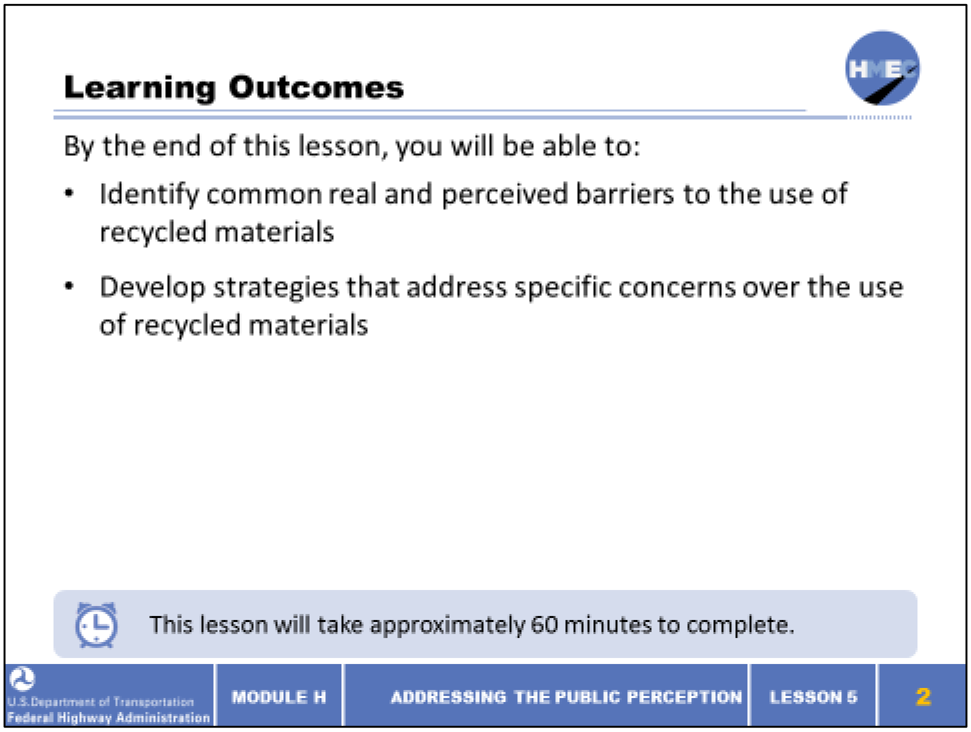
Learning Outcomes
By the end of this lesson, you will be able to:
• Identify common real and perceived barriers to the use of recycled materials
• Develop strategies that address specific concerns over the use of recycled materials
This lesson will take approximately 60 minutes to complete.
U.S. Department of Transportation
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ADDRESSING THE PUBLIC PERCEPTION
LESSON 5
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Slide 3

Likely everyone has witnessed the impact of public perception barriers related to the use of recycled materials. The public perception may generally look towards the use of certain recycled materials in a favorable manner, such as the use of recycled water in rest areas and welcome centers to nurture landscaping. However, if recycled waste water was proposed to be provided to residential users through the existing water distribution system for drinking purposes, public perception would likely change quickly. When it becomes personal, viewpoints will often change.

