Pelletized Asphalt Concrete Stanislaus County

March 2026

Produced Under Contract By: NCE

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Publication # DRRR-XXXX-XXXX [OPA editor will provide this]

Prepared as part of contract number DRR21067, Work Order 3

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Executive Summary

The California Department of Transportation (Caltrans) is the largest user of asphalt-rubber (also known as rubberized asphalt mixes) in the United States. Asphalt-rubber mixes used in California include hot mix asphalt gap- and open-graded mixes and asphalt-rubber chip seals. The use of asphalt-rubber mixes at the local level has increased over the last decade with assistance from the California Department of Resources Recycling and Recovery (CalRecycle) Rubberized Pavement Grant Program.

Asphalt-rubber modified binder, which incorporates ground tire rubber made from scrap tires into liquid asphalt, provides demonstrated economic, performance, and environmental benefits. Asphalt-rubber provides cost savings from a life-cycle perspective, extends pavement life, utilizes a recycled product, and reduces noise.

There is an expense to mobilize the equipment required for blending asphalt-rubber, and there are logistical challenges and added cost associated with field-blended asphalt-rubber at the asphalt hot mix plant. As a result, many rural local agencies in California have not utilized asphalt-rubber, and agencies generally have not used it for smaller-tonnage projects due to the higher cost. However, new technologies may encourage local agencies in rural areas or agencies with smaller-tonnage projects to specify asphalt-rubber.

CalRecycle became aware of new technologies that may encourage local agencies in rural areas or those with smaller-tonnage projects to specify asphalt-rubber. These new technologies, collectively called pelletized rubber, minimize or eliminate the expense of mobilizing equipment needed to blend traditional asphalt-rubber binder at the asphalt plant site—though feeder and metering equipment may be needed. Pelletized rubber is manufactured off-site and shipped to the asphalt plant at ambient temperature for mixing at the plant. Pelletized rubber technologies include PelletPAVE-TR from Phoenix Industries and SmartMIX™ from Liberty Tire Recycling. The PelletPAVE-TR and SmartMIX™ products are metered into the hot plant at the recycled asphalt concrete collar or into the pugmill during asphalt concrete mix production, where they melt and are mixed with aggregate and asphalt binder.

CalRecycle proposed to fund a local agency to construct test sections using these pelletized rubber products as a way to observe their production, placement, and long-term performance. Its goal is to provide information to increase the use of recycled rubber, enhance pavement performance, and make rubberized asphalt more cost-effective in remote areas and for smaller tonnage projects. CalRecycle proposed to fund the construction of the test sections (up to $500,000) and provide other no-cost services that include coordinating with potential suppliers; developing plans and specifications; inspection; sampling and testing for acceptance; and rut resistance, moisture sensitivity, and cracking resistance testing. Long-term monitoring would also be provided. The local agency would advertise and award the construction contract and administer the project contract.

In December 2021, CalRecycle solicited Letters of Intent from local agencies that are sustained users of asphalt-rubber and that would be willing to partner with CalRecycle. Local agencies proposed locations that have a two-lane road at least two miles long with uniform traffic loading, subgrade support, and pavement condition, suitable for an overlay of 0.12 to 0.20 feet thick. While the location could be a low-volume roadway, at least some heavy traffic was preferable. Ideally, the candidate roadway would be one where one-way flagging or a detour may be allowed.

Stanislaus County proposed an overlay within the limits of East Keyes Road from State Route 99 to Geer Road, approximately 3 miles long, and was selected by CalRecycle. The County initially proposed, for plans, specifications, and estimates (PS&E) and bidding, constructing a 0.2-foot-thick overlay with six different materials:

- 650 tons of conventional hot mix asphalt concrete (HMA) control,
- 3,770 tons of fiber-reinforced asphalt concrete (FORTA-FI),
- 3,770 tons of traditional Asphalt-Rubber Hot Mix (ARHM/RHMA-G),
- 542 tons of SmartMIX™,
- 542 tons of PelletPAVE-TR, and
- 542 tons of Ecorphalt.

These materials were to be placed continuously, with the HMA control, SmartMIX™, PelletPAVE-TR, and Ecorphalt serving as CalRecycle-funded test sections to allow for direct comparison and continued monitoring of the materials' performances. A formal agreement was executed between CalRecycle and Stanislaus County under which CalRecycle's contribution was increased to $715,000, and production of Plans, Specifications and Engineer's Estimate (PS&E) began.

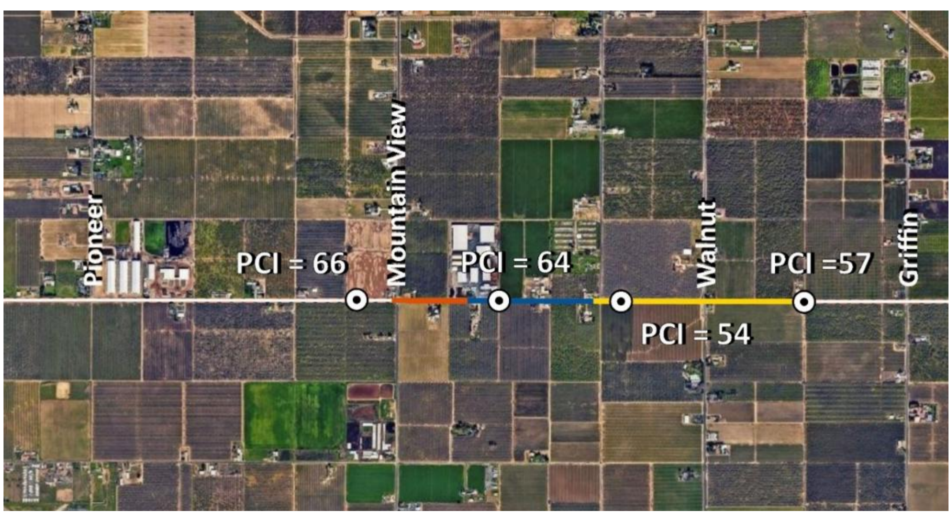
The Nichols Consulting Engineers (NCE) team—NCE, Mike Robinson, LLC, and Interwest Consulting Group—was under contract with CalRecycle and produced the Plans, Specifications and Estimate (PS&E) for this project.

Stanislaus County posted this project for bid on PlanetBids on March 21, 2024. Bids were opened, and the Stanislaus County Board of Supervisors awarded the project to United Pavement Maintenance Incorporated on April 23, 2024. For this project, it was determined that placing the responsibility for preparing the test section mix designs on the Contractor would be more efficient, would allow the Contractor more control, and would be more representative of a typical project. The Contractor selected Asphalt Pavement & Recycling Technologies (APART) in Shafter, CA to prepare the HMA control, SmartMIX™, PelletPAVE-TR, and Ecorphalt mixes. All four designs used the same three aggregate bins—intended to represent the aggregate gradation anticipated from the three hot plant hot aggregate bins—in essentially the same proportions, with essentially the same combined gradation and using the same neat base asphalt. The mixtures were designed using the same mixing and compaction temperatures and had essentially the same effective binder content, voids in mineral aggregate (VMA), voids filled with asphalt (VFA), and air voids. This consistency was intended to isolate the effects of the rubber additives and ensure a fair performance comparison.

