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INNOVATOR

Driving simulation studies helped inform the design of Puerto Rico's first diverging diamond interchange.

Credit: University of Puerto Rico at Mayagüez (modified with permission)

From Simulation to Reality: Puerto Rico's First Diverging Diamond Interchange

Fatal and injury crashes often occur at or near intersections as motorists, pedestrians, and bicyclists cross paths. During **Every Day Counts round 2** (EDC-2), FHWA encouraged transportation agencies to consider several innovative intersection and interchange designs that can accommodate traffic volumes efficiently while reducing or altering conflict points to allow for safer travel.

One of these configurations is a crossover-based design called a **diverging diamond interchange** (DDI). DDIs eliminate the signalized left-turn phase within an interchange by shifting the crossroad traffic to the left side of the roadway between the ramp terminals. Compared to a conventional diamond interchange, the DDI reduces vehicle-to-vehicle conflict points by **nearly 50 percent**.

Driving Simulation Studies Enhance Design

The Puerto Rico Highway and Transportation Authority (PRHTA) planned what became the island's first DDI as part of a bridge replacement project in the municipality of Gurabo. PRHTA proposed the DDI as a pilot project to improve the safety and operation of the interchange, which sees a high volume of traffic due to a nearby university, industrial park, and residential developments.

After learning that researchers from the University of Puerto Rico at Mayagüez previously employed a driving simulator to study the use of a dynamic toll lane on one of Puerto Rico's main highways, staff from the FHWA Puerto Rico Division Office suggested PRHTA integrate a driving simulation tool during the design of the new DDI.

"Division staff felt strongly enough about the benefits and results from the use of the driving simulation tool that they recommended it to PRHTA for studying the proposed DDI," said Juan Rivera Ortiz, highway engineer at FHWA's Puerto Rico Division Office. "The PRHTA accepted the recommendation," he said, "and so the collaboration became a part of the process to evaluate the DDI design and provide recommendations on how to improve signing and pavement marking."

University researchers successfully developed the simulation based off the project plans. They moved the driving simulator to a location close to the project and conducted research with more than 50 local drivers, who provided feedback on the traffic control devices in the DDI. The university developed a report with several recommendations for additional traffic signs and better pavement markings for the intersection.

The design team discussed the recommendations and revised the design accordingly. One

An aerial view of Puerto Rico's first diverging diamond interchange.

Credit: Puerto Rico Highway and Transportation Authority

recommendation to add overhead signs to the DDI benefited significantly from the use of the driving simulator. Because this change would require installing additional structural support at the interchange, the initial review of the design using the driving simulator helped avoid the costly retrofits that would have been necessary later had the overhead signs been installed after the DDI opened to the public.

The researchers updated the design plan in the simulator and then conducted a second investigation with local drivers, including police officers and emergency medical services (EMS) personnel. This investigation resulted in a second report and set of recommendations, which the design team incorporated into another revised plan prior to the opening of the project.

Simulation Results Support Community Outreach

One challenge with implementing a new intersection or interchange design for the first time in a community is the lack of familiarity among users. In this case, the project team was able to leverage the driving simulation results in developing a communication plan aimed at reducing driver confusion with the new DDI traffic pattern.

With the approval and support of PRHTA executive management, the communication plan described the DDI design and explained its benefits to the public through TV, radio, and social networks. PRHTA also developed a brochure explaining how to drive through the DDI and distributed it to local drivers at the intersection.

The research team made the driving simulator available to citizens and provided them with information on how to drive through a DDI during outreach efforts at the main shopping centers and at professional conferences. The research team also produced an educational video using images from the driving simulator and made it available to view on the web.

Prior to the opening of the DDI, the PRHTA traffic incident management (TIM) team conducted a tabletop exercise to prepare in the event of a major crash or incident in the area. During the exercise, personnel from the local police department, EMS, public works department, and others discussed various scenarios and how to manage detours and lane closures during incidents, which led to a recommendation to add two closed-circuit television cameras at the intersection. Staff at the PRHTA Transportation Management Center can now view the live camera feed to facilitate immediate feedback with the TIM team.

Credit: University of Puerto Rico at Mayagüez

Driving simulation experiments helped inform the design of the new diverging diamond interchange as well as the communication plan.