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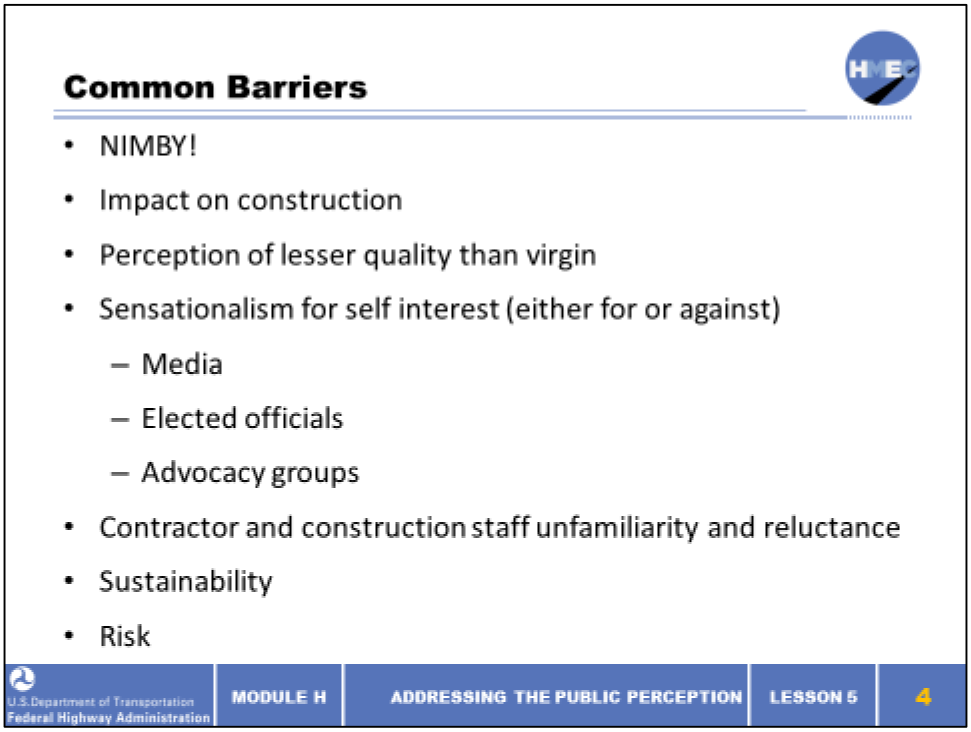
Slide 4



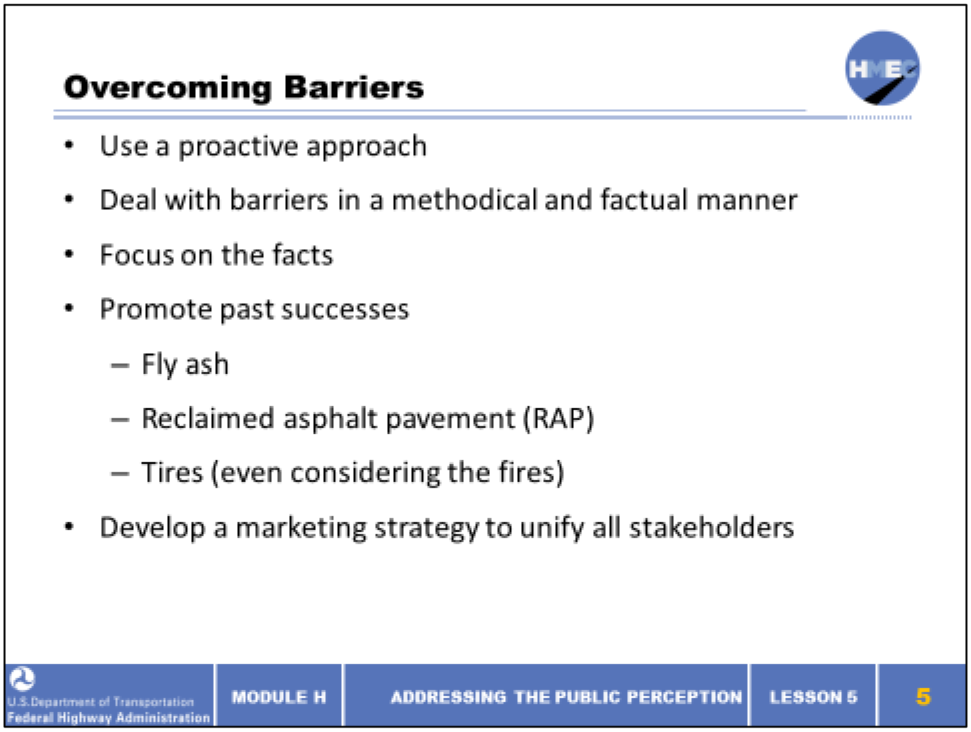
Common barriers and perceptions to the use of recycled materials exist, and a perception may become a reality if not properly addressed.

Barriers include:

• NIMBY! Although the idea of recycling and sustainability might appeal to the general public, that perception might change if it is close to home. Recycling is something that should be done… somewhere else. Reasons given may include:
  - Safety and health concerns;
  - Objectionable qualities such as smell, visually unappealing, etc.; or
  - Concern about impact on property value.
• Impact on the construction process
• The perception that recycled materials are of a lesser quality or value than virgin, including:
  - Concern about life cycle.
• Sensationalism (either for or against) for self-interests:
  - Media may either be supportive of the idea, or negative about the impact;
  - Elected officials can greatly help, or hinder, the use depending on their view; and
  - Advocacy groups can also greatly help, or hinder, the use depending on their view.