Construction was delayed allowing the completion of tomato harvesting season, to lessen traffic disruptions during construction. This delay was a concern, as asphalt-rubber requires compaction at higher temperatures than conventional asphalt mixes and at favorable ambient conditions. However, the weather conditions were suitable for the work to proceed. Work began on October 21, 2024. Repairs were conducted before paving and consisted of base repairs (digouts) as well as thin “skin patches.” While no effort was made to formally treat each section exactly the same in terms of repair, by the time construction began, the project sections were in relatively uniform condition over their entire lengths. The purpose of this was to provide relatively uniform comparisons of the performances of each of the materials placed. Drone footage by the California State University, Chico Pavement Preservation Center, was taken to document this process.

The production of the pelletized and control-section materials began early in the morning of October 29, 2024, at George Reed, Incorporated’s Munn & Perkins 8,000-pound batch plant, located at 26292 East River Road in Escalon, with the mixture containing SmartMIX™ produced first. Paving of the pelletized and control sections was performed from October 29 to October 30, 2024. Paving of ARHM (gap-graded rubberized hot mix asphalt [RHMA-G]) and fiberized AC were performed before and after these two dates, respectively. All work was completed on November 18, 2024.

Test section materials were placed in order from west to east: SmartMIX™, PelletPAVE-TR, and HMA control. Ecorphalt, due to production and delivery concerns, was not included in the project and the limits of the test products were extended to maximize the CalRecyle funding. All materials were placed in lift thicknesses of 2.5 inches (0.2 feet) from edge of pavement to edge of pavement. Taper grinds were performed at project termination points and where intersections were constructed to match existing grades. The western starting point for SmartMIX™ placement was near Mountain View Road. The eastern limit of HMA is midway between Walnut Road and Griffin Road. In addition to the CalRecycle test sections, RHMA-G was placed west of SmartMIX™, and fiberized AC was placed east of the HMA control. These sections were funded by Stanislaus County and were not the focus of this study; therefore, details of their materials and construction are not included in the remaining discussion. See map below with orange for SmartMIX™, blue for PelletPAVE-TR, yellow for HMA control.



Each test section has a delineator in the eastbound direction designating its beginning. Quality Assurance (QA) material testing based on Caltrans 2023 Standard Specifications was conducted on in-place materials on behalf of the County. All aggregate tests met specifications. All mix testing—and, in particular, compacted density and binder content—met specifications except for one binder content, which was 0.5% too high. Performance testing for moisture susceptibility and rutting passed for each mix.

This report focuses on the preliminary stages, pre-construction, and construction phases for the SmartMIX™, PelletPAVE-TR, and HMA control. Ongoing monitoring, expected on a yearly basis, will take place to assess overall pavement condition and distress development.

Concluding Remarks

Stanislaus County's and CalRecycle's paving project, consisting of two pelletized asphalt pavement sections and an HMA control section, was successfully completed in October and November 2024. While there was a learning curve associated with the use of these pelletized additives, and while producers do not currently operate in California, these test sections may demonstrate that pelletized additives can satisfactorily perform on California pavements. In addition, the use of these materials does not pose the issue of needing to obtain a rubber blending unit and associated equipment required for more commonly used gap-graded rubber in asphalt mixes, thereby potentially allowing the use of rubber in more rural and remote areas.

It is not an easy matter for any public agency to offer one of their roads to test a new pavement technology, particularly on a critical farm-to-market road with heavy truck volumes. Stanislaus County has been a recipient of prior CalRecycle grants. As such, they have witnessed and recognize the superior pavement performance of asphalt-rubber. Therefore, constructing these rubberized test sections presented reduced risks due to their familiarity with asphalt-rubber and its performance. Moreover, the County was very pleased that CalRecycle would be funding a robust inspection and material testing regime that would also reduce risk. The County was very pleased with the final result of the test project and has recently presented the project at the California League of Cities Public Works Conference. The County is committed to partnering with CalRecycle to monitor the ongoing performance of the test sections.

Introduction

Asphalt-rubber modified binder, which incorporates ground tire rubber made from scrap tires and high-natural rubber sources (crumb rubber modifier [CRM]) into liquid asphalt cement at high temperatures, provides demonstrated economic, performance, and environmental benefits. Asphalt-rubber mixes provide cost savings from a life-cycle perspective, extend pavement life, utilize a recycled product, and reduce noise.

The process of synthesizing asphalt-rubber binder from CRM and liquid asphalt cement at high temperatures allows the rubber particles to react and swell, integrating fully with the asphalt to create a thick, viscous material. Specialized equipment must be mobilized at the asphalt plant to blend the crumb rubber with asphalt. The crumb rubber is delivered to the asphalt plant and metered into a high-shear blending unit with the paving-grade asphalt binder, as shown in Figure *1*. The blending unit thoroughly mixes the crumb rubber into the hot asphalt binder, and the resulting blend is then pumped into a heated tank where the asphalt-rubber must remain in constant agitation at an elevated temperature for about 45 minutes to allow interaction between the crumb rubber and asphalt, thereby modifying the binder. The blended rubberized binder is then mixed with aggregate, paved with a standard paving machine, and compacted at an elevated temperature with steel-wheeled rollers.

There is an expense to mobilizing the blending equipment required for asphalt-rubber, and there are logistical challenges and added cost associated with field-blended asphalt-rubber at the asphalt hot mix plant. As a result, many local agencies in rural areas of California have not utilized asphalt-rubber mixes for smaller-tonnage projects due to the higher cost.

The California Department of Resources Recycling and Recovery (CalRecycle) became aware of new technologies that may encourage local agencies in rural areas or with smaller-tonnage projects to specify asphalt-rubber. These new technologies, collectively called pelletized rubber, reduce or eliminate the expense of mobilizing equipment needed to blend traditional asphalt-rubber binder at the asphalt plant site; pelletized rubber is manufactured off-site and shipped to the asphalt plant at ambient temperature. These technologies include PelletPAVE-TR from Phoenix Industries and SmartMIX™™ from Liberty Tire Recycling. The PelletPAVE-TR and SmartMIX™ products are metered into the hot plant at the recycled asphalt concrete collar or into the pugmill during asphalt concrete mix production, where they melt and are mixed with the aggregate and asphalt binder.

CalRecycle proposed to fund a local agency to construct test sections using these pelletized rubber products to observe their production, placement, and long-term performance. The goal is to provide information to increase the use of recycled rubber, enhance pavement performance, and make rubberized asphalt more cost-effective in remote areas and for smaller-tonnage projects.