The DDI opened to traffic on May 29, 2023, during the last phase of construction. Rivera Ortiz said that, despite some initial driver confusion, the DDI is now working well, thanks in part to the simulation experiments that informed the design, the agency collaborations, and the communication plan.

MORE INFORMATION

- Read a **technical report** on Puerto Rico's DDI to learn more about the benefits of using a driving simulator as a tool for evaluating the design.
- Visit the FHWA's **intersection safety** webpage.
- Contact **Juan Rivera Ortiz**, FHWA Puerto Rico Division Office, or **Mark Doctor**, FHWA Resource Center, for information and technical assistance.

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Concrete Innovation: ODOT's Strategic Approach to Internal Curing

A look at the Oregon DOT's strategy for implementing internally cured concrete.

Concrete is commonly used in bridge deck construction, and while it offers many advantages, a long-standing problem is its susceptibility to cracks. Shrinkage cracks, a type of cracking that occurs as concrete loses moisture and shrinks during drying, provide a path for water and other ions to the concrete's interior. Over time, this leads to unplanned maintenance to address the cracking and preserve the structural integrity of the bridge.

The Every Day Counts round seven (EDC-7) **enhancing performance with internally cured concrete** (EPIC^2) initiative is advancing internal curing as a remedy for shrinkage cracking issues in higher-performance concretes. Internal curing uses materials such as lightweight fine aggregates (a type of sand) to provide a source of moisture from inside the concrete as it cures, unlike conventional curing where water is supplied on the concrete's surface. The result is a more uniform cure that resists cracks and improves durability—extending bridge deck lifespans by 25 to 50 years.

The Oregon Department of Transportation (ODOT) began piloting internal curing technology in 2017 and completed 15 projects between 2017 and 2023. David Dobson, ODOT Statewide Structural Materials Engineer, described ODOT's implementation strategy during an **EDC-7 EPIC^2 webinar**. He said research and initial results showed internal curing could extend the service life of bridge decks and reduce the resources the agency was spending on bridge maintenance. However, getting contractor support was a challenge due to their perceived risk in using a new material.

Pausing the Pilots

A 2021 project, the Bear Creek Bridge, was a turning point in ODOT's internal curing implementation program as they saw inflated bid costs. ODOT had assumed a small premium for material, freight, and stockpiling, but on this project the contractor bid came in at four times the engineer's estimate. Several factors including contractor uncertainty with internal curing contributed to the higher bid. Changes in the implementation plan were needed to both gain contractor buy-in and maintain internal agency support for the technology.

Concerns voiced by contractors included that they perceived internal curing as too risky, they thought ODOT should conduct a lifecycle cost-benefit analysis, and they struggled to see the value in the technology. ODOT took a strategic pause in implementation to address these concerns.

Addressing Contractor Risk

One step ODOT took to reduce contractors' perceived risk was to simplify agency specifications to make them more straightforward and user friendly. They simplified the specification for internal curing by pre-determining the amount of lightweight fine aggregate needed to reach the desired hydration level. This amount, specifically for ODOT mixtures, came to about 350 pounds per cubic yard. Moving from providing a formula to making the specification more prescriptive reduced uncertainty for contractors at the time of bid, which improved buy-in.

ODOT also modified the agency's standard test method to enable better aggregate conditioning and quality control during concrete production.

Dobson said the modifications simplified the conditioning process and streamlined moisture testing, which improved consistency for contractors.

During this pause in the program, ODOT added approved sources to its Qualified Products List that would be ready to go during bid and mixture design development, providing a quick reference for contractors. ODOT also performed additional educational activities on internal curing with both contractors and suppliers.

Quantifying the Benefits

ODOT surveyed 11 of its bridge decks to compare shrinkage cracking in internally cured and traditionally cured decks, and the results were significant.

"We knew the research showed internal curing reduces cracking," said Dobson, "and after our first projects, we knew the bridge inspectors were saying, 'Hey, these bridge decks look really good. They're not cracking like we typically see.' But we didn't have a number, so we decided to do a crack survey on high-performance concrete and compare normally cured decks with internally cured decks, and we saw a 70-percent reduction in crack density."

Listen to David Dobson in a short webinar clip to learn more.

ODOT also performed a cost-benefit analysis on internal versus traditional curing using service life and maintenance needs for comparison. They found internal curing was comparable at (up to three times) the bid price of traditional concrete.

