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Lessons Learned from the Construction and Initial Performance of a Double Chip Seal over a Paving Mat Pilot Project

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Abstract: Single chip seals are used by many agencies to maintain or preserve their roadways. While the construction and performance of single chip seals can be easily found from literature, the construction of double chip seals with and without paving fabric or paving mats is still not common. This paper investigates four double chip seal strategies used in a pilot project constructed on US 395 in Inyo County, California, by Caltrans. Within the double chip seal project limits, eight Performance Evaluation Sections (PESs) using four treatment strategies were established for detailed performance monitoring and evaluation: 1—a 3/8-inch asphalt rubber chip seal followed by a 1/4-inch PME chip seal without pavement-reinforcing fabric (PRF) or a paving mat as a control section; 2—a 3/8-inch PME chip seal over PRF, followed by a 1/4-inch PME chip seal; 3—a 3/8-inch PME chip seal over a paving mat, followed by a 1/4-inch PME chip seal; and 4—an asphalt rubber 3/8-inch chip seal over a paving mat, followed by a 1/4-inch PME chip seal. This pilot project was monitored during construction and evaluated 1 year later to help identify any construction issues and was used to improve the specifications and performance of Caltrans' chip seals. This paper presents the initial findings following construction, and the one-year performance of the pilot project and lessons learned. The findings presented were accomplished by using these four treatment strategies on a highway with a very adverse high desert climate type and high traffic volumes. Project reviews are also planned for up to seven years to determine the long-term project performance.

Keywords: chip seals; double chip seals; asphalt rubber (type II); polymer-modified emulsion (PME); pavement-reinforcing fabric (PRF); paving mat

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1. Introduction

Chip seal is one of the most commonly used pavement preservation treatments for asphalt pavement roads in California, and it has been successfully used worldwide. Most chip seals are single chip seals that are placed when a road is in fair condition. There are many guides available on when and how to use single chip seals both nationally and internationally [1–14]. The usage of double chip seals is not commonly cited in these guides. PRF combined with chip seals is also not commonly cited. Caltrans has been using asphalt rubber chip seals as a pavement preservation maintenance strategy and as an interlayer for pavement rehabilitation projects since the 1970s [15]. Although the asphalt rubber chip seal is more expensive than emulsion chip seals, it generally performs better because it lasts longer [16–19]. In California, the asphalt rubber (AR) binder used in chip seals is typically a field-blended asphalt rubber binder (Type II), which consists of asphalt binder, oil extender, and crumb rubber modifier (scrap tire crumb rubber and high-natural-crumb rubber) [20]. This product is normally constructed as a single chip seal without PFR or a paving mat; however, this pilot project was constructed to evaluate the performance of a double chip seal using a paving mat, a geosynthetic woven fabric, over the existing hot mix asphalt (HMA) pavement. Another reason to use a double chip seal over a paving mat is that the pre-existing asphalt pavement has extensive fatigue cracking and it is believed that a paving mat with a double chip seal would delay reflective cracking from the underlying fatigue cracking longer than single unreinforced chip seals. A double chip seal with a reinforcing paving mat is a cheaper alternative when compared with rehabilitation alternatives. Herein, for the double chip seal over a paving mat, the first chip seal was placed over the paving mat placed on the existing pavement using an asphalt rubber binder (Type II) chip seal, and then, it was followed by a polymer-modified-emulsion chip seal, creating a double chip seal.

The objective of this pilot project is to evaluate the relative field performance of the following four combinations of materials for chip seal applications. Except for the PESs, this project used the Treatment 4 strategy for the remaining 14.2 miles of the southbound 2-lane highway on US 395. The treatment strategies for the PESs used the following materials for the double chip seals:

Treatment 1—a double-layer (1) 3/8-inch asphalt rubber binder (Type II) chip seal, and (2) 1/4-inch PME chip seal.

Treatment 2—a double layer over pavement-reinforcing fabric (PRF), (1) 3/8-inch PME chip seal, and (2) 1/4-inch PME chip seal.

Treatment 3—a 1/4-inch double layer over a GlasPave 50 paving mat, (1) 3/8-inch PME chip seal, and (2) 1/4-inch PME chip seal.

Treatment 4—a double layer over a GlasPave 50 paving mat, (1) 3/8-inch asphalt rubber binder (Type II) chip seal, and (2) 1/4-inch PME chip seal (typical application for the project).