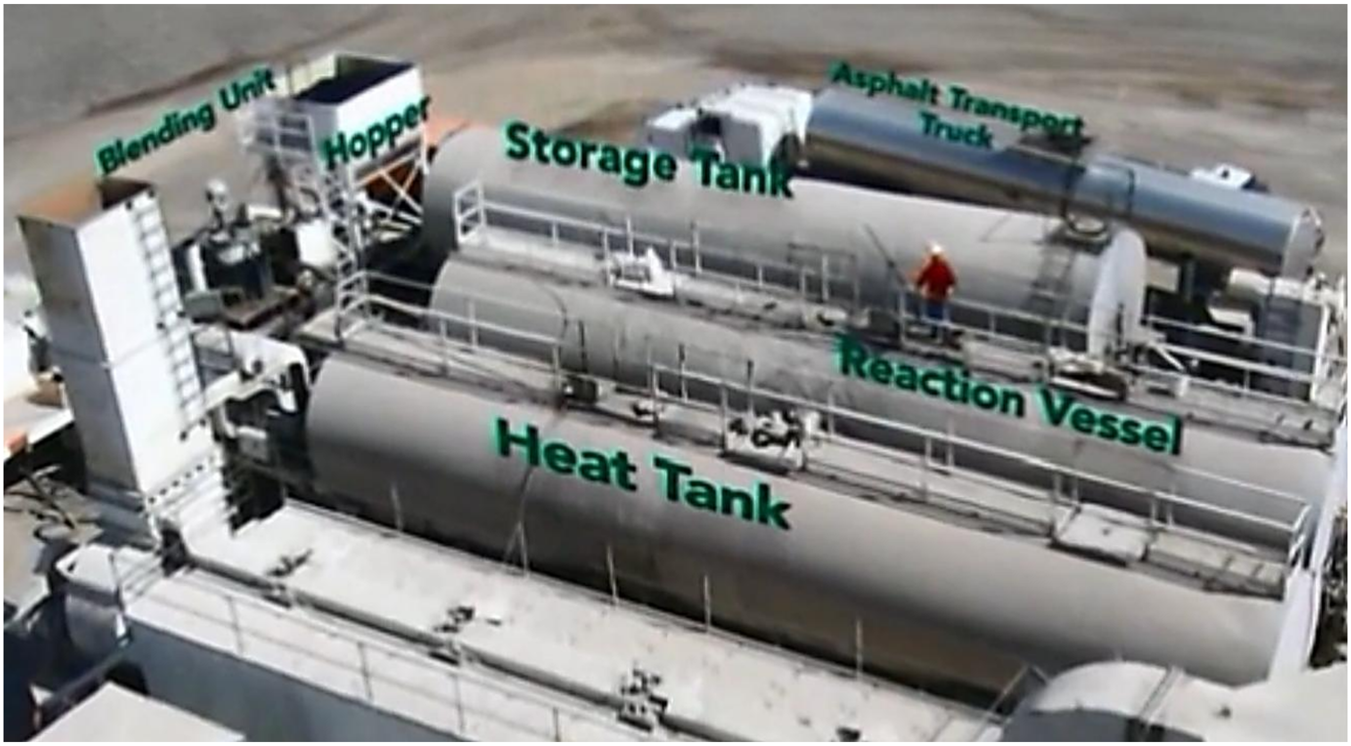


Figure 1. Mobilized equipment needed for Asphalt-Rubber Hot Mix

CalRecycle proposed to fund the construction of the test sections (up to $715,000) and provide other no-cost services that include coordinating with potential suppliers; developing plans and specifications; inspection; sampling and testing for acceptance; and rut resistance, moisture sensitivity, and cracking resistance testing. Long-term monitoring would also be provided. The local agency would advertise and award the construction contract and administer the project.

In December 2021, CalRecycle solicited Letters of Intent from local agencies that are sustained users of asphalt-rubber and that would be willing to partner with CalRecycle. Local agencies proposed locations that have a two-lane road with uniform traffic loading, subgrade support, and pavement condition, suitable for an overlay of 0.12 to 0.20 feet thick, at least two miles long. While the location could be a low-volume roadway, at least some heavy traffic was preferable. Ideally, the candidate roadway should be one where one-way flagging or a detour may be allowed.

Stanislaus County proposed an overlay within the limits of East Keyes Road from State Route 99 to Geer Road, approximately 3 miles long, for the test project, and was selected by CalRecycle. The County initially proposed, for plans, specifications, and estimates (PS&E) and bidding, constructing a 0.2-foot-thick overlay with six different materials:

- 650 tons of conventional hot mix asphalt concrete (HMA) control,
- 3,770 tons of asphalt concrete (AC) reinforced with FORTA-FI fiber blend,
- 3,770 tons of traditional asphalt-rubber hot mix (ARHM),
- 542 tons of SmartMIX™,
- 542 tons of PelletPAVE-TR, and

- 542 tons of Ecorphalt.

The project required pre-overlay base repair and skin patches. A formal agreement was executed between CalRecycle and Stanislaus County, and the production of Plans, Specifications, and Engineer's Estimate (PS&E) started.

This report focuses on the preliminary stages, pre-construction, and construction phases of the SmartMIX™, PelletPAVE-TR, and HMA control. Ecorphalt, due to production and delivery concerns, was not included in the project—details follow. RHMA-G and fiberized asphalt, while placed along with these test sections, are not part of the pelletized test section project and are not discussed further in this report.

Project Bidding and Award

The NCE team of NCE, Mike Robinson, LLC, and Interwest Consulting Group, was under contract with CalRecycle and produced the PS&E for this project.

Stanislaus County posted this project for bid on February 8, 2024, and bids were opened on March 21, 2024. The Stanislaus County Board of Supervisors awarded the project to United Pavement Maintenance Incorporated on April 23, 2024.

Bid prices were received for all materials (in-place). For the pelletized test project, the prices were:

- SmartMIX™: $224/ton
- PelletPAVE-TR: $250/ton
- HMA Control: $126/ton

It took some time for the Contractor to prepare and obtain approval of the test material mix designs. The project was then delayed allowing completion of the tomato harvesting season, to lessen traffic disruptions during construction. Work began on October 21, 2024, with base repairs/digouts. Paving of the two pelletized experiment sections was conducted October 29–30, 2024. ARHM (gap-graded rubberized hot mix asphalt [RHMA-G]) and fiberized AC were placed before and after these dates, respectively, with all work completed on November 18, 2024. This delay was a concern, as asphalt-rubber requires compaction at higher temperatures than conventional asphalt mixes and at favorable ambient conditions. However, the weather conditions allowed the work to proceed.

