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Internal curing reduces shrinkage cracking in bridge decks and other concrete applications.

2 Internally Curing Concrete Produces EPIC² Results

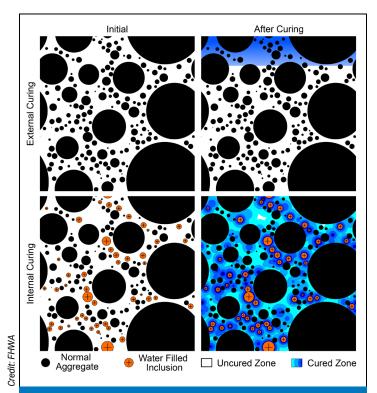
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Internally Curing Concrete Produces EPIC² Results

A proven but underutilized technology known as internal curing is garnering the attention of many States because it can increase the service life of concrete bridge decks by 25 to 50 years. Internal curing helps prevent cracks that occur as concrete shrinks. The cracks can be detrimental because they provide a direct path for chlorides to reach embedded steel reinforcement in the bridge, which leads to corrosion.

"Internal curing was explicitly designed to solve early-age cracking issues that are inherent to higher-performance concretes," said Tim Barrett, co-leader of the Federal Highway Administration Every Day Counts (EDC) **enhancing performance with internally cured concrete** (EPIC²) team. "It's a fairly easy technology to implement."



The above graphic compares traditional curing, represented in the top two squares, to internal curing in the early stages (bottom left) and the simulated distribution of internal curing water (bottom right).

Unlike conventional curing, where water is supplied on the concrete's surface, internal curing provides a source of moisture from inside the concrete mixture, improving its resistance to cracking and overall durability. To create internal curing, a portion of the fine aggregate is replaced with pre-wetted lightweight aggregates. "As the concrete dries, it creates empty pores, which automatically creates pressure that pulls water out of the aggregates and into the empty pores," said Barrett.

Bridges are structurally engineered with a 75-year design life, and signature structures (bridges for which additional effort and cost for extended service life are warranted) frequently have design lives far greater than 100 years. Unfortunately, bridge decks deteriorate faster than any other bridge component due to exposure to various extreme conditions. This results in an average service life in the range of 25 to 50 years. "We are making bridges that require more than one bridge deck from the start, but we don't need to limit ourselves to that because we have technology that allows us to make higher-performance concrete that can be designed upfront to make 75-year bridges a reality," said Barrett.

Internal curing is not limited to use in bridge decks. It is appropriate for any concrete application that could benefit from reduced shrinkage or cracking potential. For example, repair materials that need to gain strength rapidly often contain a high amount of cement, which inherently creates shrinkage. Concrete pavements with internal curing have narrower cracks that are spaced farther apart and the pavement experiences less curling.

Extensive studies over the last 30 years show that internal curing addresses the root cause of self-drying shrinkage, but EDC is the first national, coordinated effort to educate stakeholders about its benefits. Three States have adopted the innovation as standard practice and use it regularly on projects. Four States and Federal Lands Highway are assessing internal curing and adjusting processes for full deployment. An additional 14 States plan to pilot the technology for the first time in the next 2 years. "The studies show that it works, and the States that have adopted it are getting extraordinary results," said Barrett.

Case Studies

The New York State Department of Transportation (NYSDOT) began using internally cured concrete 15 years ago and now uses it on all multi-span bridge decks as part of **NYSDOT Standard Specifications**. Starting in 2008, NYSDOT began piloting internal curing on 20 bridges. In 2015, the agency conducted a performance review and found the bridges showed a 70-percent reduction in cracking compared to those that did not employ internal curing.

In 2015, the Louisiana Transportation Research Center (LTRC) completed **two pilot projects** using internally cured concrete. Each project included internally cured trial sections and control sections with conventional concrete. After nearly 2 years, LRTC leaders said the reduction in cracking in the internally cured concrete bridge sections was evident. The Lafayette Consolidated Government was so impressed by the pilot project results that it began requiring internally cured concrete for bridge deck construction in late 2016.

