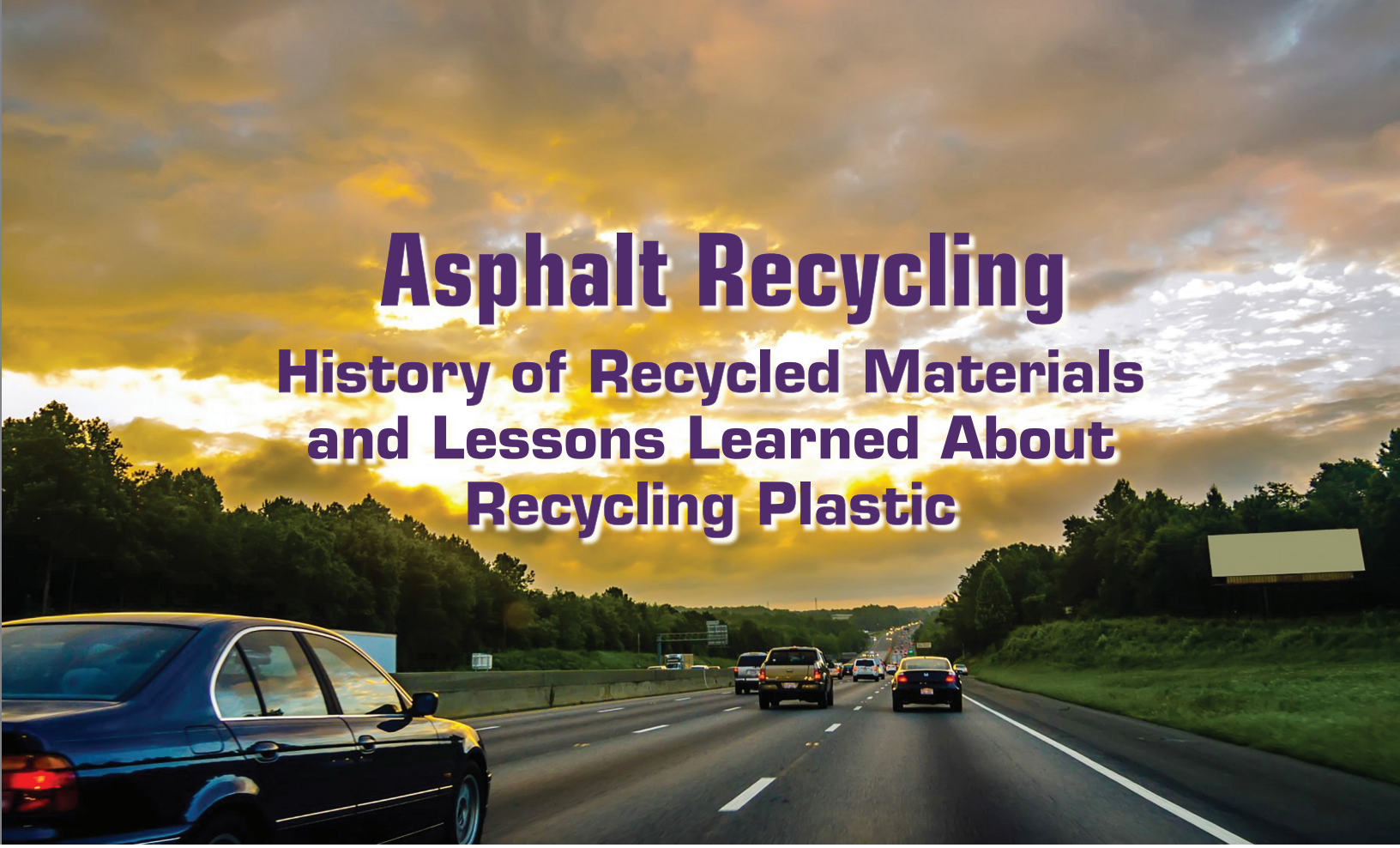

Asphalt Recycling

History of Recycled Materials and Lessons Learned About Recycling Plastic

Photo: Pixabay

J. RICHARD WILLIS AND ISAAC L. HOWARD

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Above: Traffic runs smoothly along an asphalt highway. For decades, the asphalt pavement industry has mixed asphalt with recycled materials—such as old tire rubber and roofing shingles—as a viable alternative to concrete roads. Today, it is pinning its hopes on recycled plastic.