Project Site

East Keyes Road from State Route 99 to Geer Road, owned and maintained by Stanislaus County, is a two-lane, east-west running, high-truck-traffic route in Keyes, CA, just north of Turlock. A key feature of this road is that it serves as a haul route for the County's agriculture, notably tomatoes and almonds. There is also considerable Class 9 ("18 wheeler") tractor-trailer traffic and passenger vehicle traffic in addition to the agricultural trucking. Vehicle speeds are relatively high, typically 45–55 mph. Typical haul traffic is shown in Figure 2.

Figure 2. Typical truck traffic

A map of the pelletized and control HMA sections is shown in Figure 3. All materials were placed in lift thicknesses of 2.5 inches (0.2 feet) from edge of pavement to edge of pavement. Taper grinds were performed at project termination points and where intersections were constructed to match existing grades. The western starting point for SmartMIX™ placement is near Mountain View Road at the eastern end of the RHMA-G material. The western limits of SmartMIX™ placement are staggered in the eastbound (EB) and westbound (WB) directions by approximately 200 feet due to the previously placed RHMA-G material terminating at different locations. SmartMIX™ WB was placed for 920 feet and EB was placed for 800 feet, for a total placement of 460 tons. This included reconstructing the intersection at Mountain View Road. PelletPAVE-TR was placed over a 1,660-foot length of road in both WB and EB lanes, for a total placement of 720 tons. The HMA control was placed over a 2,760-foot length of both EB and WB lanes, for a total of 1,330 tons placed.

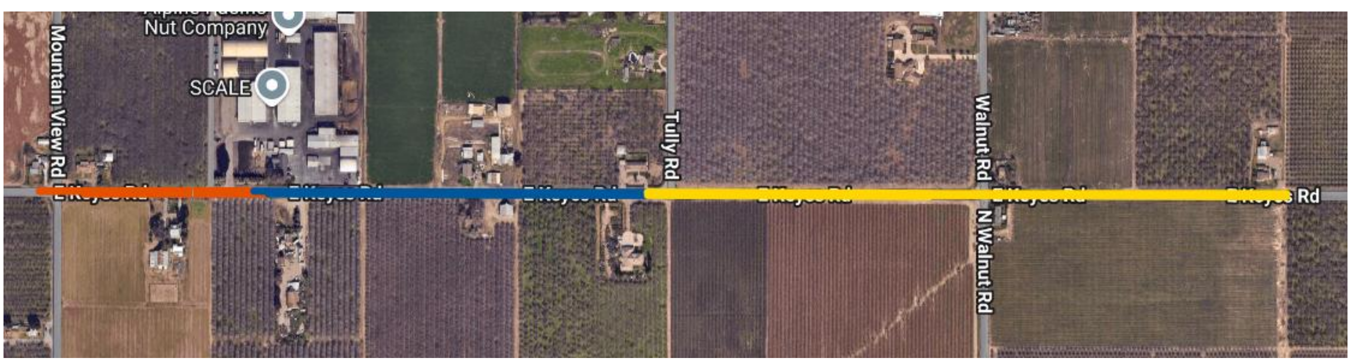


Figure 3. Material placement limits – Orange represents SmartMIX™, blue represents PelletPAVE-TR, and yellow represents the HMA control

A map of the overall limits of the County's project with pre-construction pavement condition indices (PCIs) is shown in Figure *4*. The road was in fair condition with PCIs ranging from 54 to 66. The colors refer to the initial plan for the project and do not map exactly onto the actual built limits. The road exhibited a mix of distresses, most predominantly longitudinal and transverse cracking, block cracking, utility reflective cracking, varying severities of alligator cracking, wheelpath rutting, and overall weathering and raveling.

Figure 4. Overall County project with PCIs

Figure *5* to Figure *9* present typical pavement conditions prior to paving. Due to budget constraints and common County practices, not all distress was repaired prior to the overlays. For this project, it was practice to leave low- and medium-severity cracking—wheelpath, joint, block, or transverse cracks—untended. Typical distresses that warranted repairs are shown in Figure *7* to Figure *9*. Repairs consisted of both base repairs (digouts) with replacement asphalt thicknesses of 6 inches and "skin patches," where the top 2–3 inches were milled off and replaced. Areas for base repair typically consisted of high-severity alligator cracking and rutting. Skin patches were typically used for environmental cracking such as high-severity and pervasive block cracking and thermal cracking.

The pre-overlay repairs on East Keyes Road were performed across the entire length of the project. While no effort was made to formally treat each section exactly the same in terms of repair, by the time construction began, the project sections were in relatively uniform condition over their entire lengths. The purpose of this was to provide relatively uniform conditions to allow comparison of the performance of each of the materials placed.

Figure 5. Typical pavement conditions – weathering and raveling and cracking

Figure 6. Typical pavement conditions – longitudinal cracking, transverse cracking

Figure 7. Typical pavement conditions – longitudinal cracking, medium alligator cracking

Figure 8. Typical pavement conditions – utility/block cracking, rutting - treated with base repairs

Figure 9. Typical pavement conditions – patching, rutting - treated with base repairs

Chico State University used drones to take footage of the condition of the pavement prior to construction and after base repairs were performed. The pervasive environmental cracking and load-related wheelpath cracking are evident in the on-site photos. Figure *10*, Figure *11*, and Figure *12* show the locations of the drone images and images of the pavement condition.