Some of the first **internally cured concrete** pavements in the United States were constructed in the Dallas/Fort Worth, TX, area beginning in 2005. These included a continuously reinforced concrete pavement freeway. Crack surveys were performed on a 430-foot test section of the highway 76 days after construction. The internally cured section had developed fewer shrinkage cracks at an average spacing of 31 feet between cracks—much larger than the typical 3to 6-feet spacing of cracks on regular concrete. Researchers estimated that internal curing reduced maintenance costs by 15 percent.

Cost Analysis

Internal curing hides water inside a manufactured aggregate that expands with heat and creates extra porosity. This aggregate often has to be shipped, so in new applications there is an



The dark aggregates in this cross section of a standard 4-inch-diameter cylinder are fine lightweight aggregates that are typically used for internally curing any concrete mixture.

estimated potential 20 percent initial concrete material cost increase for internal curing or, when rolled into the project's entire cost, a 2- to 5-percent increase overall. However, NYSDOT evaluated costs over the past 10 years and could not find any cost difference for the past 2 years because the market in New York is fully developed. The primary payoff benefit is found in the lifecycle cost assessment. "We've seen numerous studies that looked at life cycle costs," said Barrett. "They estimate a 30- to 70-percent cost reduction over the structure's life due to internal curing technology."

MORE INFORMATION

- **K** Visit the FHWA EPIC² webpage.
- Read the Internally Cured Concrete tech brief.
- **Subscribe to the EPIC² e-bulletin**.
- Watch the FHWA Concrete Clips: Internal Curing video.
- Contact Tim Barrett of FHWA's Turner-Fairbank Highway Reach Center or Mike Praul of FHWA's Office of Infrastructure.
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Environmental Product Declarations Help Create Sustainable Highways

The United States has **pledged** to lower greenhouse gas (GHG) emissions from 2005 levels by 50 percent by 2030 and achieve net zero by 2050. In transportation, meeting GHG reduction goals often focuses on operational carbon emissions such as tailpipe emissions. Now the Federal Highway Administration (FHWA) is shining a spotlight on reducing embodied carbon associated with manufacturing, transporting, and producing construction materials such as aggregate, asphalt, cement, asphalt mixtures, concrete mixtures, and steel reinforcement.

"We're making design, construction, maintenance, and preservation decisions that impact embodied carbon emissions," said FHWA Pavement Design and Performance Team Leader LaToya Johnson. "We need to be able to make informed decisions early in the process. We can't go back once a project is complete and reduce the embodied carbon emissions."

FHWA is encouraging transportation agencies to implement a new innovation as part of Every Day Counts (EDC) round 7 called **EPDs for sustainable project delivery**. An EPD, or environmental product declaration, is a third-party verified report used to document embodied carbon and communicate the GHG emissions of construction materials in a transparent and standardized manner.

Industry creates EPDs to provide environmental impact information, help transportation agencies make informed decisions, encourage industry efficiency, and reduce environmental impacts.

State of Practice

The passage of new legislation in recent years has increased the popularity of EPDs. In December 2021, President Biden signed Executive Order 14057: Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability, creating the first **White House Buy Clean Task Force** to provide recommendations for establishing a Buy Clean Policy for Federal agencies. After several meetings, the task force recommends that Federal agencies collect EPDs when purchasing concrete, asphalt, steel, and flat glass.

In August 2022, President Biden signed the Inflation Reduction Act (Pub. L. No. 117-169), authorizing \$2 billion for a Low-Carbon Transportation Materials program. FHWA can reimburse or incentivize eligible recipients to use construction materials with substantially lower levels of embodied GHG emissions. EPDs will be used to identify low-carbon materials eligible for the program.

Increasingly, public agencies throughout the country are using EPDs to address GHG emissions. States such as California, Colorado, Minnesota, and Oregon are implementing Buy Clean policies that require EPDs to help procure construction materials with lower embodied GHG emissions.

Colorado

Colorado House Bill 21-1303, adopted in 2021, prompted the Colorado Department of Transportation (CDOT) to collect EPDs. "For States where Buy Clean legislation is being considered, DOTs should learn about the EPDs for sustainable project delivery initiative so they are better informed," said CDOT Pavement Engineer Hailey Goodale.