The waste hierarchy of "reduce, reuse, recycle" is so simple and learned at a young age. As elementary students, many of us remember crushing aluminum cans at home so they could be recycled. We remember feeling good about doing our part—and making a little spending money. But it never occurred to us that someone else then had to take the crushed cans and find a responsible way to reuse that aluminum.

Recycling is a concept that most of society supports as a practice that can benefit the environment and overall well-being, as well as reduce the needs and costs associated with raw materials. However, the conversation needs to shift from just recycling to responsible recycling. People make the same mistake with other words when they sometimes unintentionally reduce the word's scope. For example, "sustainability" has been limited by some to mean just "green" or "environmentally responsible" materials. However, economics and the well-being of people are just as relevant to fully understanding whether a material is truly sustainable.

Recycling for the sake of recycling may be fine in passing conversation, but for those who design, research, and build today's infrastructure—and to the public, who often owns this infrastructure—responsible recycling is key to a more sustainable future. Some say that people are turning highways into linear landfills—and that could be the case if recycling is done without further analysis. However, research can determine whether recycled materials could add benefits to our infrastructure network. In that case, recycling is a responsible action.

The asphalt pavement industry is looking at recycled plastic as a potential new source of waste material for use in its product, and it is expected to increase the durability of the world's roadway networks.

This article describes how asphalt paving technologists have been leaders in recycling for many years, summarizes several of the materials that have been

recycled (or evaluated), and uses this history to provide some perspective on recycling plastic: a topic of worldwide interest. A prevailing theme is that logical decisions backed by engineering, science, and economics have led to successful outcomes, but recycling without doing so responsibly may not be best for the longevity of asphalt pavements.

Truly sustainable practices come in many forms but unify around the environment, economics, and social well-being. Portions of this *TR News* issue provide other ways that transportation is working to be part of a sustainable society, such as using titanium dioxide in highway barriers to facilitate oxidation of air pollutants on the barrier surface. A second example is the recently completed research on sustainable highway construction practices performed under the National Cooperative Highway Research Program (NCHRP) Project 10-91A and documented in Muench et al. (*1*). A third example is work through the Transportation Research Board (TRB) Standing Committee on Resource Conservation and Recovery and its Recycled Material Web Map, an ArcGIS warehouse of the location of various recycled materials intended to connect the supply to construction market demand.[1]

The Plastic Crisis

In 2017, China passed the National Sword policy focusing on the protection of the environment and human health. As part of this policy, effective January 2018, China would no longer take in approximately 45 percent of the world's plastic waste, as it had been doing. This meant that 106 million metric tons of plastic waste needed to find a new home quickly. It is expected that, by 2030, almost 111 million metric tons of plastic waste will be displaced because of this policy. Currently, it is estimated that only about 9 percent of the world's plastic is recycled annually, with more than 80 percent ending up in landfills or in the natural environment. Between four and 12 million metric tons find their way into the oceans each year (*2*).

[1] Recycled Material Web Map. http://rmwm.caps.ua.edu/.

Photo: Pixabay

A plentiful supply of discarded plastic bottles are available to be recycled and mixed with asphalt, offering responsible recycling—and increased durability and affordability—to the world's roadway network.

Since 2018, U.S. cities and counties have responded by banning plastic straws, restaurants have replaced plastic utensils with compostable forks, and people outside of the asphalt pavement industry are now looking to asphalt to help resolve the plastic problem. In 2018, the Plastics Industry Association's New End Market Opportunities for Film working group published *Literature Review: Using Recycled Plastics for Compounding and Additives* (*3*), which—based on previous research—identified the use of plastic film waste in asphalt as a new potential end market opportunity.

It was not long before videos were going viral on social media, and traditional forms of media were reporting that plastic-modified asphalt could increase the life of a pavement by 10 times compared with standard neat asphalt. This solution would solve two of America's greatest issues: the plastic crisis and aging infrastructure.

Then, on November 28, 2018, at a hearing titled "Addressing America's Surface Transportation Infrastructure Needs," the chair of the U.S. Senate Committee on Environment and Public Works asked Robert Lanham, then vice president of the Associated General Contractors of America, about the use of recycled materials—specifically plastics—in roads to build longer lasting, more resilient infrastructure. The topic surfaced in early drafts of legislation. A bill was drafted in the California State Senate that would require the California Department of Transportation to evaluate the use of plastic in asphalt. And in the Fiscal Year 2021 House Transportation Housing and Urban Development Funding Bill, a study on plastics in asphalt was specifically mentioned.