"Internally cured bridge decks are still cost comparable even if you were paying three times the bid price of your normal deck mixture," said Dobson. "We're getting a good bargain out of adding 350 pounds of sand, absolutely."

Improving the Value Proposition

Since ODOT resumed implementation of internal curing, as-installed prices have decreased and stabilized, and the agency is seeking to further improve the value for contractors. ODOT is pursuing a decrease in wet-cure duration for internally cured bridge decks, from 14 days down to 7 days, to provide contractors a time savings.

The Salt Creek Bridge was one of several internally cured bridge deck projects the Oregon DOT surveyed that showed significantly less shrinkage cracking versus traditionally cured concrete decks.

They are also investigating additional material sources within the region.

Internal curing is now ODOT's default standard concrete for bridge decks, and staff are looking into other ODOT use cases, including paving and overlays. They are also recommending the practice to other agencies within Oregon.

"The 70-percent reduction in cracking is going to directly increase the service life of our bridge decks and fundamentally change the maintenance strategy," said Dobson. "When we have a bridge deck that doesn't crack, we have a lot more options in maintenance, a lot more flexibility, and time is not nearly as critical, because chlorides aren't getting right down to the reinforcement on day one."

MORE INFORMATION

- View the **EPIC² webinar** for more details on Oregon DOT's internal curing implementation process.
- Visit the EDC-7 **EPIC² webpage** for links to internal curing resources.
- Contact **Tim Barrett**, FHWA Turner-Fairbank Highway Research Center, for information and technical assistance.

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EDC Legacy: Collaborating to Solve Road Data Challenges

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. From 2013 to 2014, EDC round two (EDC-2) encouraged agencies to use **geospatial data collaboration** tools to increase information sharing that could improve the quality and speed of decision-making.

Brian Gardner, of FHWA's Office of Planning, Environment, and Realty, said EDC-2 focused mostly on applications for environmental products, then in EDC-3, **regional models of cooperation** expanded the emphasis to include more types of planning data.

"Those early rounds of EDC raised awareness among agencies of the value of collaborative data tools and approaches by demonstrating what peer agencies were doing and the benefits they were seeing," said Gardner. "This helped lay the groundwork for current, much broader efforts to develop a consistent means of collecting, maintaining, and publishing all road network data."

Sharing Road Network Information

Imagine navigating a city without a map or attempting to repair a road without knowing its condition. This is the challenge that transportation agencies confront daily, and the solution lies in road data collaboration—local agencies working together with State departments of transportation (DOTs) to share essential information about road networks. This collaborative approach ensures improved planning, safer roads, and more efficient use of resources for everyone.

Road data collaboration is akin to a team effort where each government entity contributes expertise and data. Local agencies manage their road networks, collecting details such as road type, width, pavement condition, and traffic patterns. State DOTs oversee the broader highway system and need local data for effective planning.

Collaboration enables agencies to gain a comprehensive understanding of the entire road network, which is crucial for informed resource allocation, project prioritization, and improved transportation decision-making.

The types of data shared include road classifications, characteristics, mileage, lane configurations, pavement conditions, traffic counts, and work zones, as well as structural assets in the right-of-way.

Most State DOTs use Geographic Information Systems (GIS) to manage and exchange this road data. GIS allows for both data integration and visualization. Cloud-based data portals can let local agencies upload data for sharing with State agencies. These portals may include data validation tools to ensure quality and accuracy. State DOTs incorporate this data into their State Roads management system to prepare a statewide roads dataset with contributions from local agencies. The data flow on these centralized GIS platforms is governed by digital processes that develop a unified data model by integrating various information sources, combining road geometry and relevant attributes data.