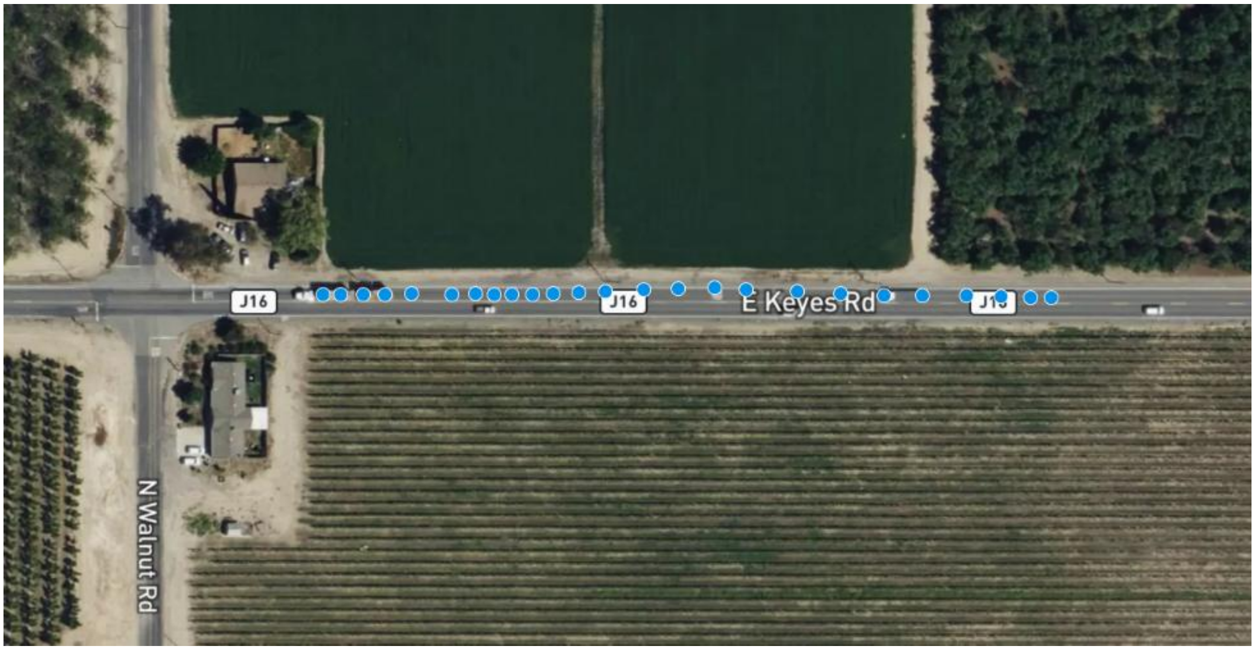


Figure 10. Drone image locations near North Walnut Road

Figure 11. Drone image of the existing pavement near North Walnut Road

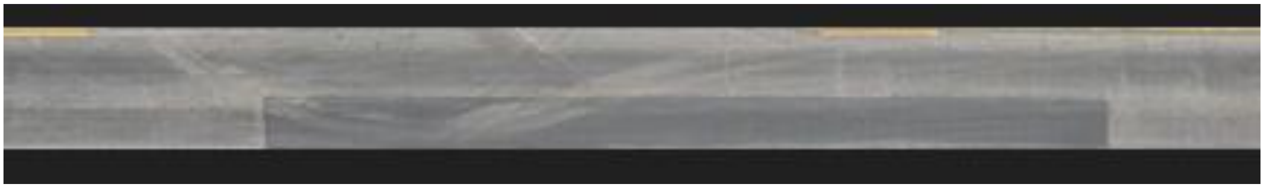


Figure 12. Drone image of base repair/skin patch west of North Walnut Road

Pelletized Materials

Material Descriptions

According to Liberty Tire Recycling, the manufacturer of SmartMIX™™, it is "a line of dry mix rubber additives for high-performance paved surfaces and is a next generation technology for rubberized asphalt. It uses proprietary technology to provide a pre-swelled, reacted rubber particle that can be simply incorporated into an asphalt mixture at the mix plant. The easy integration of SmartMIX™ does not require an additional binder, elevated mixing temperatures, longer mixing times or lengthy storage times."[1] The SmartMIX™ material is shown in Figure *13*.

Figure 13. SmartMIX™ sampled from bulk delivery bag

Phoenix Industries produces a number of products for asphalt paving. For this project, PelletPAVE-TR was used, which is considered "an alternative to terminal blended type rubber modified binders." This product is a specifically formulated PG 64-22 binder with SBS polymer and about 50% of a fine ground tire rubber powder. It is typically used to enhance the performance of dense graded mixes."[2] The PelletPAVE-TR material is shown in Figure *14*.

[1] https://libertytire.com/Products/Commercial-Products/AsphaltSmartMIX/ accessed December 26, 2024.
[2] https://pelletpave.com/PelletPAVE-TR.html accessed December 26, 2024.

Figure 14. PelletPAVE-TR sampled from bulk delivery bag

A third pelletized material, Ecorphalt, was considered for this project but not constructed. “Ecorphalt is a polymer modifier, made primarily from recycled tires that enhances the performance and durability of asphalt.”[3] It is produced by Full Circle Technology, and is made from devulcanized scrap tires. Although the product was included in the project bid package, shortly before construction began the manufacturer indicated they were unable to obtain scrap tires from California—a requirement imposed by CalRecycle—so no mixtures incorporating Ecorphalt were produced or placed.

Additional information can be found in Appendix A.

Mix Designs

The use of pelletized rubber additives in a paving project was originally planned for the summer of 2023. For several reasons, construction did not occur, and that project was cancelled. This occurred after the California Pavement Preservation Center at Chico State University prepared several mix design iterations using SmartMIX™™, PelletPAVE-TR, and Ecorphalt. None of these mix designs were used in this project.

For this project, it was determined that placing the responsibility for preparing the mix designs on the Contractor would be more efficient, would allow the Contractor more control, and would be more representative of a typical project. The Contractor selected Asphalt Pavement & Recycling Technologies in Shafter, CA to prepare the HMA control, SmartMIX™™, PelletPAVE-TR, and Ecorphalt mixes. All four designs used the same three aggregate bins—intended to represent the aggregate gradation anticipated from the three hot plant hot aggregate bins—in essentially the same proportions, with essentially the same combined

[3] https://ma-records.wixsite.com/fullcircle/ecorphalt accessed December 26, 2024.

gradation and using the same neat base asphalt. The mixtures were designed using the same mixing and compaction temperatures and had essentially the same effective binder content, voids in mineral aggregate (VMA), voids filled with asphalt (VFA), and air voids.

The Contractor-controlled mix design process was not fully transparent, which created some confusion and made it more difficult to draw conclusions. For example, the conditioned and dry tensile strengths for the four laboratory-compacted mixes differed significantly, as did the tensile strength ratios (TSR). The SmartMIX™ and PelletPAVE-TR laboratory-mixed materials also performed poorly in the Hamburg Wheel-Tracker. After some discussion, it was determined that the actual minus 200 mesh content would be higher during production than was shown in the mix designs, and that increased dust may have a mastic effect, improving the rut-testing performance. The SmartMIX™ design was altered to match the anticipated dust content and tested for rutting again, with an improvement of about 30%. After considering this information, the applicability of the typical Caltrans rut-testing requirements to this project, the history of CRM performance, and the fact that, at least in general, lower rut resistance generally indicates better fatigue, thermal, and reflective cracking performance and better durability, it was decided to proceed with the existing designs. The limited time available to revise mix designs and still complete the project on time, and the fact that performance-related testing and performance monitoring would be conducted for these materials, also informed this decision.

Upon mix design review, it was noticed that both the PelletPAVE-TR and SmartMIX™ were added at 20% by weight of binder, which resulted in approximately 10% and 20% CRM by weight of binder, respectively, rather than the target of 15% for each. Given the time constraints, and noting that constructing and monitoring the test sections would still provide useful information, the mix designs were not revised.

These complexities demonstrate that clear communication is critical in developing mix designs using materials other than the typical aggregates, binder, reclaimed asphalt pavement (RAP), and anti-strip additives. It was difficult to discern from the mix designs exactly how to set the plant controls to mimic the designs, and, while the pelletized materials were intended to be added by weight of binder, the mix designs treated them as part of the aggregate. There is no "right" way to prepare, record, and communicate the design process and resulting parameters, but it is essential that everyone involved in mixture design, production, and testing understands the process and has the information they need.