- Contractor and construction staff unfamiliarity and reluctance:
    - Uncertainty with use of a new material; and
    - Concerns about impact on schedule.
- Sustainability
    - Uncertainty about future use of a previously recycled material.
- Risk (factual or perceived):
    - Risk to contractor;
    - Risk to traveling public; and
    - Risk to neighbors (at production site and project location).

Slide 5



How do we overcome these barriers, particularly those that are perceptions rather than fact?

Take a proactive approach to the use of recycled materials. Attempt to deal with barriers in a methodical and factual manner. Remember the evaluation process we learned with AASHTO R 65, and focus on the facts.

Consider the successes for recycled materials that faced and overcame barriers in the past and are now routine practices in the construction of transportation facilities. Reclaimed asphalt pavement (RAP) and fly ash initially had negative perceptions in some cases and are now embraced as beneficial, economical, and are a part of sustainable construction activities. The cost/benefit of using recycled materials can also be highlighted to show how the appropriate use of recycled materials may result in a cost savings which can translate into being able to do more on a project, or to do a better job resulting in an increased service life.

Because coal is used as fuel for many purposes, large volumes of fly ash and other combustion byproducts exist. The value added as a component of concrete produces a better quality and longer life span. The use of fly ash in concrete began in mass concrete to reduce the heat of hydration, and over time has become a routine valuable component of concrete that enhances the quality and durability of in place concrete. High volume fly ash mixes are common today as a part of a sustainable construction strategy.

RAP is an economical and available source of both aggregate and residual asphalt binder in the production of hot mix asphalt. The use of RAP leveled out at around 15% of the mix for many years, but advances in knowledge and technology have allowed for dramatic increases in the amount of RAP incorporated in mixes. Fractionation of the RAP into different sizes and blending it back into mixes in a similar manner to how virgin aggregates are treated has allowed contractors to use more of it and produce a more uniform mixture.

Approximately one tire per person in the United States enters the waste stream each year (approximately 300 million), and using them as tire-derived fuel and in tire shred embankments is a beneficial and economical way to avoid placing them in landfills.

Agencies should use effective marketing techniques to inform the public and contractors about the benefits, and potential cost savings by effectively using recycled materials where practical from engineering, environmental, and economic perspectives. Significant research, testing, monitoring, and evaluations are conducted before pushing the limits on expanding the use of existing recycled materials. Developing an effective marketing strategy related to the use of recycled materials can unify all stakeholders and change negative perceptions into positive ones.

Slide 6

The EPA had a program offering funds for marketing efforts related to expanding recycling efforts. In the early 2000's a Roofs to Roads effort was established and several states and local agencies took advantage of the grants to promote and try using tear off shingles in hot mix asphalt. Marketing strategies are effective, but the promotion of marketing efforts should be balanced by the impact of using the materials. The use of shingles does introduce the possibility of cracking issues, particularly in colder climates.