2. Project Information

Caltrans has recently updated its chip seal specifications, and this pilot project was selected to evaluate the performance of a double chip seal placement with a paving mat (GlasPave 50), and with pavement-reinforcing fabric (PRF), compared with Caltrans' double chip seal. The AADT for this section of US 395 was 6500 and the truck percentage was about 16.6% based on the Caltrans 2013 Traffic survey [21]. This project is located in a high-desert-climate region with an average highest temperature of 100 °F and an average lowest temperature of 28 °F. This high-desert area has a very harsh weather environment with extreme low and high temperatures. The adverse weather in this climate region makes this an ideal project to monitor performance for early distress or failure.

The four different chip seal treatments were placed in the southbound No. 2 lane from PM 77.4 to PM 91.6, with Pavement Evaluation Sections (PESs) between PM 77.4 and PM 78.1. This pilot project included treatment test sections, as shown in Figure 1. Within each treatment test section, two Performance Evaluation Sections (PESs) were established for performance monitoring. Each PES was 200 feet long and the existing condition of each PES was evaluated via detailed crack mapping, and pre-construction photographs. Figure 2 shows examples of alligator cracking and pumping in the test sections. By Caltrans' definition, Alligator A cracking is characterized by single or double unconnected cracks in the wheel path, while Alligator B cracking is characterized by interconnected cracks in the wheel path [22]. Alligator cracking is normally due to traffic loading on deficient pavement structures. Table 1 presents a summary of the initial PES distress survey before construction. The results show that there are only small differences in the existing pavement conditions between the PESs.

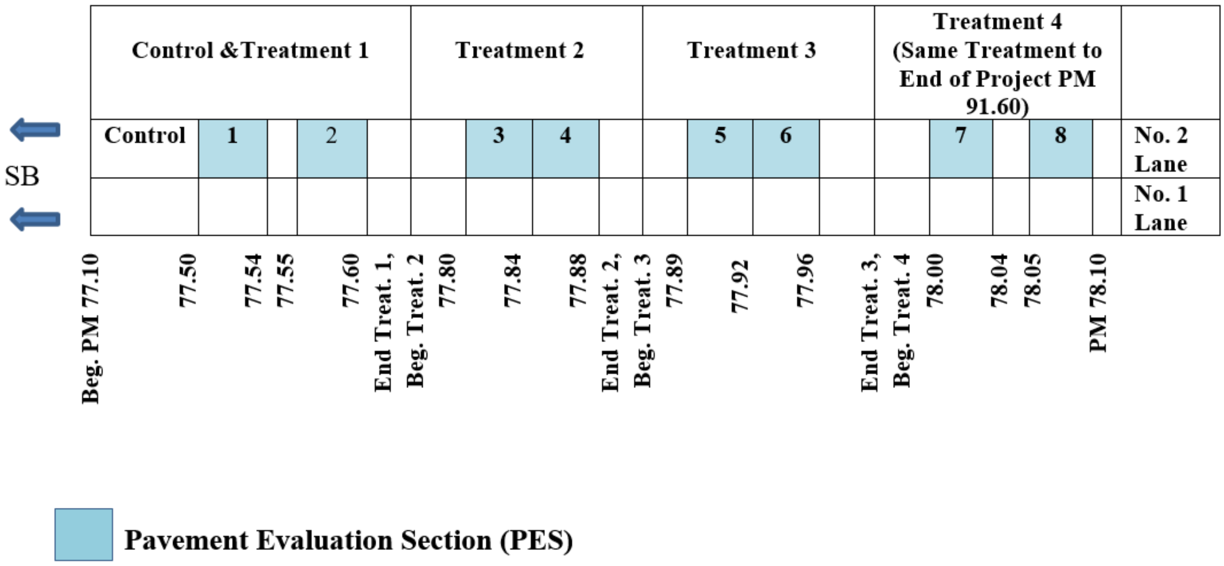
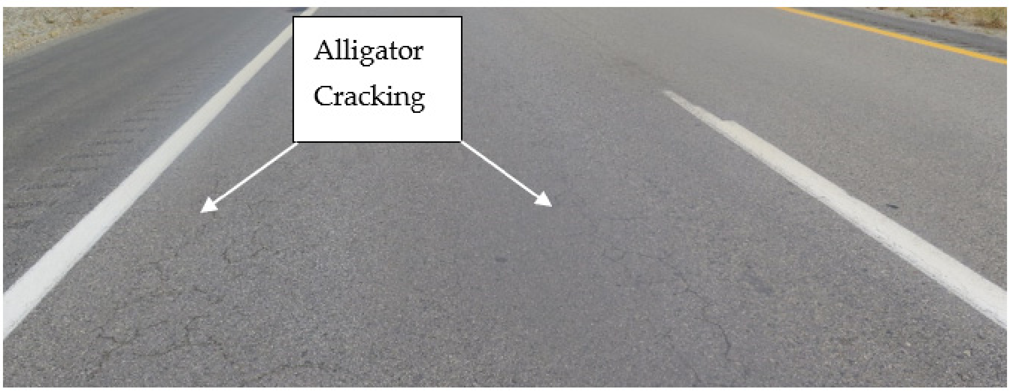