Colorado's new Buy Clean legislation created a requirements timeline. In 2022, CDOT began collecting EPDs for eligible materials defined as cement and concrete, asphalt, and steel. CDOT will use information from the EPDs to benchmark and create a policy to set maximum allowable global warming potential limits for these materials by January 2025. In July 2025, all winning bidders of CDOT construction contracts must submit EPDs for eligible materials in accordance with the CDOT policy. CDOT will begin reporting GHG reduction progress to the State legislature in 2026 and will have the opportunity to review and adjust the CDOT policy every 4 years.



Oregon

The Oregon Department of Transportation's (ODOT's) experience with EPDs started in 2021 with the release of its Strategic Action Plan. The plan directed ODOT staff to set an emissions baseline through a GHG inventory and begin phasing in low-carbon materials, fuels, and best practices. ODOT's GHG inventory found that 70 percent of ODOT operations emissions come from concrete, asphalt, and steel the agency uses to build and maintain the State's transportation system.

"It is typical for any business, including a DOT, to have a majority of emissions associated with the upstream supply chain," said ODOT Sustainability Program Manager Zechariah Heck. "The production of conventional cement and steel, two of the most frequently used building materials, accounts for approximately 15 percent of global GHG emissions."

The ODOT GHG inventory project resulted in over 40 recommendations, including maximizing the use of supplementary cementitious materials to reduce GHG emissions and developing an EPD program to identify ways to reduce pavement embodied carbon.

The recommendation to develop an EPD program became law in June 2022 when the Oregon House passed Bill 4139. The legislation requires ODOT to collect EPDs on asphalt, concrete, and steel by the end of 2025 and to devise two strategies to reduce GHG emissions from the materials used to construct and maintain the State transportation system.

"Sustainability is just good engineering; it's just doing the best business we can for everyone on this planet," said FHWA Sustainability Program Manager Migdalia Carrion. "I want to encourage State transportation departments and local public agencies to start collecting EPDs and understanding them so we can improve how we do business."

MORE INFORMATION

- Visit the Every Day Counts EPDs for Sustainable Project Delivery webpage.
- ► Visit the FHWA Sustainable Pavements Program webpage for links to EPD webinars and other resources.
- (Contact LaToya Johnson or Migdalia Carrion of the FHWA Office of Infrastructure for information and technical assistance.

Nighttime Visibility for Safety: Visible Solutions

How can transportation professionals protect pedestrians crossing the roadway at night when drivers often cannot see them? The answer: apply the latest technology improvements where they are needed most.

The nighttime fatality rate on U.S. roadways is three times higher than the daytime rate, and 76 percent of pedestrian fatalities occur at night. Nighttime visibility for safety, an Every Day Counts round seven (EDC-7) initiative, will accelerate the deployment of methods for enhancing nighttime roadway visibility that can save lives.

The nighttime visibility for safety initiative will help promote improved lighting and other countermeasures transportation agencies can deploy to enhance visibility for all road users, particularly near activity centers like transit stops, schools, parks, and entertainment hubs.

"Our attention is focused on enhancing visibility at locations where we know pedestrians are expected to cross the roadway to get to a destination," said George Merritt, senior safety and geometric design engineer at the Federal Highway Administration (FHWA) Resource Center and co-lead for the EDC-7 innovation. "With this focus, we are committed to assisting agencies large and small to create safe access to community resources and essential services."

"This EDC-7 initiative is an opportunity for FHWA to work closely with State and local agencies to save lives by implementing improvements when and where we can make the most difference," Merritt added.

Safe System Approach

A focus on pedestrian safety must reach beyond educating road users on how best to navigate the road network. The EDC-7 effort will focus on creating safer roads, which is an element of the Safe System Approach (SSA). The SSA addresses transportation system risks by



Watch a video to learn how the Florida DOT increased pedestrian safety by installing LED lighting.

Based on preliminary data reported by States, the Governors Highway Safety Association estimated that drivers struck and killed 7,508 pedestrians in 2022—an average of **20 deaths a day** and the highest number since 1981. Data from the National Highway Traffic Safety Administration also showed that pedestrians in minority populations were at **greater risk** of dying in a crash than white pedestrians.

building and reinforcing multiple layers of protection to both prevent crashes from happening in the first place and minimize the harm caused to those involved when crashes do occur.

The EDC-7 implementation team will offer technical training and support for lighting and other visibility improvements to Local Technical Assistance Program and Tribal Technical Assistance Program centers.