Early media reports made claims about the use of plastic-modified asphalt without providing much data. People were asking "why are we not recycling?" instead of "is it responsible to recycle?" The asphalt industry and state agencies have faced this dilemma before in a long history of using recycled materials and can learn from it moving forward.

The Big Three

The asphalt industry has a 60-year history of recycling postconsumer products, with varying levels of success. In fact, asphalt is one of the most recycled materials in the world (*4*). Terrel et al. (*5*) identified rubber tires, glass, shingles, petroleum-contaminated soils, incinerator residue, slags, and polymers as the most common waste—or postconsumer—materials added to asphalt

mixes. Other materials—such as printer toner and sulfur—have even been incorporated in some asphalt mixtures. But three materials provide the most relevant lessons and blueprints on how to successfully implement recycled materials into asphalt mixtures: recycled tire rubber (RTR), recycled asphalt shingles (RAS), and reclaimed asphalt pavement (RAP).

RECYCLED TIRE RUBBER

RTR—often used as smaller particles and referred to as ground tire rubber—is typically mixed with either asphalt binder or an asphalt mixture to improve the asphalt binder properties and make it more resistant to rutting or cracking. The first modern use of this recycled material in asphalt mixtures was a product called asphalt rubber. It was introduced in the 1960s in Arizona as a field-blended product (*6*). In the late 1980s, other states began to evaluate the use of rubber-modified asphalts. For example, state Senate Bill 1192 urged Florida to begin a research program that showed that the rubber modification did indeed improve the overall performance of the mix (*7*).

In 1991, Section 1038(d) of the Intermodal Surface Transportation Efficiency Act shifted the use of RTR from a voluntary action to a federal mandate when it required states to use a minimum amount of RTR each year beginning in 1994. Although the mandate increased RTR usage, it also prematurely moved a material from the research phase to implementation. Because of pushback, the mandate was removed in 1995 under Section 205(b) of the National Highway System Designation Act. RTR usage continued in some states, but most states discontinued RTR programs and did not reconsider its use again until 2008, when the price of polymers increased, and states needed another option for modification. In 2019, a survey conducted by asphalt mixture producers showed the use of RTR in only 10 states (*4*).

RECYCLED ASPHALT SHINGLES

RAS was first thought to be a potential replacement for asphalt binder in new asphalt mixtures in the early 1980s. However, it was not until the cost of asphalt binder rose significantly in the mid-2000s that asphalt mixture producers and road owners really began to explore its use. Between 2009 and 2012, the amount of RAS used in asphalt mixtures rose from 0.702 million to 1.863 million tons. In 2014, RAS usage hit an all-time high of 1.964 million tons. But, then, usage began to drop, and in 2019 it was estimated that only 0.921 million tons of RAS were used in asphalt mixtures (*8*).

When RAS was introduced, states would commonly allow up to 5 percent RAS in new mixtures, with some states going as high as 7 percent. For example, the Texas Department of Transportation (DOT) did a preliminary study that suggested that RAS could be used in asphalt mixtures, allowing up to 5 percent in surface mixtures and up to 10 percent in base mixtures. The department then developed an implementation plan (*9*). RAS usage in Texas has decreased over the past few years, because the agency began to see poor performance of mixtures with RAS. Other states and contractors have reduced RAS usage intentionally, for similar reasons.

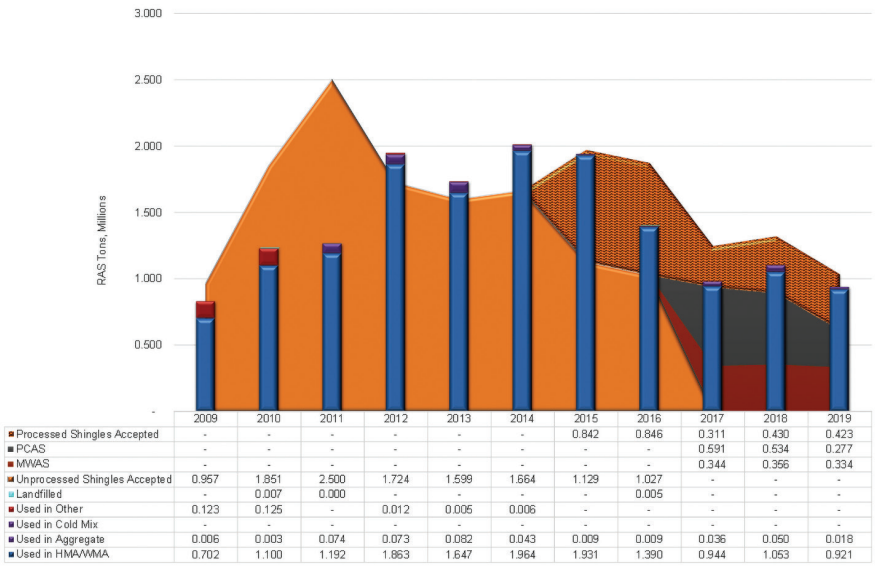
Numerous studies and organizations have found that RAS can be used effectively. However, these mixtures must be engineered to ensure performance. Such engineering includes using well-characterized RAS and ensuring that mixtures contain enough virgin asphalt binder. Construction and production of these mixtures are also critical (*8*). As Figure 1