Figure 1. PES Locations for Double Chip Test Strips on US Route 395. Note: SB means southbound direction.

Table 1. PES cracking condition summary.

Distress	PES 1	PES 2	PES 3	PES 4	PES 5	PES 6	PES 7	PES 8	Total
Alligator B Cracking Low-to-Medium Severity, Linear feet, Left Wheel Path	200	200	200	120	200	200	200	200	1520
Alligator B Cracking Low-to-Medium Severity, Linear feet, Right Wheel Path	200	120	200	200	200	200	200	200	1520
Right and Left Wheel Paths Total linear feet	400	320	400	320	400	400	400	400	1340
Pumping (ft^2)	0	0	0	0	112	198	472	636	1418

Notes: no other distress was identified in this pre-construction survey performed on 7/11/2018.



(**a**)

Figure 2. *Cont*.

(**b**)

Figure 2. Alligator cracking. (**a**) Alligator B cracking on both left and right wheel paths, and pumping. (**b**) Example of pumping at wheel paths with fines in alligator cracking at test sections.

3. Construction

3.1. Construction Materials

The following are the major construction materials used in this double chip seal pilot project.

3.1.1. Aggregate

The hot pre-coated 3/8-inch chips and uncoated 1/4-inch chips were crushed and furnished by Chandler Aggregate from its plant in Lake Elsinore, California. The aggregates had a minimum cleanness value of 80 and met the gradation and other requirements for the 2015 Caltrans Standard Specifications [23].

3.1.2. AR (Type II) Binder

The AR (Type II) binder was produced and supplied by the company American Pavement Systems (APS). The base binder was a Lunday-Thagard Company PG 64-16 binder from South Gate, CA, USA. The crumb rubber modifier was supplied by BAS Recycling, Inc. from Moreno Valley, CA, USA and the oil extender was from the San Joaquin Refining Company from Kern County, CA, USA.

3.1.3. Asphalt Emulsions

For PME chip seal, the polymer-modified emulsion, PMCRS-2H, was produced by Ergon Asphalt and Emulsions, Inc. (Memphis, TN, USA), and supplied to American Pavement Systems. The project also uses the flush coat as the final application to help retain loose chips. The emulsion used for the flush coat was CQS-1H, supplied by Ergon Asphalt and Emulsions.

3.1.4. Paving Mat and Paving Fabric

The majority of the project used a geosynthetic paving mat, GlasPave 50, which was produced and supplied by Tensar International (Alpharetta, GA, USA). Traditional pavement-reinforcing fabric (PRF) was also used for performance comparison with Treatment 2. This PRF resists ultraviolet and biological deterioration, rotting, and naturally encountered basics and acids, as specified. The PRF has a melting point of about 300 °F (149 °C), while the GlasPave 50 paving mat has a melting point above 400 °F (204 °C).

3.1.5. Asphalt Binder

A PG 70-10 asphalt binder, produced by the Valero Company, was used as the asphalt binder for both the PRF and the GlasPave 50, and was directly applied to the HMA for bonding the PRF and the paving mat for this pilot project.