Establishing a Framework for Collaboration

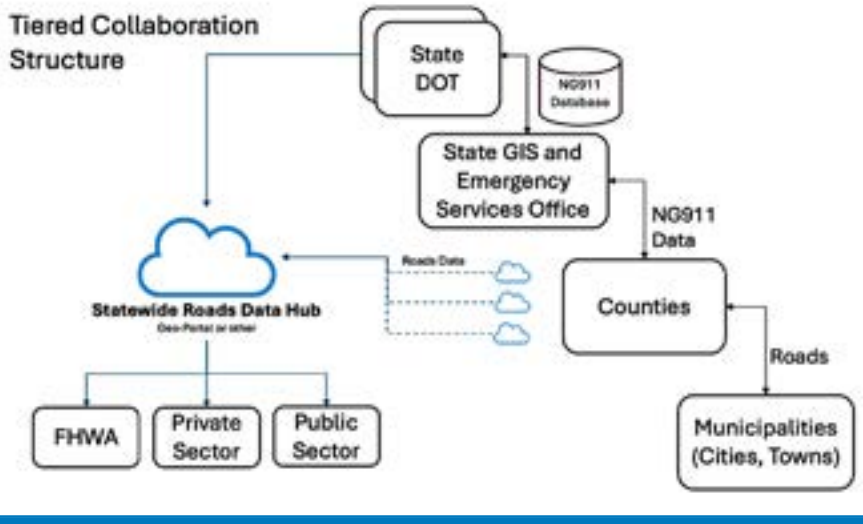
In 2018, FHWA launched the **Applications of Enterprise GIS in Transportation** (AEGIST) initiative to address challenges in road data management and governance. The associated pooled fund study involved 18 State DOTs focused on establishing a framework for collaboration, including guidelines for road data modeling, exchange, integration, publication, and use.

Phase 1 of the study produced the **AEGIST Guidebook** to help agencies migrate to the enterprise level for creating, maintaining, and governing roadway data. FHWA is currently updating the guidebook to document the best practices and implementation approaches

developed by the AEGIST States during phase 2 of the pooled fund study.

One of these approaches is the **California Road Sharing (CaRS) program**. CaRS is a current effort by the California DOT (Caltrans), the California Office of Emergency Services, and local agencies to work together to develop a reliable road data source in the State.

The CaRS program aims to standardize road data, enhance quality, and ensure accessibility. It establishes a supply chain for local agencies to submit road data for validation and integration into Caltrans' records. The CaRS framework in California follows practices from AEGIST States like Georgia, Arizona, and Pennsylvania, where DOTs utilize local road data to create a statewide dataset.



Credit: FHWA

In road data collaborations, cloud-based data portals let local agencies upload data for sharing with the State DOT and State GIS and emergency management offices.

Benefitting from Robust Datasets

The benefits of road data collaboration are significant for all stakeholders, from government agencies to the general public. Access to comprehensive road data allows State DOTs and local agencies to create effective transportation plans, from identifying upgrade and expansion areas to formulating emergency response strategies. Analyzing shared data can also help ensure agency funding targets critical projects, such as prioritizing maintenance for deteriorating roads based on pavement condition data.

Having comprehensive road data will enable agencies to more effectively manage assets, such as bridges and culverts, leading to improved maintenance and extended asset lifespans. A unified view of the road network also empowers agencies to make informed, data-driven decisions to support enhanced safety analysis.

Looking ahead, robust road datasets will likely facilitate new technologies such as connected and autonomous vehicles and artificial intelligence or machine learning applications.

Joseph Hausman in FHWA's Office of Planning, Environment, and Realty said the benefits of road data collaboration will go beyond simple information sharing—they are establishing a foundational framework designed to enhance transportation accessibility for everyone.

"These cooperative efforts are allowing local transportation agencies and State DOTs to create a road network dataset that is more accurate, reliable, and accessible," said Hausman. "The datasets will lead to more effective planning, increased roadway safety, and optimized resource use, ultimately benefiting all communities along with the road network."

MORE INFORMATION

- Visit FHWA's **GIS in Transportation** webpage for links to program resources.
- Visit the **Applications of Enterprise GIS in Transportation** (AEGIST) webpage for information on pooled fund State activities.
- @ Contact **Joseph Hausman** or **Brian Gardner**, FHWA Office of Planning, Environment, and Realty, for details and technical assistance.

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Systemic Safety Analysis: The Power of Prevention

Agencies are advancing a systemic approach to safety analysis to prevent crashes before they happen.

One of the biggest challenges for highway safety practitioners is identifying locations that could become future crash sites and ensuring the best decisions are made on which treatments to implement.

During Every Day Counts (EDC) rounds three and four, the **data-driven safety analysis** initiative promoted **systemic analysis**, which uses crash, roadway, traffic data, and more to identify roadway features that correlate with particular crash types. Practitioners can use this data to prioritize safety improvements on roadways proactively, before the next crash occurs.

Transportation agencies at all levels of government are making tremendous progress in incorporating systemic analysis as part of their comprehensive safety management strategies.