Photo: Pixabay

Old tires brought new hope to the asphalt pavement industry in the 1960s, when Arizona introduced recycled tire rubber (RTR)—also known as ground tire rubber—as a field-blended product to resist rutting and cracking. Although it showed some improvement in performance, premature implementation via federal mandates resulted in reduced usage over the years. By 2019, only 10 states still used RTR.

Photo: Missouri Department of Transportation

Used as an asphalt binder, recycled asphalt shingles—or RAS—took off around 2009. In 2014, it reached its peak usage at 1.964 million tons. But it was all downhill from there. By 2019, only 0.921 million tons was in use as an asphalt mixture.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Processed Shingles Accepted	-	-	-	-	-	-	0.842	0.846	0.311	0.430	0.423
PCAS	-	-	-	-	-	-	-	-	0.591	0.534	0.277
MWAS	-	-	-	-	-	-	-	-	0.344	0.356	0.334
Unprocessed Shingles Accepted	0.957	1.851	2.500	1.724	1.599	1.664	1.129	1.027	-	-	-
Landfilled	-	0.007	0.000	-	-	-	-	0.005	-	-	-
Used in Other	0.123	0.125	-	0.012	0.005	0.006	-	-	-	-	-
Used in Cold Mix	-	-	-	-	-	-	-	-	-	-	-
Used in Aggregate	0.006	0.003	0.074	0.073	0.082	0.043	0.009	0.009	0.036	0.050	0.018
Used in HMA/WMA	0.702	1.100	1.192	1.863	1.647	1.964	1.931	1.390	0.944	1.053	0.921

FIGURE 1 Comparison of tons of RAS accepted and tons of RAS used or landfilled (million tons), 2009–2019. Processed RAS acceptance first tracked in 2015 (*8*).

shows, the freefall on RAS usage plateaued and seemed to stabilize over the past three years, but more confidence in the product is needed for increased usage.

RECLAIMED ASPHALT PAVEMENT

RAP became a valuable material in the 1970s. The Arab oil embargo was driving up the price of crude oil, and the Federal Highway Administration (FHWA) responded by partially funding Demonstration Project 39 to include and document the use of RAP in pavements. Over the next 20 years, NCHRP and FHWA published guidelines and recommendations for the effective use of RAP in asphalt pavements (*10*).

From the late 1990s through the early 2010s, NCHRP and state departments of transportation funded research to help engineers understand how to use RAP effectively in mixtures (*10*). In 2013, research was completed on how contractors and agencies could move to high-RAP mixtures (*11*). Despite some countries using high-RAP mixtures effectively (*12*), the average RAP content in the United States in 2019 was about 21 percent but has steadily increased since 2009 (*4*), as shown in Figure 2. Although this calculation is about a 5 percent increase from the 2009 value, more recent research shows contractors and agencies whether and how to use recycling agents to increase recycled material content (*13*, *14*).

To move the industry and private road owners to a national average of 21 percent RAP usage, it has taken more than 40 years and millions of research dollars. It has also required road owners, the asphalt pavement industry, and academia to ask questions and find solutions to ensure that RAP is used responsibly. FHWA's policy on recycled materials states the following:

1. Recycling and reuse can offer engineering, economic, and environmental benefits.
2. Recycled materials should get first consideration in materials selection.
3. Determination of the use of recycled materials should include an initial review of engineering and environmental sustainability.
4. An assessment of economic benefits should follow in the selection process.
5. Restrictions that prohibit the use of recycled materials without technical basis should be removed from specifications. (*15*).

This policy shows that it takes research, collaboration, and time to ensure responsible recycling. When recycling is done responsibly, it is encouraged and even applauded. Data and analysis are needed to develop the technical merit, and only time can prove field performance.

Is Plastic in Asphalt the Answer?