3.2. General Construction Process

The following describes the general construction process for this double chip seal project:

- For each treatment, the pavement markers were removed, and the pavement was swept. No crack sealing was applied on the existing pavement because most of the surface distress was alligator cracking, which was too small for crack sealant application.
- For the paving mat or fabric, the PG 70-10 binder was applied using a BearCat distributor truck also equipped with a bracket for unrolling the GlasPave 50 or PRF directly onto the pavement. The fabric or mat application process was performed simultaneously with the binder application, as shown in Figure 3. Within 10 s after the application, two rubber-tired rollers started working to remove the bubbles and smooth any wrinkles prior to applying the chip seals.
- The first layer of binder (hot AR binder or PME) was applied with predetermined application rates using a hooded distributor truck for the AR binder to control air pollution.
- The 3/8-inch aggregate application (pre-coated hot chips for AR binder or uncoated chips for PME) was carried out using a BearCat chip spreader, with various aggregate dump trucks supplying the material. The aggregate application followed closely behind the binder distributor truck.
- The roller followed very closely after chip application. The minimum number of passes was achieved using two rubber-tired Caterpillar rollers. The fresh chip seal coats were repeatedly rolled and swept after the AR (Type II) binder had cooled and the PME binder was well set.
- The repeated rolling of these binders was performed to compact and to embed the chips into the binders.
- Sweeping was performed approximately three times using a series of two to four self-contained sweepers. Sweeping was performed to remove the loose chips and to decrease the chances of windshield breakage once the road was opened to uncontrolled traffic.
- The second layer of binder (PME) was applied with predetermined application rates. The distribution trucks, without hoods, applied the PME, with aggregate application following closely behind the distribution truck.
- The finer 1/4-inch aggregate application was carried out using the same BearCat chip spreader and various dump trucks.
- The rolling followed very closely after 1/4-inch chip application. Again, the minimum number of passes was achieved using two rubber-tired Caterpillar rollers.
- Sweeping was performed again multiple times to remove the loose chips prior to applying a flush seal.
- A flush coat was applied without sand over the 1/4-inch chip seal. Temporary striping was applied to the new chip seal prior to opening the lanes to uncontrolled traffic.

3.3. Construction Observations and Lessons

Overall, this project went down relatively smoothly. The equipment appeared to be in good condition, and there were not any major breakdowns. Table 2 shows the application rates for the four treatments during construction.

- **Treatment 1** includes PES 1 and PES 2. This treatment included an AR (Type II) binder with a 3/8-inch chip seal followed by a PME binder with a $\frac{1}{4}$-inch chip. The 1/4-inch chip seal was followed by a flush coat of CQS-1H. Treatment 1 did not include either PRF or GlasPave 50.
- **Treatment 2** included PES 3 and PES 4. This treatment, over PRF, included a PME binder with a 3/8-inch chip seal followed by a PME binder with a 1/4-inch chip seal.

The 1/4-inch chip seal was followed by a flush coat of CQS-1H. The PRF was applied simultaneously with the PG 70-10 binder over the existing pavement.
- **Treatment 3** included PES 5 and PES 6. This treatment, over GlasPave 50, included a PME binder with a 3/8-inch chip seal followed by a PME binder with a 1/4-inch chip seal. The 1/4-inch chip seal was followed by a flush coat of CQS-1H. The GlasPave 50 was applied simultaneously with the PG 70-10 binder over the existing pavement.
- **Treatment 4** included PES 7 and PES 8. This treatment, over GlasPave 50, included an AR (Type II) binder with a 3/8-inch chip seal followed by a PME binder with a 1/4-inch chip seal. The 1/4-inch chip seal was followed by a flush coat of CQS-1H. The GlasPave 50 was applied simultaneously with the PG 70-10 binder over the existing pavement.

Figure 3. Distributor truck equipped with fabric bracket to apply PG 70-10 binder and paving mat or PRF.

Table 2. Material application rates for different treatments and PESs.

Steps	Materials	Treatment 1 (PESs 1, 2)	Treatment 2 (PESs 3, 4)	Treatment 3 (PESs 5, 6)	Treatment 4 (PESs 7, 8)
1	PG 70-10/GlasPave 50	--	--	0.20 gal/yd^2	0.20 gal/yd^2
2	PG 70-10/PRF	--	0.35 gal/yd^2	--	--
3	AR (Type II)	0.6 gal/yd^2	--	--	0.6 gal/yd^2
4	PMCRS-2H Emulsion	--	0.32 gal/yd^2	0.32 gal/yd^2	--
5	3/8-inch Chips	32 lbs/yd^2	25 lbs/yd^2	25 lbs/yd^2	32 lbs/yd^2
6	PMCRS-2H Emulsion	0.26 gal/yd^2	0.26 gal/yd^2	0.26 gal/yd^2	0.26 gal/yd^2
7	1/4-inch Chips	16 lbs/yd^2	16 lb/yd^2	16 lb/yd^2	16 lb/yd^2
8	Flush Coat, CQS-1H (50/50)	0.10 gal/yd^2	0.10 gal/yd^2	0.10 gal/yd^2	0.10 gal/yd^2