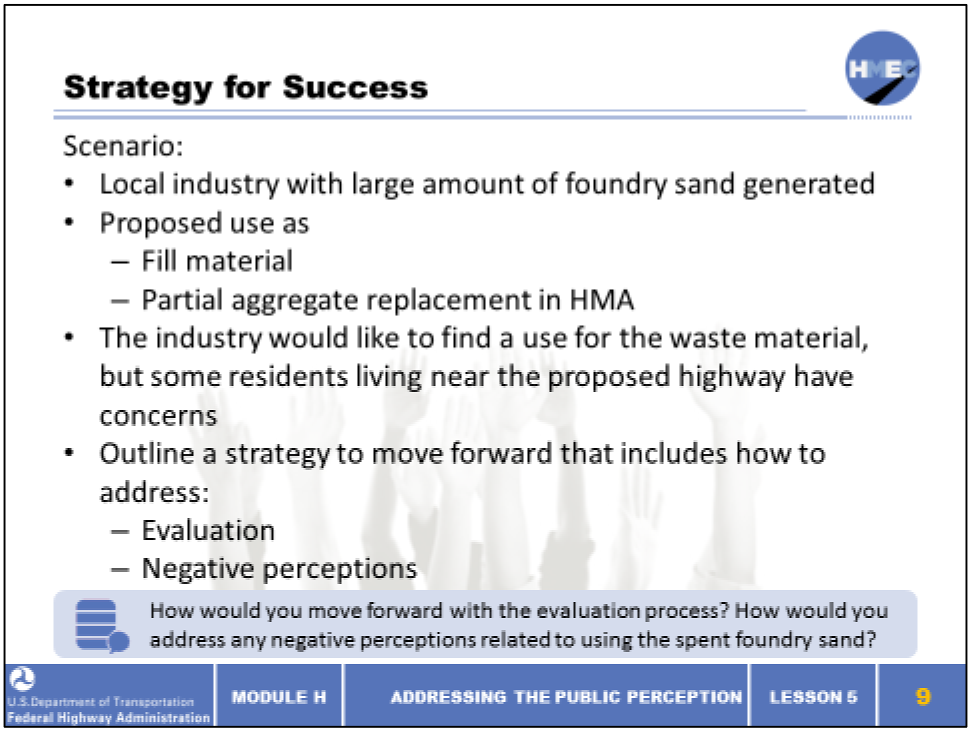
Slide 7

Traditionally, engineers and public agencies focus on solving problems and providing services to their customers and do not use marketing strategies to highlight the sustainability initiatives that are routinely being used. This is a group exercise whereby participants discuss ways that transportation agencies can do a better job of marketing the appropriate use of recycled materials in the future.

Slide 8

Engineers and transportation agencies do not market themselves well for a variety of reasons. How can we change that?

Slide 9



How could a focused marketing effort help with the perception of using a new recycled material?

Consider a situation where a local industry has a large volume of some byproduct from their manufacturing process. The industry is involved in using castings in their process and has a large foundry on site that results in a large volume of spent foundry sand generated annually.

A major highway project is being proposed in the vicinity of this industry, and the contractor is proposing to use the waste foundry sand in the embankment and as an aggregate replacement in the asphalt pavement.

Obviously, the industry would like to find a use for the waste material, but some residents living near the proposed highway have concerns.

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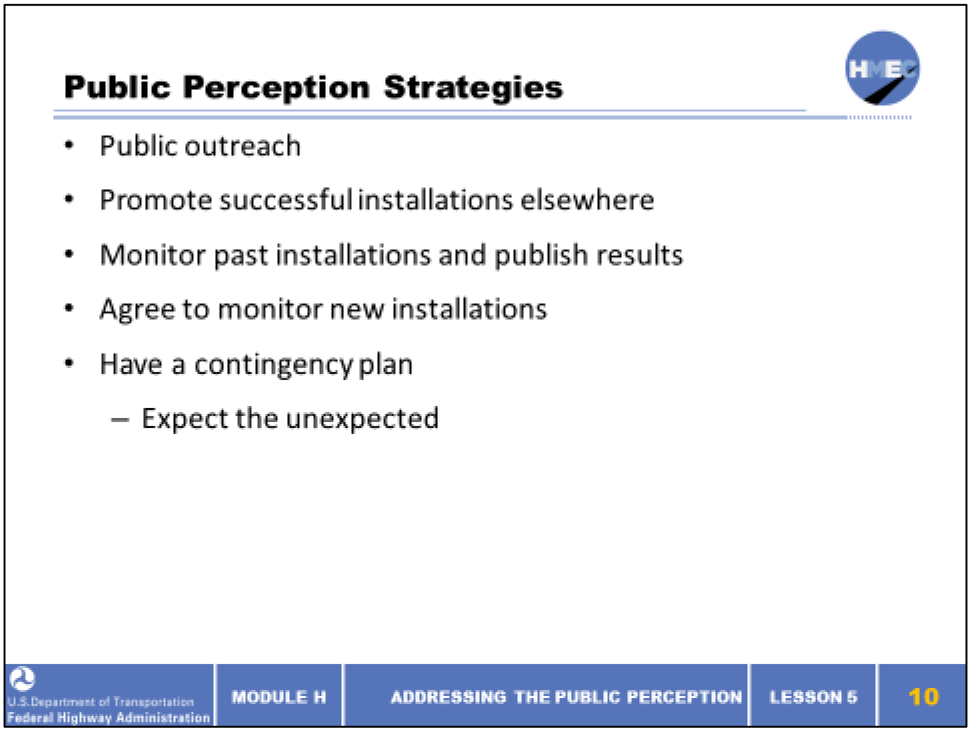
Slide 10



The use of some type of public outreach can help shape public perception, particularly if a consistent message is delivered by the transportation agency and other stakeholders. A proactive informational promotion can help citizens understand the benefits of using recycled materials in a beneficial manner.