When asphalt pavement industry technologists are asked how they feel about using plastics in asphalt, they commonly respond that they are "cautiously optimistic."

Road owners, researchers, and others

(*continued on page 26*)

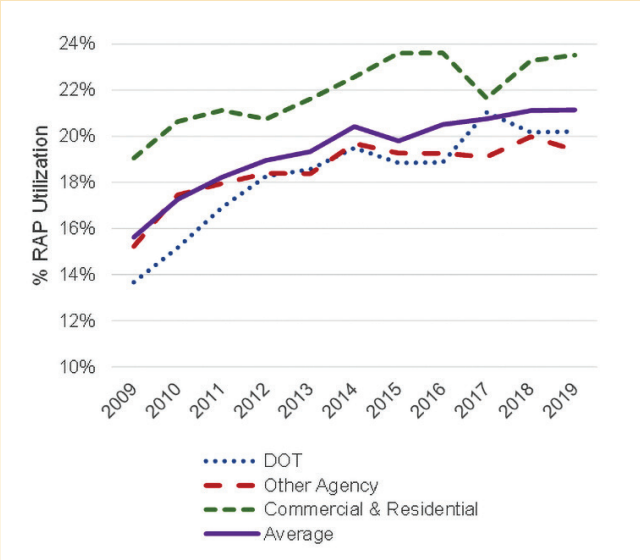


FIGURE 2 Average percent RAP used by sector (*4*).

When Funding and Sustainability Collide

J. RICHARD WILLIS AND ISAAC L. HOWARD

Informally, "green" is everywhere in the sustainability conversation: economics have a financial green, the environment often has a very different green, and social well-being is optimized when these two shades of green harmoniously interact. But, unfortunately, they often do not align. In Figure 1, asphalt binder—represented by PG 67-22 grade (or equivalent)—was generally $100 to $200 per ton from 1980 through 2005 (an average of $138). Just after Hurricane Katrina in 2006, prices spiked and have never achieved previous levels (values shown are actual prices and are not adjusted for inflation). The average price from 2006 through mid-2020 was $461 per ton, and polymer for modifying the material to PG 76-22 would have increased this price to roughly $600 per ton.

The other important value to consider in Figure 1 is the fuel tax. Although many states have recently passed legislation that has raised money for local roads, the federal fuel tax has not increased since 1993. As state agencies are doing more with less (adjusted for inflation), recycling becomes more enticing because it can sometimes lead to a cost reduction. For example, the cost of milling and processing reclaimed asphalt pavement typically is less than the cost of extracting and processing new aggregate sources or of refining crude oil into asphalt binder.

Not all recycled materials have a positive economic impact. There are times when recycling may be a break-even replacement or, because of processing, it may even cost more than nonrecycled alternatives. In the low-bid system wherein most pavements are constructed, the additional cost of some materials might dissuade use of recycled materials—unless there is an economic incentive to recycle.

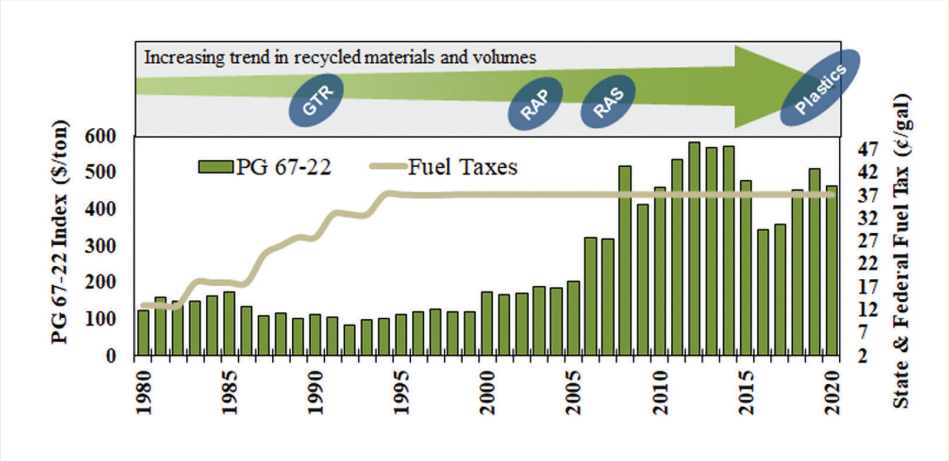


FIGURE 1 Paving market summary.