Treatments 1 and 4 were put down without significant problems during construction. Treatment 2, which included PESs 3 and 4, showed bleeding during the very hot afternoon after all of the southbound traffic was shifted to the No. 2 lane (truck lane) past the No. 2 lane edge stripe. This was when the temperature of the new double PME seal coat was measured to be 148 °F in the distressed right wheel path on the edge stripe. Figure 4 shows the bleeding of the double PME chip seal during the afternoon (one day after construction).

When the ambient temperature reached 105 °F, the PME had low viscosity, but it did not delaminate from the PRF.

Treatment 3, which included PESs 5 and 6, showed severe bleeding and some delamination in the very hot afternoon after all of the southbound traffic was shifted to the No. 2 lane past the edge stripe. Figure 5 shows the delamination of PME from the GlasPave 50 during the afternoon, when the ambient temperature reached 105 °F. This was one day after construction and the pavement temperature was close to 150 °F. The GlasPave 50 had a lower-strength bond with the partially cured asphalt emulsion, which caused delamination under active traffic.

The low viscosity problem in Treatments 2 and 3 was remedied by the contractor shifting traffic away from the edge stripe on the No. 2 lane and applying water to cool these PESs.

Another lesson that was encountered pertained to the positioning of the GlasPave 50. There was too much overlap at the centerline between the No. 1 and the No. 2 lanes, which required that the top layer of the GlasPave 50 be trimmed.

Figure 4. Treatment 2: PME bleeding in right wheel path at PES 4.

Figure 5. Treatment 3: delamination from GlasPave 50 and bleeding at PES 6.

3.4. Field Vialit Test Results

The modified field Vialit test was used to test the adhesion between the binder (emulsion or hot binder) and aggregate [24]. It involved dropping a 500 g steel ball onto a Vialit plate three times to evaluate the percentage of rock retained on the plate. Caltrans specified a 95% rock retention for the design for the pilot project. Table 3 shows the Vialit test results using the double chip seal field samples; all the double chip seal field samples show good chip retention results, which exceeded the specified retention for this double chip seal.

Table 3. Field sample Vialit test results.

PES Section	**2**	**4**	**6**	**8**	
Sample Description	**Double Chip—1/4″ Chip with PME over 3/8″ Chip with AR**	**Double Chip—1/4″ Chip with PME over 3/8″ Chip with PME**	**Double Chip—1/4″ Chip with PME over 3/8″ Chip with PME**	**Double Chip—1/4″ Chip with PME over 3/8″ Chip with AR**	**Retention Specification for Double Chip Seal**
Retention Results (%)	99	98	99	99	95

4. Finished Product

The overall finished double chip seal product looked uniform and smooth. Figure 6 shows the overall pavement condition, looking north from the south end of the project, while Figure 7 shows the overall double chip seal condition at each PES. Bleeding was visible for PES 5, and delamination near the right edge striping was shown in PES 6.

Figure 6. Looking north near south end of project on new double chip seal.