"We believe some of the most important community activity assets such as schools, recreation centers, transit, entertainment, and hospitals are where we should improve safe access for pedestrians, especially after the sun goes down," Merritt said, noting the innovation is especially useful to agencies that consider equity in safety a priority. "People need and want safer access to essential services and community resources. If we focus on developing partnerships with community stakeholders in these locations, we are confident we will help expand what works to make communities safer and more accessible."

Research indicates that continuous lighting installed on both rural and urban highways may reduce nighttime injury crashes by 28 percent. Nighttime crashes at rural and urban intersections can also be reduced by up to 38 percent using lighting.

Florida is one State already seeing pedestrian safety benefits from improved roadway lighting. The Florida Department of Transportation (FDOT) invested \$100 million at the district level to replace high-pressure sodium lighting with light-emitting diodes (LEDs) at 80 percent of the State's most dangerous intersections—creating better visibility where it was needed most. FDOT's District 7 has **reported crash reductions** at locations with the new LED lighting of up to 65 percent.

"With the opportunity to promote this innovation, we want to help promote SSA," said Joe Cheung, senior safety engineer at FHWA Office of Safety and co-lead for the EDC-7 innovation. "By focusing on visibility enhancements for safer roads, they will be able to provide a redundancy in safety for all road users."

Beyond Lighting

Transportation agencies can also improve nighttime safety by applying crosswalk visibility enhancements, applying edge and center line markings, and improving signing and pavement marking practices and procedures, among other traffic control device enhancement strategies.

"It is important we reach local agencies," Merritt said. "It's going to take everyone doing all we can to help reduce the number of nighttime fatalities."

This effort benefits from resources already available through several initiatives on **lighting and visibility** underway by FHWA.

"There is a lot about nighttime visibility that most people don't fully appreciate—it is a very complex area," Merritt said. "We hope to give agencies the tools and resources to apply improvements that will reduce the risk of serious injury or fatal crashes."

MORE INFORMATION

- Visit the EDC-7 Nighttime Visibility for Safety webpage.
- Visit FHWA's Roadway Lighting Resources webpage.
- Ontact Joe Cheung of FHWA's Office of Safety or George Merritt of the FHWA Resource Center.
- Subscribe to the Nighttime Visibility for Safety **e-bulletin**.

EDC Legacy–Laying the Foundation for the Safe System Approach

For more than a decade, FHWA's Every Day Counts (EDC) program has promoted proven but underused innovations that enhance roadway safety, improve project delivery, and reduce traffic congestion. Across the country, agencies attest to the value of adopting these new technologies and processes, along with creative strategies for innovation deployment. As the transportation community participates in EDC round seven, Innovator is featuring articles that reflect on the program's accomplishments.

Since roughly half the Nation's most severe crashes occur at intersections, efforts to reduce conflicts and improve safety performance at these locations can save lives. From 2013 to 2014, Every Day Counts round two (EDC-2) promoted innovative intersection and interchange geometrics that can accommodate traffic volumes efficiently while focusing on conflict points to allow for safer travel. The EDC-2 effort focused on five design types—diverging diamond interchanges, displaced left-turn intersections, median u-turn intersections, restricted crossing u-turn intersections (RCUTs), and roundabouts that share the common attribute of reducing or eliminating left-turn conflicts.

Facing the Headwinds of Change

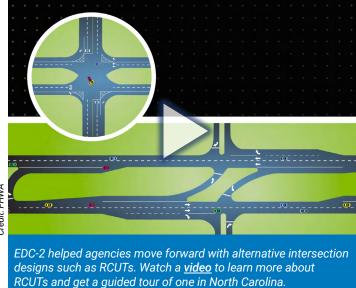
When EDC-2 began more than 10 years ago, intersection projects were likely to involve traditional designs—those controlled by a stop sign or traffic signal with all direct movements occurring at the main intersection. Many agencies were uncomfortable using roundabouts or other alternative intersection designs. Today the landscape is much different, with alternative designs appearing more commonly and encountering fewer barriers in planning from engineers and the public.