Creating Safer Streets for Pedestrians and Bicyclists in Seattle

The Seattle Department of Transportation (SDOT) is using systemic safety analysis to identify high-priority areas for pedestrian and bicyclist safety. This is accomplished through a multi-phase effort that includes the development of pedestrian and bicycle safety performance functions (SPFs) for several specific crash types. The SPF models crash risk and assists SDOT with identifying the risk at various intersections across the city, producing a ranked list of priority locations for treatment.

One of the systemic safety investments identified through the program is **leading pedestrian intervals** (LPIs). LPIs allow pedestrians to enter an intersection crosswalk 3 to 7 seconds before vehicles are given a green light, increasing pedestrian visibility to drivers. SDOT studied the locations where LPIs had been installed from 2009 to 2018 and found a 48-percent reduction in turning movement pedestrian crashes and a 34-percent reduction in serious injury and fatal pedestrian collisions.

Seeing their effectiveness, SDOT began **implementing LPIs** across the city in 2018 using a systemic prioritization approach. In 2019, SDOT adopted a new policy to evaluate adding an LPI every time they build a new traffic signal or do other signal maintenance work that provides an opportunity to make this upgrade. This is an example of how a systemic countermeasure can sometimes progress to become a systematic countermeasure, where it is considered for all locations based on policy or other agency criteria.

Improving Project Evaluation in the Atlanta Region

The Atlanta Regional Commission (ARC) has incorporated a systemic safety approach into the agency's project evaluation process for its Transportation Improvement Program (TIP).

Credit: FHWA

The six-step process of applying the systemic approach to safety.

A few years ago, ARC embarked on a mission to have a **Regional Safety Strategy** with a data-informed perspective. They found that the types of crashes overrepresented in fatalities and serious injuries in the region involved intersections, a car running off a road or leaving its lane, and pedestrians or cyclists. ARC identified several risk factors for why these crashes occurred historically and applied the factors to every road in the region. The agency then produced a **Risk Factors Web Map** that shows corridors and intersections at high risk for severe crashes based on the presence of roadway design characteristics and other data.

ARC Transportation Planner Tejas Kotak said the analysis has helped the agency better understand which projects will best adhere to their safety goals and reduce unnecessary deaths and injuries in the region.

"This was a really important factor for us in deciding which projects to fund during this round of our TIP solicitation, and it's something that we're going to continue tweaking as we do more TIP solicitations and project reviews," he said.

Targeting Safety Program Funds in Ohio

In 2022, the Ohio DOT (ODOT) launched a new annual application for Highway Safety Improvement Program (HSIP) funding that began with a systemic safety analysis.

To identify a priority network for implementation of systemic projects, ODOT began with two crash types: roadway departure and pedestrian crashes. They used a **machine learning-enabled analysis process** to identify where specific roadway characteristic bundles were present, indicating the highest risk for a serious crash for the two crash types. ODOT then took the output from the model and created a Geographic Information System (GIS) -based **map** of the agency's priority segments and corridors eligible for systemic improvements.

For the HSIP application, local agencies can access this map and identify specific points along ODOT's priority segments where they would like to implement a project. They then select a recommended countermeasure from ODOT's multimodal design guide based on the location's existing or desired geometrics.

Credit: FHWA

*Watch an **FHWA video** for an overview of the systemic approach to safety analysis.*

Most of the applications ODOT awarded in the program's first year are now beginning construction or being completed, so over the next couple years ODOT is planning to conduct a performance evaluation to gauge the program's success in terms of reducing fatal and serious injury crashes.

Jeremy Thompson, ODOT Highway Safety Program Engineer, said the agency invests in other systemic initiatives as well, including countermeasures such as **rumble strips**, **SafetyEdge**SM, and **reflective backplates**.

"A lot of the things that in the past we've started as systemic have become more systematic in nature," said Thompson, "and they're now just a part of our everyday processes when we go to program and implement projects."

MORE INFORMATION

- Visit the FHWA **Systemic Approach to Safety** webpage for additional noteworthy practices and case studies.
- @ Contact **Matt Hinshaw**, FHWA Office of Safety, or **Derek Troyer**, FHWA Resource Center, for information and technical assistance, including a one-day workshop training opportunity.

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States Innovate!