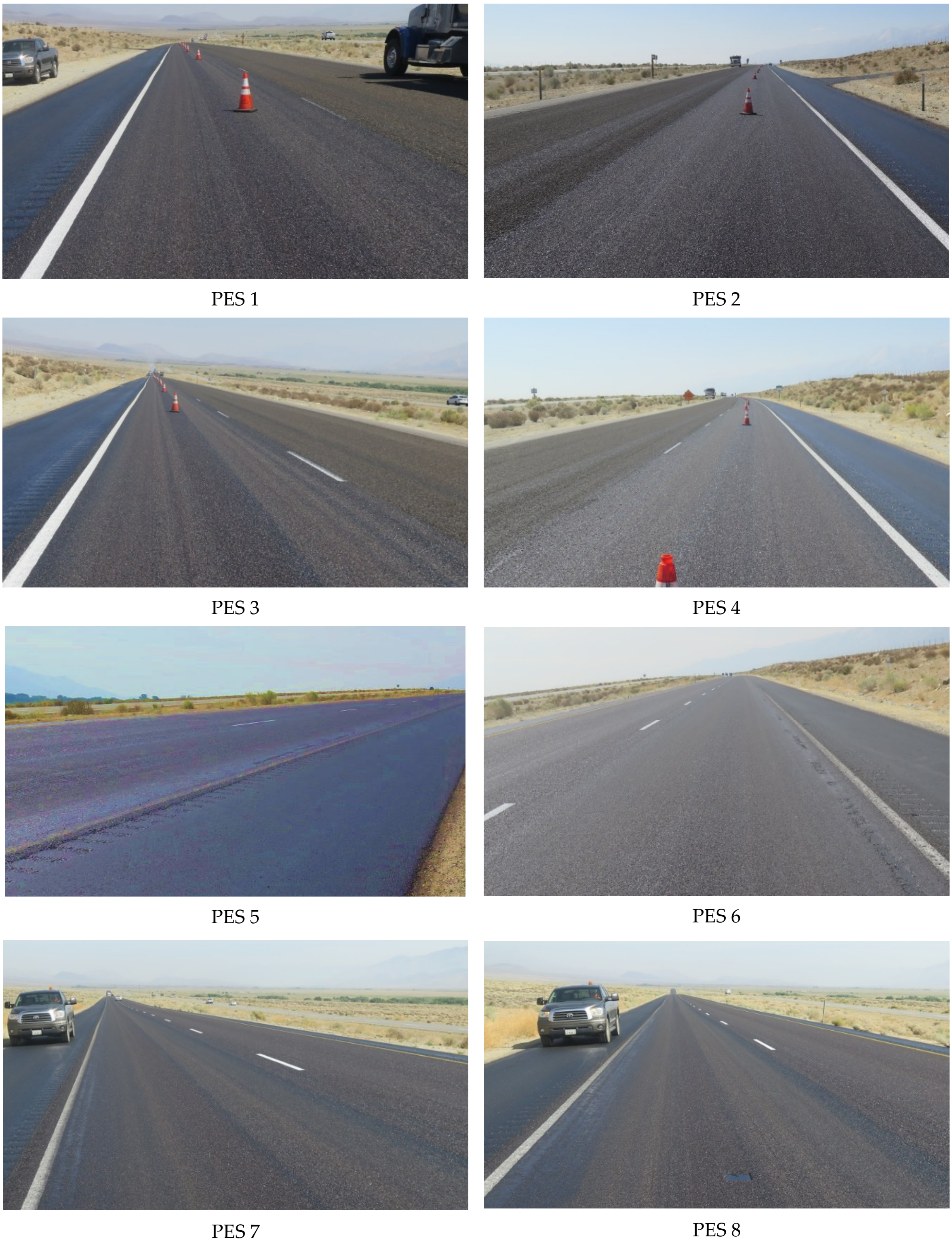


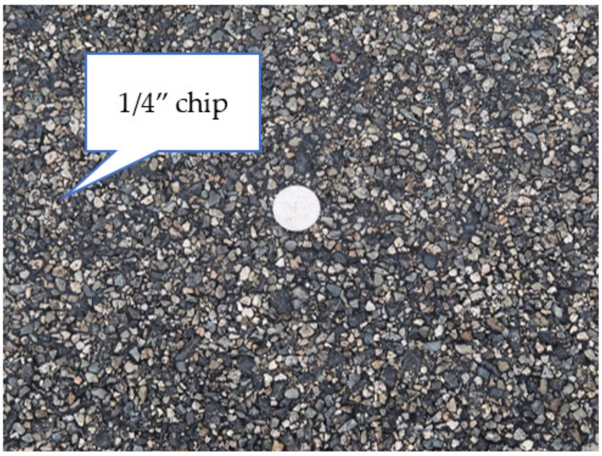
Figure 7. Overview of finished PESs.