Providing batch-weight information from the mix design for each constituent and each blend is recommended, as that allows for verification of blend calculations and confirmation of proper plant control settings and operation. It is also recommended the material producers be involved early in the mix design process, and that ample time be allowed to prepare, evaluate, and, if necessary, modify the mix design(s). Finally, since the modifier for these pelletized materials is CRM, the potential for rubber-modified binder behavior—in particular, swelling after compaction—should be considered, especially as CRM contents increase. The importance of this post-compaction swelling became apparent during testing of the plant-mixed material, which will be discussed later, as it may have affected the TSR and rut-testing performance of the laboratory-mixed materials.

The mix designs are included in Appendix A.

Hot Plant Production

The production of the pelletized and control-section materials began early in the morning of October 29, 2024, with the mixture containing SmartMIX™ produced first, as shown in Figure *15*. There was only enough SmartMIX™ to produce about 460 tons of mixture. It appears this was due to the mix design including 20% by weight of binder, while the quantity supplied was based on 15% by weight of binder.

Figure 15. Morning production at George Reed Munn & Perkins plant

Mixture production occurred in George Reed, Incorporated's Munn & Perkins 8,000-pound batch plant located at 26292 East River Road in Escalon. The first SmartMIX™ batch was dry-mixed (aggregates and pelletized material only) for one second, then mixed for 32 seconds with the asphalt added (wet). With the exception of the last batch, discussed later, all batches of PelletPAVE-TR were mixed for 5 seconds dry and 25 seconds wet. Other than startup batches and the final PelletPAVE-TR batch discussed below, the completed mixes were discharged into the slat conveyor, delivered to a storage silo, and loaded from the silo into the trucks.

The RAP system was used to store, meter, and deliver the SmartMIX™ to the weigh hopper, with the SmartMIX™ delivery sacks dumped into a wheel loader bucket and then into the RAP feeder bin. The SmartMIX™ material has relatively low density and was added at about 1% by weight of aggregate to obtain 20% by weight of binder. This small flow of material resulted in some batch-weight confusion, particularly when there were gaps in the stream of SmartMIX™ on the conveyor belt. Changing the belt speed helped, and most of the production occurred with no known errors or discrepancies in batch weights.

After the SmartMIX™ material was produced and loaded for delivery to the project, production switched to the PelletPAVE-TR mixture late on the morning of October 29. Although Kelly Sockwell, the PelletPAVE-TR manufacturer's representative, expressed concerns that the PelletPAVE-TR may have formed clumps in the delivery sacks and that dumping the material into a three-sided bin and mixing with a wheel loader may be necessary, this did not appear to be a concern; the material was dumped directly from the storage sacks into a wheel loader bucket and then into the RAP feeder bin. Kelly mentioned that a small feeder with a 12-inch weigh belt is often used and can provide more precise feeding of the pelletized material than a RAP system may be capable of. He also mentioned that PelletPAVE-TR can be mixed directly with the binder in a high-shear mill if desired. Presumably these alternatives would be available for SmartMIX™ or other products, and discussions with the manufacturer prior to the start of a project are recommended.

The PelletPAVE-TR material seemed to feed better than the SmartMIX™™, likely due at least in part to the larger quantity of material necessary to provide a given CRM content, since PelletPAVE-TR contains roughly 50% virgin asphalt and additives and 50% CRM. For either material, it appears that gaps in the stream of pelletized material caused the plant control system “snapshots” to show zero weight when there was actually material in the weigh hopper. As with any change in procedure or materials, the processes specific to the plant producing these mixes should be reviewed, monitored, and adjusted as necessary.

At the request of Kelly Sockwell, Technical Director for Phoenix Industries, LLC, the last batch had 30% PelletPAVE-TR added by weight of binder, which provided 15% CRM by weight of binder. The material was mixed for 5 seconds dry and 30 seconds wet, discharged into a wheel loader, and placed in a pile. A significant number of spherical agglomerations of PelletPAVE-TR were noted, with some as large as approximately two inches in diameter. When broken open, these agglomerations appeared similar to PelletPAVE-TR at ambient temperature, with no apparent softening of the virgin binder. This indicates that, for PelletPAVE-TR contents greater than 20% by weight of binder, additional heating and mixing time and/or higher production temperatures may be required. Because of the heterogeneous nature of this material, it was not sampled or tested as part of this project.

The control mixture—essentially the same aggregate and asphalt blend used for the SmartMIX™™ and PelletPAVE-TR mixes, but without the additives and with the virgin binder content adjusted to provide similar mixture volumetrics—was produced and placed on October 30, 2024. This material was also placed in lieu of the Ecorphalt mixture, as Ecorphalt was not available as noted above.

Test Results

Loose hot mix samples for mixture properties and cores for field density were obtained for the SmartMIX™, PelletPAVE-TR, and HMA control mixes. The extracted gradations for all three mixes were generally close to the design values for all sieves except the #4, where the control was 6% higher and the SmartMIX™ and PelletPAVE-TR were 3% higher than the target value. All three mixes showed 0.5% to 1.6% higher minus #200, which was anticipated. Ignition asphalt contents were similar to the target values for the control and PelletPAVE-TR mixes, but 0.45% above the target for the SmartMIX™. Since binder content is generally controlled accurately in a batch plant, this may be due to the SmartMIX™ behavior in the ignition oven, as the air voids were at 4% and the Gmm was somewhat higher than the mix design values, neither of which indicates high binder content.

Gmm values were generally higher for the plant-mixed samples than the lab-mixed samples, which may simply be due to a different laboratory testing the materials. Gmb values were higher than anticipated for the measured binder content for all three mixes as well, also likely due to testing by a different laboratory. Air voids ranged from 1.7% for the control to 2.9% for PelletPAVE-TR to 4.1% for SmartMIX™. This is likely due to higher binder contents, more minus #4 and minus #200 material, and the relatively greater increase in Gmb values for a given binder content for the plant-mixed versus laboratory-mixed materials. VMA, which is a function of Gmb and binder content, was lower for the plant-mixed materials than for the laboratory-mixed materials. VFA for the field-mixed materials was higher for the control and PelletPAVE-TR, and lower for the SmartMIX™, than VFA for the laboratory-mixed materials.

Dry (unconditioned) indirect tensile strengths for the field-mixed materials were similar for the control, somewhat higher for PelletPAVE-TR, and more than double for SmartMIX™ relative to the laboratory-mixed materials. Wet (conditioned) strengths were somewhat to substantially higher for the field-mixed samples of all three mixtures, as were TSRs. While the TSRs for the control and PelletPAVE-TR were greater than 80, the SmartMIX™ TSR was 70. Both wet and dry strengths for SmartMIX™ were approximately double those of the other mixes. Hamburg Wheel-Tracker testing found the rut depth to increase from 7 to 11 millimeters for the HMA control, but to decrease to less than six millimeters at 25,000 cycles for both PelletPAVE-TR and SmartMIX™, when comparing field-mixed to laboratory-mixed materials. This is the opposite of what the mix design data indicated (i.e., less rutting for the control and much greater rutting for PelletPAVE-TR and SmartMIX™). Clearly, care must be taken when preparing mix designs with these materials, and differences—sometimes significant—can be expected between laboratory-mixed and field-mixed materials in some cases, particularly with regard to performance-related testing such as moisture sensitivity and rut testing.