Washington State Pilots UAS for Graffiti Removal

The Washington State Department of Transportation (WSDOT) is testing an innovative new use for **unmanned aerial systems** (UAS) as platforms for graffiti removal. Removing graffiti in hard-to-reach locations such as bridges, overpasses, and tall retaining walls can expose maintenance crews to high-fall hazards and high-speed traffic. To test whether UAS could reduce risks to employees while performing this type of work, WSDOT developed a prototype UAS equipped with a spray nozzle linked to a supply of paint on the ground. In a **blog post** on the pilot program, WSDOT noted that the areas being treated are in closed work zones or managed with rolling slowdown closures while the UAS are in use. The initial field testing results, published in WSDOT's December 2024 **Graffiti Proviso report**, show that UAS technology is providing a more resource-efficient way to cover graffiti while reducing safety risks to maintenance crews. Watch a **WSDOT video** to see the graffiti-removing UAS in action.

Credit: Washington State Department of Transportation

*Watch this **Washington State DOT video** to learn about the agency's graffiti-battling UAS pilot program and read the agency's **2024 Graffiti Proviso report** to see the results.*

South Carolina Expands Public Engagement with Virtual Tools

The South Carolina Department of Transportation (SCDOT) enhanced and broadened the reach of its public engagement efforts for the **Interstate 526 (I-526) Lowcountry Corridor West** project by implementing several **virtual public involvement** (VPI) strategies. I-526 West is part of a larger family of SCDOT projects aimed at alleviating congestion in the Charleston region. The project includes widening a portion of I-526 from two to four lanes in each direction along with improving many of the ramps. To offer a variety of opportunities for community members to provide input, SCDOT held hybrid public hearings with both in-person and virtual participation options. In addition to a traditional project website that allows the community to view public hearing materials, SCDOT developed a 360-degree **virtual reality public hearing room**. Using VPI helped SCDOT present project information to a much larger audience compared to traditional outreach methods. SCDOT reported that at the end of the comment period, the project website logged over 8,000 visitors and the virtual hearing room recorded nearly 1,000 clicks. The agency noted that traditional hearing materials presented in person typically only reached hundreds of people.

Missouri Spotlights Crowdsourcing Success

The Missouri Department of Transportation (MoDOT) uses a **crowdsourcing** tool called Pothole Customer Proactive Reporting (CPR) to acquire reliable and accurate location data on potholes, enabling maintenance crews to locate and fix them quickly. The Pothole CPR tool is currently being highlighted as part of the agency's Transportation Systems Management and Operations (TSMO) **Success Stories video series**. Pothole CPR obtains crowdsourced data through the Waze® app, which allows users to report

Credit: Colorado Department of Transportation

Colorado's Region 2 Bridge Bundle project replaced 17 aging structures on key rural highway corridors.

pothole locations. When a pothole is reported, Waze records and stores its GPS location. Waze provides this data daily to Kansas City Scout, the bi-State traffic management system used by the Missouri and Kansas DOTs, allowing them to locate and fix potholes quickly and efficiently. Pothole CPR has also been highlighted by FHWA in an **Adventures in Crowdsourcing webinar**.

Credit: Missouri Department of Transportation

*Watch a **Missouri DOT video** to learn about the Pothole Customer Proactive Reporting system, which uses crowdsourcing to obtain accurate pothole locations.*

Colorado Cuts Construction Time with Innovative Project Delivery Methods

The Colorado Department of Transportation (CDOT) completed its **Region 2 Bridge Bundle** project about 5 months ahead of schedule and $2 million under budget with the help of innovative project delivery methods. CDOT used **project bundling** and **design-build** to replace 17 structurally deficient structures in rural southeastern and south-central Colorado. The structures are located on three separate essential corridors that support commerce and access to tourist destinations. In an agency **news release**, CDOT reported that by using the design-build delivery method, crews were able to begin construction on the first structures while the other structures in the bundle were being designed. The agency said this proved to be the most successful and efficient method of construction for the project, cutting months of construction time from the schedule.

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INNOVATOR, published by the FHWA's Office of Technical Services, advances the implementation of innovative technologies and accelerated project delivery methods in highway transportation.

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Enhance Concrete Performance with Internal Curing

Cracks in concrete bridge decks can become direct paths to the steel reinforcement for water and chlorides, allowing the corrosion process to begin. **Internal curing** increases concrete's resistance to early cracking, allowing the production of higher-performance concretes that may last more than 75 years. Watch an **Every Day Counts spotlight video** for information on how this technology works.

Credit: FHWA

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