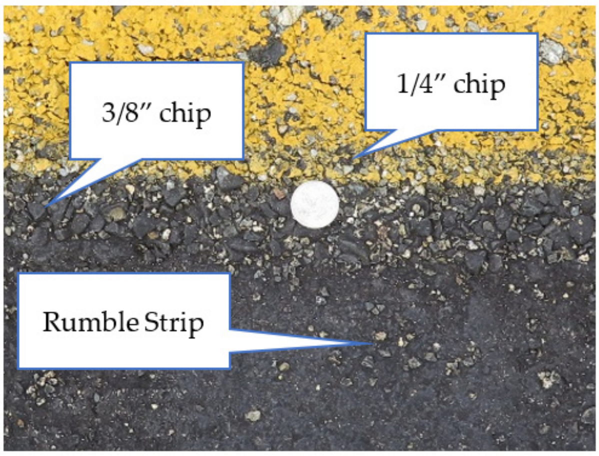
5. Initial Field Performance

The double chip seal project was visited one year after the construction. Overall, as shown in Figure 8, there was no alligator cracking throughout the project, and the double chip seal with the GlasPav 50 paving mat prevented reflection of the fatigue cracking successfully for one year. Figure 8a shows the overall texture of the double chip seal surface.

In a chip seal lane, the surface was covered with 1/4-inch rock (Figure 8b), while at the edge of the chip seal (Figure 8c), some 3/8-inch rocks were visible.

(**a**)

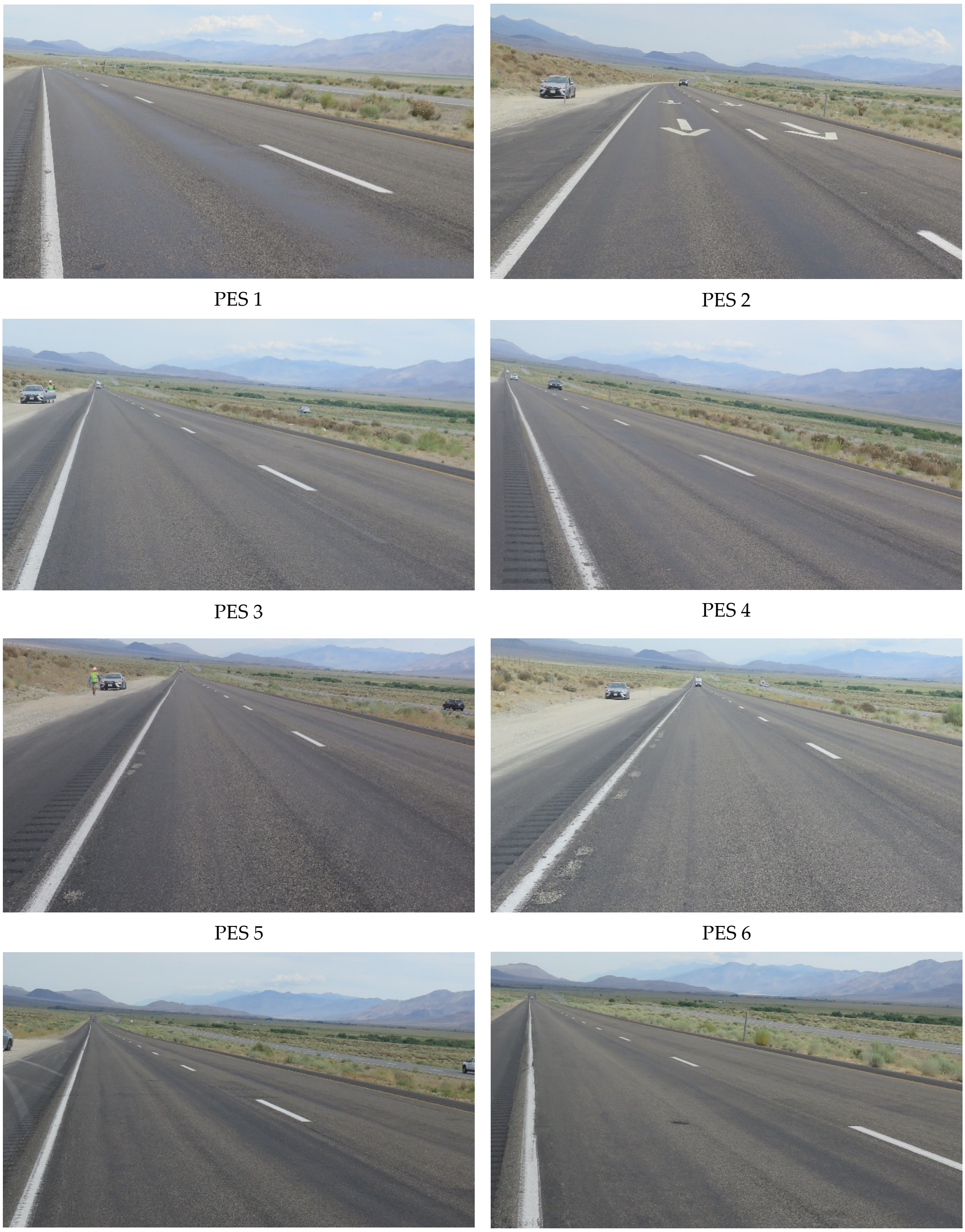




(**b**) (**c**)

Figure 8. The surface texture of the double chip seals. (**a**) Overview of double chip seal over GlasPav 50 one year after construction; (**b**) Middle of a lane; (**c**) edge of the chip seal surface.