The initial test results for SmartMIX™ indicated 8% air voids. Initial testing used a 10-minute dwell or hold time to reduce or eliminate swelling of the specimens after removal from the molds, but because the results did not appear to be correct, the remainder of the sample was retested using a 20-minute hold. This lowered the Gmb and air voids and increased the TSR strengths significantly. Future users should keep this in mind and make sure swelling of specimens does not result in unreliable or non-representative information.

Coring indicated average compaction of 95.5% of Gmm for the HMA control, 93.6% for PelletPAVE-TR, and 93.8% for SmartMIX™, with all individual results in excess of 92%. No changes in roller patterns or mix behavior were noted between the three materials.

The test results can be found in Appendix B.

Mix Delivery and Placement

Delivery

The first delivery truck of SmartMIX™ left the plant at 7:30 a.m. on October 29, 2024, with trucks organized for delivery to the project site as in Figure *16*. Mix delivery southbound from the Munn & Perkins plant in Escalon to the intersection of East Keyes Road and Mountain View Road was approximately a 40- to 45-minute trip; trucks were routed from the south as they neared the project site due to traffic on East Keyes Road.

Figure 16. Trucks arranged at Munn & Perkins plant for mix delivery

Bottom dump trucks were staged along East Keyes Road throughout the day, as shown in Figure *17*.

Figure 17. Mix delivery truck staging on East Keyes Road

Paving

Paving began west of the Mountain View Road intersection and proceeded eastward in the EB lane. The following equipment was used for this project:

- Elgin Road Wizard broomer sweeper
- Bear Cat tack coat distributor from Pacific Northwest Oil
- John Deere 210L EP tractor loader
- Caterpillar AP1055 paver
- Weiler PM1025 windrow elevator (pickup machine)
- Caterpillar CB10 (breakdown), CB 13 (intermediate), and CB 24 (finish) rollers

The paving process for all three materials started with brooming, as shown in Figure *18*, followed by application of 80:20 SS-1 tack coat at 0.070 gallons per square yard, or about 0.036 gallons per square yard of residual asphalt, as shown in Figure *19*.

Figure 18. Initial brooming of pavement

Figure 19. Tack coat application

Windrows and a pickup machine were used to facilitate paving as shown in Figure *20* and Figure *21*. Rolling followed mix placement as shown in Figure *22*.

Figure 20. Windrow and pickup machine

Figure 21. Pickup machine and paver staged for next material

Figure 22. Compaction rolling

The stop-and-start transitions for each change in materials were deliberately prepared using a loader to sharply cut the existing material, as shown in Figure *23*. Visual inspection of these locations showed them to be tight, smooth, and relatively imperceptible, particularly at traffic speeds. The transition between PelletPAVE-TR and HMA control is shown in Figure *24*.

Figure 23. Loader cutting stop and start transitions for each material

Figure 24. Transition between PelletPAVE-TR and HMA (courtesy Google Streetview)

Timing

<u>SmartMIX™</u>

Paving SmartMIX™ EB began at 8:30 a.m. Air temperature was approximately 50°F. Paving was completed by 10 a.m. Sanding then followed, and the EB lane was opened to traffic at 10:10 a.m. Paving began WB at 11:05 a.m. and was completed by 12:15 p.m.

<u>PelletPAVE-TR</u>

Paving for PelletPAVE-TR followed the same sequence as SmartMIX™, with brooming and tack coat applied starting at 12:20 p.m. and 12:30 p.m., respectively. Placement began WB at 12:40 p.m., with windrow temperatures taken at 298°F. At this point, pavement surface temperatures exceeded 80°F. EB paving started at 2:15 p.m. and was completed at approximately 3:30 p.m.

<u>HMA Control</u>

On October 30, 2024, sweeping commenced at 7:45 a.m., with tack coat application at 8:15 a.m. Mix trucks left the plant starting at approximately 8:20 a.m. and arrived, beginning to dump mix at 9:00 a.m. Paving started EB at 9:05 a.m. Air temperatures were slightly below 50°F and rising. Paving EB was completed at 11:30 a.m. WB paving began at 12:50 p.m. and was completed at approximately 3:30 p.m.

A photograph of the completed project, including striping, is shown in Figure *25*.

Figure 25. Completed project

Following completion of paving and striping, test section identification signs, as shown in Figure *26*, were placed along East Keyes Road at the points of pavement material change to identify the test sections and inform the public.

Figure 26. Test section identification signs

Quality Assurance (QA) Testing

QA material testing, based on Caltrans 2023 Standard Specifications, was conducted on in-place materials on behalf of the County. Given the small size of these sections, *one* standard 750-ton lot was needed for SmartMIX™, *one* lot for PelletPAVE-TR and *two* lots for HMA Control. Moore Twining Associates, Inc. performed aggregate testing, field nuclear gauge testing, and density core sampling, while Trinity Engineering Laboratories performed mix testing.

Nuclear gauge testing for density per CTM 375 was performed by field inspectors. Density testing (percent of theoretical maximum density [TMD]) results by material/lot shown below:

- SmartMIX™ (Lot 1): 92.5% (93%, 92%)
- PelletPAVE-TR (Lot 2): 92.5% (94%, 91%)
- HMA Control (Lot 3 and Lot 4): 94% and 91%

Testing reports are presented in Appendix B.

QA laboratory testing was performed on the project aggregate. Aggregate was collected from the plant (Figure *27*), and the same aggregate was used for all three mixes (four lots).

Figure 27. Aggregate sampled from plant

QA aggregate tests were conducted for each mix (four lots total). Aggregate testing consisted of:

- Gradation
- Sand Equivalent (AASHTO T 175)
- Percent Crushed Particles (AASHTO T 335)
- Flat & Elongated Particles (ASTM D4791)
- Los Angeles Abrasion (“Rattler”) (AASHTO T 96)
- Fine Aggregate Angularity (AASHTO T 304, Method A)
- Moisture Content (AASHTO T 255)

QA aggregate tests passed Caltrans requirements. Aggregate testing results are presented in Appendix B.