Consider the situation where an industrial byproduct is being stockpiled and is either creating an eyesore, or allowing runoff to impact surrounding areas. Using an appropriate means to either encapsulate the material into a pavement or other application in the system can be marketed positively. The outreach should acknowledge the problem that the existing stockpiled material is creating, and clearly explain how the material will be either transformed or encapsulated such that any impact can be mitigated. The use could also be more economical, thereby creating a true win-win situation.

If the recycled material is being transported from another location, or another State, regulatory issues may come into play and should be addressed. A detailed public outreach program can help explain the sustainability benefits of using this material and help to break down resistance.

Part of the public outreach should include detailed factual information about successful installations using the material in other locations, including any monitoring that has been performed at the other locations. This information can be obtained through building relationships with peers in other States, published research, and various organizations and industry associations involved in recycling. The cost/benefit of using recycled materials can also be highlighted to show how the appropriate use of recycled materials may result in a cost savings which can translate into being able to do more on a project, or to do a better job resulting in an increased service life.

If concerns exist, agree to monitor the installation for an appropriate length of time. For example, if leaching concerns exist, agree to monitor groundwater for a period of time. If tire shreds are used in an embankment, agree to monitor both the groundwater for potential leaching, and internal temperature of the fill to calm any concerns about an exothermic reaction.

For the first use of a recycled material, or any new material virgin or recycled for that matter, some degree of follow up should be used along with a contingency plan if an early failure is identified.

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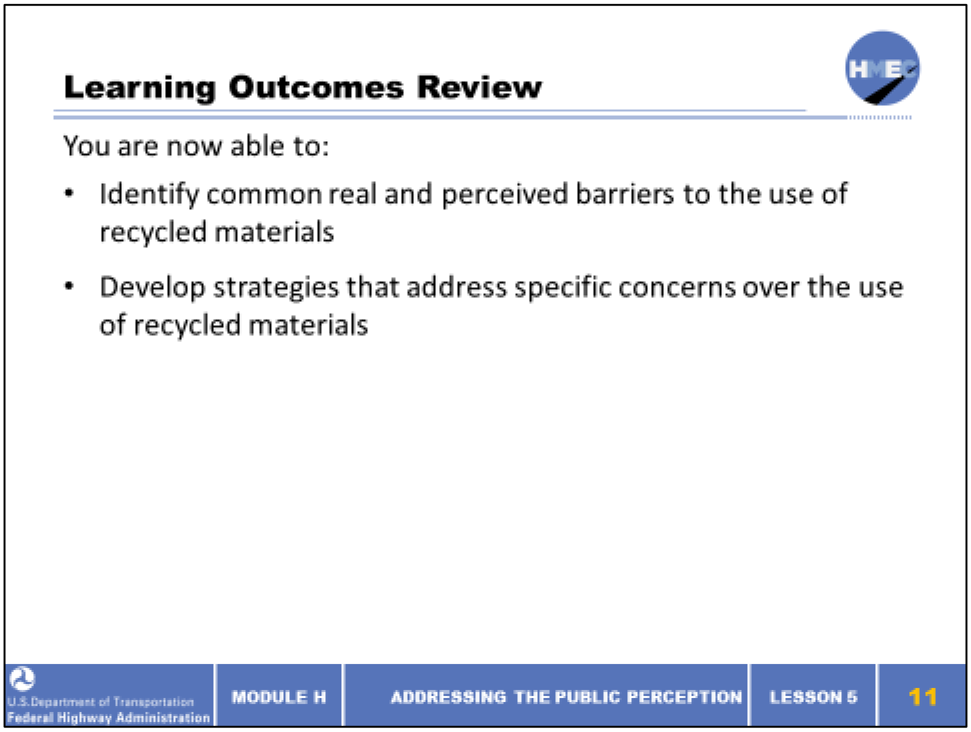
Slide 11


Learning Outcomes Review
You are now able to:
• Identify common real and perceived barriers to the use of recycled materials
• Develop strategies that address specific concerns over the use of recycled materials
U.S. Department of Transportation
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Slide 1