"Changing the way we evaluate and improve intersections, especially alternative intersections, was a tough sell," said George Merritt, FHWA senior safety and geometric design engineer. "The intersection and interchange geometrics team helped propel the state of practice forward through education and technical support. The data on these designs were too compelling to ignore, and the performance of alternative intersections objectively gave transportation officials a reasonable chance to overcome objections."

The FHWA team focused on giving practitioners tools to show the value, use cases, and benefits for each, as well as training and technical support to answer questions, review preliminary designs, assist agencies in making the pitch to introduce new intersection types, and help get projects off the ground. Informational guides gave practitioners key information that helped take new intersection designs from concept to plan sheet. This information, backed by FHWA subject matter experts, helped speed adoption of new intersection designs and begin the conversation around which new designs an agency should choose.

"Any time there's a new intersection type, there tends to be pushback until they're built and opened," said Jeff Shaw, Intersection Safety Program Manager, FHWA Office of Safety. "After they're built and opened, there's acceptance and conversion. Each community goes through this process but getting that first one is where the level of effort is most intense."

During EDC-2, the number of States implementing two or more of these designs increased from



16 to 38 plus Puerto Rico. Since EDC-2 ended in 2014, the number of roundabouts identified in the United States has nearly doubled, according to **research presented** at a Transportation Research Board conference in 2022. According to Shaw, RCUT intersections probably benefited the most from EDC, gaining significant momentum in agencies across the country. This is noteworthy because the niche for RCUTs is intersections along high-speed, divided four-lane highways, where the potential for severe crashes is high and safer designs are most needed.

"The background work and technical expertise of the team really helped to encourage change," added Merritt. "We provided support that helped agencies build confidence and ultimately move forward on new projects. EDC led to an institutional change in how agencies address intersections. We helped to strategically relocate the left turn movement, and there's no question that has reduced serious crashes."

A New Approach is Born

Out of the newfound choices came the need for a method to quantitatively evaluate possible intersection designs rather than relying on personal preferences or incomplete information. This need spurred the development of a new approach to intersection project development intersection control evaluation (ICE). ICE is a performance-based approach used to screen possible intersection designs and identify the optimal solutions. "ICE is the real legacy of EDC-2," said Shaw. "When you're growing the options to solve safety problems, you need a consistent, objective method to evaluate them. ICE provided a way to evaluate safety and operations as separate metrics. The ICE framework insists that safety performance and operations performance be parallel considerations in intersection design. The conversation has shifted from whether an agency should do it to which choice is best and how to do them right."

More recently, the ICE methodology is being dovetailed into the **Safe System Approach** (SSA), where eliminating conflicts and separating users in space and time are fundamentals, widening the perspective through which safety on a roadway system is evaluated and planned. Alternative intersections play an important role in the SSA and provide an opportunity for better pedestrian and bike safety.

Now, in grant programs like **Safe Streets and Roads for All**, more alternative intersection designs are appearing in applications. Overall, the number of alternative intersection designs being proposed and designed has greatly increased—the result of a seed planted by the work in EDC-2. Road safety is also being taught as part of intersection design in higher education—additional evidence that this new design paradigm is taking root.

"The state of practice is evolving on alternative and more complex intersections," added Dave Petrucci, Senior Safety Engineer with FHWA's Resource Center. "Engineers are moving away from rote use of level of service, asking for more nuanced evaluations, and using intersection conflicts in the decision process as compared with practices more than 10 years ago. The result, saved lives, is worth the effort."

MORE INFORMATION

- Read the FHWA intersection control evaluation (ICE) fact sheet.
- K Visit the FHWA ICE webpage.

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STIC Showcase Features Homegrown Innovations



As part of the Every Day Counts round seven (EDC-7) **virtual summit** held in February, the **National STIC Network Showcase** provided a platform for State Transportation Innovation Councils (**STICs**) to share more than 100 homegrown innovations developed and implemented in their States with a wider audience to expand their potential use and impact. The virtual summit featured presentations from State and local agencies on several of these homegrown innovations, including the following from New Jersey and Washington State, which can be watched **on-demand** from the summit website.

Virtual Public Involvement

The North Jersey Transportation Planning Authority (NJTPA), one of New Jersey's metropolitan planning organizations (MPOs), has used several innovative forms of virtual public involvement (VPI) to increase community participation in its long-range planning process. To gather public input, NJTPA used online ads geo-targeted to regions and invited people to participate in an online survey covering the plan's seven focus areas. The campaign reached 1.6 million people over 6 weeks and received a robust response. NJTPA also created a Tuesday Symposium series for planning and transportation professionals, advocates, and other interested parties that focused on emerging issues and equity themes in transportation.