Each of the three pelletized/control mixes (four lots total) was tested for acceptance from sampled material and HMA cores. The tests performed were:

- Binder Content (AASHTO T 308)
- HMA Moisture (AASHTO T 329)
- Air Voids (AASHTO T 269)
- VMA (Asphalt Institute MS-2)
- Dust Proportion (Asphalt Institute MS-2)
- Nuclear gauge (CTM 375)
- Hamburg Wheel (CTM 389)
- Moisture Susceptibility (“Modified Lottman”) (AASHTO T 283)

A summary of key pelletized and control mix test results on the sampled material and HMA cores follows in Table *1*. All three mixes met in-place compaction requirements as a percent of TMD. Note that these percent compaction results vary slightly from the nuclear gauge testing, yet all pass specifications. Complete material testing results are presented in Appendix B.

Table 1. QA Binder Content and Compacted Density (% Rice/Gmm) by Mix

Mix	Binder Content Specification (%)	Binder Content Result (%)	Compacted Density Specification (% Rice)	Compacted Density Result (% Rice)
SmartMIX™	5.75 (-0.4, +0.5)	6.2	91 to 97	93.8
PelletPAVE-TR	5.50 (-0.4, +0.5)	5.8	91 to 97	93.6
HMA Control	5.55 (-0.4, +0.5)	5.8	91 to 97	95.5

Performance-related testing was also conducted; results found in Table *2*.

Specifications:

- Moisture Susceptibility ("Modified Lottman") (AASHTO T 283) – Dry ≥ 100 psi; Wet ≥ 70 psi.
- Hamburg Wheel-Tracker (CTM 389) – Repetitions to 0.5-inch rut depth, > 15,000.

Table 2. Performance Testing – TSR and Hamburg Wheel-Tracker Results

Mix	Dry Tensile Strength	Wet Tensile Strength	Tensile Strength Ratio (TSR)	Result
SmartMIX™	136.4	87.3	64%	>15,000
PelletPAVE-TR	122.9	89.5	73%	>15,000
HMA Control	176.8	114.3	65%	>15,000

Each of the mixes placed passed moisture susceptibility and Hamburg Wheel-Tracker.

Conclusions

General

Stanislaus County's and CalRecycle's paving project, consisting of two pelletized rubber asphalt pavement sections and an HMA control section, was successfully completed in October and November 2024. This project consisted of development of pelletized mix designs using rubber from California tires, creation of PS&E documents, and construction.

While there was a learning curve associated with the use of these pelletized additives, and while producers of pelletized additives currently do not operate in California, these test sections may ultimately demonstrate that these materials can satisfactorily perform on California pavements. In addition, these materials do not impose the added costs and mobilization issues of the rubber blending unit associated with the more commonly used gap-graded rubber in asphalt mixes; therefore, they may be a practical option for more rural and remote areas of California.

County Perspective

It is not an easy matter for any public agency to offer one of their roads to test a new pavement technology, particularly on a critical farm-to-market road with heavy truck volumes. Stanislaus County has been a recipient of prior CalRecycle grants. As such, they have witnessed and recognize the superior pavement performance of asphalt-rubber. Therefore, constructing test sections with rubberized products presented a relatively low risk. Moreover, the County was very pleased that CalRecycle would be funding a robust inspection and material testing regime that would also reduce risk. The County was very pleased with the final result of the test project and has recently presented the project at the California League of Cities Public Works Conference. The County is committed to partnering with CalRecycle to monitor the ongoing performance of the test sections.

Recommendations for Future Monitoring

The development of mix designs and placement of these pelletized materials on East Keyes Road were not done with the intent to make them formal pavement test sections. That said, CalRecycle and the County will continue to monitor these pavement sections on a regular basis—looking at overall performance, reflective cracking, rutting, and durability.

On October 9, 2025 (approximately one year after initial placement), a visual survey of the pavement condition test sections and conventional asphalt control was conducted by CalRecycle and NCE staff. Photos are shown in Figure 28, Figure *29*, and Figure *30*. The team utilized the Pavement Surface Evaluation and Rating (PASER) method to evaluate the existing pavement conditions. The 1-10 PASER rating system for road pavement condition was developed by the University of Wisconsin-Madison Transportation Information Center. It uses visual inspection to evaluate pavement surface conditions. The PASER assessment method does not require measurements of individual distresses, making it a quick and efficient way to assess road segments. The two pelletized rubber asphalt pavement sections and conventional asphalt control were evaluated, demonstrated no visual pavement distress, and had a PASER rating of 9 (excellent).

In the future, existing drone videos of the pavement obtained following base repair and before initial construction will be compared against future drone videos, and on-pavement walking surveys will be conducted. The overall goal is not to determine a ranking of materials, but rather to assess the suitability of these materials for use by local agencies—and rural agencies in particular.

Figure 28. Beginning of SmartMIX™ test section October 2025

Figure 29. Beginning of PelletPAVE-TR test section October 2025

Figure 30. Beginning of conventional HMA test section October 2025

Abbreviations and Acronyms

CalRecycle - State Department of Resources Recycling and Recovery

Caltrans – California Department of Transportation

AC – asphalt concrete (conventional)

ARHM (-G) – asphalt-rubber hot mix gap-graded

CRM – crumb rubber modifier

HMA – hot mix asphalt

PASER – pavement surface evaluation and rating

PS&E – plans, specifications, and estimate

QA – quality assurance

RAP – recycled asphalt pavement

RHMA-G – rubberized hot mix asphalt gap-graded

RMSE – root mean square error

SMA – stone matrix asphalt

TMD – theoretical maximum density

TSR – tensile strength ratio

UCPRC – University of California Pavement Research Center

VFA – voids filled with asphalt

VMA – voids in mineral aggregate

Glossary of Terms

Asphalt-Rubber. A blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 15% by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles (ASTM D8 Standard Terminology Related to Materials for Roads and Pavements).

Dense graded. A continuously graded aggregate blend typically used to make HMA with conventional or modified binders.

Gap-graded. Aggregate that is not continuously graded for all size fractions but is typically missing or low on some of the finer-size fractions (minus No. 8 or finer). Such gradations typically plot below the maximum density line on a 0.45-power gradation chart. Gap grading is used to promote stone-to-stone contact in HMA and is similar to the gradations used in stone matrix asphalt, but with relatively low percentages passing the No. 200 sieve size. This type of gradation is most frequently used to make asphalt-rubber gap-graded paving mixtures.

Pavement condition index (PCI). Numerical rating system, ranging from 0 (poor) to 100 (very good), to assess the overall pavement condition based on, for example, cracking, rutting, and rideability.

Reflective cracking. Cracks occurring in asphalt pavement overlays directly above existing cracks in the underlying pavement.

Theoretical maximum density (TMD). The density to which an asphalt mixture can be compacted resulting in zero percent air voids, and only solid material. It is used as the basis by which compaction results are measured. It is also called “Rice density” as named after James Rice who developed the concept and testing process.

Appendix A
PELLETIZED ASPHALT MIX DESIGNS

Appendix B

CONSTRUCTION QUALITY ASSURANCE TESTING RESULTS