Photo: Caltrans

In July 2020, the California Department of Transportation (Caltrans) made highway history for the state when the department repaved Highway 162 between the Feather River and Christian Avenue in Oroville. Using recycled asphalt pavement and liquid plastic made from single-use plastic bottles, Caltrans marked the first time the department had paved a road with 100 percent recycled materials. The project illustrated responsible recycling at its best: a one-mile segment of pavement recycled approximately 150,000 plastic bottles.

(*continued from page 24*)

in the industry should consider the following factors when the subject is broached:

1. Not all plastic is the same. Some plastics will not melt at typical asphalt plant temperatures. And some plastics release toxic gases when heated. Research needs to evaluate how—or even if—each plastic type might best be leveraged in an asphalt mix.
2. This is not the first time the industry has tried to use plastic products in asphalt mixtures. In the 1990s, low-density polyethylene was used in asphalt mixtures with varying success. Lessons learned about plastics in asphalt have been synthesized to help technologists understand what the industry knows with regard to performance (*16*).
3. The industry needs to ask and researchers need to answer the following questions:
   a. How should a standard be written to ensure plastic quality?
   b. Does running plastic through an asphalt plant affect permitting because it changes the fumes released?
   c. Do microplastics leach into the environment over time as traffic moves over the pavement?
   d. If microplastics are released into the air during milling activities, do they pose health and safety risks for workers?
   e. Does incorporating plastic in the asphalt mixture prevent it from being recycled again? If so, is the industry exchanging a giant pile of plastic for a larger pile of asphalt? In 2019, 89.2 million tons of asphalt mixture were recycled into new pavements (*4*).
   f. Does the industry need to modify any current testing methods to characterize mixtures with plastic?
   g. If the plastics are added at the wrong point in a plant, could they ignite and set the plant on fire? Additionally, if the fine plastic particles are not totally captured by the binder and aggregate, then they may escape into the plant's baghouse filters and reduce functionality.

What Can We Do?

There is no quick and seemingly magical solution, but whether plastic in asphalt can be the next great recycling story boils down to patience, partnership, and open communication.

Right now, patience is most important. Research takes time, and rushing the use of plastic in asphalt for political reasons—as with RTR—or for economic reasons—as with RAS—is not optimal. The new NCHRP Project 09-66 focuses on plastics used in asphalt. FHWA is sponsoring research on the chemistry of plastic binder compatibility. Texas DOT is conducting research on the subject. And states and private road owners are starting demonstration projects to help answer questions.

After the science bears out, the asphalt industry, the plastic industry, academia, and road owners need to work in partnership to responsibly deliver safe, durable, and sustainable pavements to the driving public.

Good communication will ensure that the public understands the industry's current recycling efforts, as shown in the Mississippi State University video

Construction Matters 2: Recycling.[2] The TRB Standing Committee on Production and Use of Asphalt has focused efforts to assemble and communicate information on recycling plastic in asphalt to the industry and related agencies. One notable product is a pending TRB E-Circular that will tell part of the story of plastic in asphalt. It will present a historical overview, discuss binder compatibility, and provide two case studies of projects that have used plastic in asphalt.

Although plastic was incorporated in the past and worked well in varying degrees, the market has since changed considerably. Today's market factors may or may not be suitable for plastic. India uses plastic waste in a dry process, and France uses plastic in its high-modulus asphalt mixtures. However, coming full circle, patience is needed for partner-driven research to evaluate plastic waste's worthiness in conventional asphalt mixtures. Asphalt industry technologists should avoid the mindset of "this isn't going to work" or "the amount of plastic waste that the asphalt industry could reduce is just a blip on the radar." They also should avoid thinking that "just because we *can* recycle asphalt doesn't mean that we *should*." Any of these phrases may or may not be true. Time is the best storyteller, and the industry should let time tell the story of plastic in asphalt while it works toward as much responsible recycling as possible.

[2] *Construction Matters 2: Recycling*. https://www.youtube.com/watch?v=ho8eKKwsnqM.

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CENTENNIAL QUOTE

"My vision for the Transportation Research Board and the transport industry 100 years from now is that we will have transitioned to better, more efficient, and accessible modes of transportation that also take into consideration the complex utility needs of its users. The more technologically advanced society becomes, the greater the desire for community and human connection. I hope we, as transport-industry professionals, reimagine and build a transportation system that better accommodates all of us for a truly cohesive sense of community and oneness as a human race—if aliens aren't a thing by then.

—WINNIE OKELLO
Senior Civil Engineer,
Pennsylvania Department of Transportation, Harrisburg