HMEC
Highway Materials Engineering Course
Lesson 6: Hot Topics
Evaluating Recycled Materials for Beneficial Uses in Transportation Construction
U.S.Department of Transportation
Federal Highway Administration
MODULE
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Appendix A: Acronyms

The following are acronyms referenced throughout the course that are important agencies or organizations:

Acronym	Proper Name
AASHTO	American Association of State Highway and Transportation Officials
ACAA	American Coal Ash Association
ACI	American Concrete Institute
ACPA	American Concrete Paving Association
AI	Asphalt Institute
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CFR	Code of Federal Regulations
DOT	U.S. Department of Transportation
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
NACE	National Association of Corrosion Engineers
NAPA	National Asphalt Pavement Association
NCAT	National Center for Asphalt Technology
NCHRP	National Cooperative Highway Research Program
NEPCOAT	North East Protective Coating
NHI	National Highway Institute
NRC	National Recycling Coalition
NRMCA	National Ready Mixed Concrete Association
NSA	National Slag Association
NSBA	National Steel Bridge Alliance

Acronym	Proper Name
NTPEP	National Transportation Product Evaluation Program
OSHA	Occupational Safety and Health Administration
RCSC	Research Council on Structural Connections
SSPC	Society for Protective Coatings
TRB	Transportation Research Board
USGS	U.S. Geological Survey

Appendix B: Resources

The resources for content for Module H have been identified and are described in this section.

Primary Resources

- NHI 131050 Hot Mix Asphalt In-Place Recycling
- FHWA/NHI Innovations Series Web-conference (archived): http://www.nhi.fhwa.dot.gov/resources/webconference/viewconference.aspx?webconfid=19407
- NHI 131023 Recycling module (handouts and resources); these materials, used at the last presentation, were not polished or completely developed. We are working from a mostly clean slate.

Additional Resources

- National Cooperative Highway Research Program (NCHRP) Synthesis 435 – Recycled Materials and Byproducts in Highway Applications: http://www.trb.org/Publications/NCHRPSyn435.aspx. Contains details about various products, chemical composition, specifications, and users.
- FHWA Formal Policy on the Use of Recycled Materials: https://www.fhwa.dot.gov/legsregs/directives/policy/recmatmemo.htm
- EPA Resource Conservation Challenge: www.epa.gov/waste/rcc/index.htm
- Office of the Federal Environmental Executive: www.ofee.gov
- FedCenter.gov: www.fedcenter.gov
- RecycledMaterials.org: www.recycledmaterials.org
- Recycled Materials Resource Center (RMRC) Past Research on Recycling: http://rmrc.wisc.edu/category/research/past-research/
- AASHTO Center for Environmental Excellence: http://environment.transportation.org
- Transportation and Environmental Research Ideas Database (TERI): http://environment.transportation.org/teri_database/
- Foundry Industry Recycling Starts Today (FIRST): www.foundryrecycling.org
- US Composting Council: www.compostingcouncil.org
- American Coal Ash Association: www.acaa-usa.org
- Construction & Demolition Recycling Association: www.cdrecycling.org
- National Slag Association: www.nationalslag.org
- Rubber Manufacturers Association/Scrap Tires: www.rma.org/scrap_tires/
- Asphalt Shingle Recycling: www.shinglerecycling.org/
- National Recycling Coalition: www.nrc-recycle.org
- Northeast Recycling Council: www.nrec.org
- Solid Waste Association of North America: www.swana.org
- UB Center of Integrated Waste Management: www.ciwm.buffalo.edu
- Association of State and Territorial Solid Waste Management Officials (ASTSWMO): www.astswmo.org

- Glass Packaging Institute: www.gpi.org
- Sustainable Highways Initiative: http://www.sustainablehighways.dot.gov/
- Green Highways Partnership (The partnership is no longer active, but the website is still in place and contains valid information and case histories): http://www.greenhighwayspartnership.org/
- FHWA Pavement Recycling: http://www.fhwa.dot.gov/pavement/recycling/rectools.cfm
- American Concrete Paving Association: Recycling Concrete Pavements (available for purchase)
- American Concrete Paving Association: Concrete Pavement Technology Series http://www.pavement.com/Downloads/TS/EB043P/TS043.4P.pdf Several briefing sheets related to the production, properties and use of recycled concrete aggregate (RCA)
- Resource Conservation and Recovery Act (RCRA): http://www.epa.gov/osw/basicinfo.htm