Another of New Jersey's MPOs, the Delaware Valley Regional Planning Commission (DVRPC), convenes a **Futures Group** to discuss emerging trends and forces affecting the region. A subset of the larger Futures Group conducts exploratory scenario planning exercises as part of long-range planning. Dialogue within the Futures Group benefits both DVRPC and the group's participants, who are able to take what they learn back to their organizations.

Diversity, Equity, and Inclusion Plan

The Washington State DOT (WSDOT) created and implemented a **Diversity, Equity, & Inclusion (DEI) Plan** to guide these practices into all aspects of its work, both internally and externally. The plan is a blueprint for creating a more inclusive work culture and business and career opportunities for underrepresented individuals and business owners, and enhancing community engagement.

WSDOT

Diversity, Equity, & Inclusion Plan

AUGUST 2022

Washington State DOT formed an agency-wide workgroup of volunteers to produce its <u>Diversity, Equity & Inclusion Plan</u>.

To create its **DEI Plan**, WSDOT formed an agency-wide workgroup of employee volunteers from all disciplines. The workgroup collaborated with both internal and external partners in focus areas such as diversity, workforce, data-informed decisions, and Washington State's Healthy Environment for All Act. WSDOT reports that the DEI plan is helping improve the agency's decision-making practices, enhancing access, and creating a culture of belonging for the community and employees.

MORE INFORMATION

➤ Visit the National STIC Network Showcase webpage to read more about these and other Homegrown Innovations.

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States innovate!

New Jersey Puts Aging Drawbridge on a Road Diet

Following a mechanical failure on the 90-year-old Shark River Drawbridge, the New Jersey Department of Transportation (NJDOT) discovered significant damage to the steel structure beneath the roadway. To preserve the drawbridge machinery and keep the bridge open, NJDOT needed to find a way to redistribute the traffic load away from the damaged steel. The agency implemented a road diet on the structure, reconfiguring it to one lane in each direction. This allowed NJDOT to add an innovative bicycle-safe grid across the



Watch a <u>video</u> to learn how the New Jersey DOT implemented a road diet that improved safety on an aging drawbridge.

bridge as well as nearby intersection improvements to Route 71. NJDOT reports that the Shark River Drawbridge now has improved traffic flow, increased safety, and reduced congestion in this busy tourist area. NJDOT's **emergency repair and road diet project** was named a regional winner of a 2023 **America's Transportation Award** from the American Association of State Highway and Transportation Officials.

Flying to the Rescue: UAS Revolutionize Alaska's Emergency Services

The Alaska Department of Transportation & Public Facilities (DOT&PF) is expanding its use of **unmanned aerial systems** (UAS) to assist communities during emergencies. The agency's **Alaska Rural Remote Operations Work Plan (ARROW) Program** is aimed at improving emergency response capabilities in rural areas of the State. Alaska DOT&PF will provide 10 communities with UAS and access to a shared geographic information system (GIS). The ARROW program leverages funding provided by U.S. DOT and strategic partnerships with the Federal Aviation Administration and Alaska Center for UAS Integration that will allow Alaska DOT&PF and community partners to begin using UAS beyond visual line of sight (BVLOS) for critical infrastructure inspection. Enabling remote communities to conduct BVLOS missions using UAS will allow them to collect critical data for the shared statewide GIS. The data will be used to help ensure responders are dispatched quickly to natural and human-made disasters affecting critical infrastructure in historically underserved communities.

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INNOVATOR

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EDC Outtakes: EPDs for Sustainable Project Delivery

Two of the latest editions in the EDC Outtakes video series focus on **Environmental Product Declarations (EPDs) for sustainable project delivery**, an Every Day Counts round seven (EDC-7) innovation. **LaToya Johnson**, co-lead for EDC-7, talks about the importance of addressing embodied carbon during construction, and **Migdalia Carrion**, co-lead for EDC-7, shares how reporting tools encourage sustainable procurement, design, and asset management.





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Credit: FHWA