Figure 9 shows the overall pavement conditions for PESs. There was light to moderate bleeding at wheel paths on the test sections. The binder application rates could be reduced and the design guidelines are available [25,26]. In addition, there was some patching to repair the delaminated areas near the edge stripe of PESs 5 and 6.



PES 1 PES 2
PES 3 PES 4
PES 5 PES 6
PES 7 PES 8

Figure 9. Overall performance of PESs one year after construction.

Table 4 shows the summarized distress found in each PES one year after construction. PESs 1 and 2 had moderate bleeding in the wheel paths, while the other PESs had only light bleeding. Both the paving mat and PRF may help absorb some of the excess binders. The bleeding also suggests that lighter application rates on binders should be considered in future double chip seal applications. There were a few spots that showed raveling or delamination in PESs 7 and 8. These spot locations were because of the collection of field Vialit sample plates, which were embedded in the chip seals.

Table 4. Summary of distress in PESs one year after construction.

Distress	PES 1	PES 2	PES 3	PES 4	PES 5	PES 6	PES 7	PES 8
Moderate Bleeding (ft^2)	400	400	0	0	0	0	0	0
Light Bleeding (ft^2)	0	0	400	400	400	400	400	400
Patching (ft^2)	0	0	0	0	26	112	0	0
Raveling (ft^2)	0	0	0	0	33	0	6	0
Delamination (ft^2)	0	0	0	0	0	0	0	3

6. Summary Findings, Lessons Learned, and Recommendations

6.1. Summary

The following are the major findings from this double chip seal-over-paving mat pilot study:

- The pre-existing pavement appeared to have relatively uniform distress and major alligator cracking throughout the southbound No. 2 lane of the project, and where the PESs were constructed.
- PESs 5 and 6 had delamination near the edge stripe when the ambient temperature was 105 °F the following day with traffic shifted from the No. 1 Lane to the No. 2 (PES) Lane.
- The contractor placed the GlasPave 50 simultaneously with the PG 70-10 binder, followed immediately by two rubber-tired rollers, which was promptly followed by asphalt rubber binder application with hot pre-coated 3/8-inch aggregate for the chip seal. This application was immediately followed by a train of two rollers to achieve aggregate embedment into the freshly applied binder. The loose chips were then swept into two self-contained sweepers. The construction process seemed efficient.
- The field Vialit test results showed that all double chip seals had a chip retention rate of more than 95%. Based on the one-year performance review, rock loss was not observed and was not a problem for the double chip seal project.
- Based on the pavement performance one year after construction, no alligator cracking was shown in the pilot project. Therefore, double chip seal with and without a paving mat successfully prevented reflective cracking for one year.
- More pilot projects should be constructed in different regions, such as mountain regions as well as valley regions of California, to verify performance.

6.2. Lessons Learned

The following are the major lessons learned from this pilot project:

- Moving high-volume traffic to the fresh PME chip seal with high ambient temperatures and high pavement surface temperatures caused moderate bleeding and delamination over the GlasPave 50 fabric.
- The asphalt rubber binder appeared to adhere better to the paving mat, GlasPave 50. No delamination occurred with the asphalt rubber binder.
- The PME binder adhered better to the PRF than it adhered to the GlasPave 50. No delamination occurred with the PME binder placed over the PRF; however, it bled with traffic running on it one day after placement with high pavement temperatures.
- The double chip seal treatment applied directly to the HMA had heavier bleeding than the double chip seal over the paving mat or the PRF. The paving mat and the PRF appeared to help absorb some excess binder.

- The contractor should have a water truck available to water-cool PME chip seal sections when there is hot weather and the PME is showing distress from low viscosity due to high temperatures.

6.3. Recommendations

The following are our recommendations for this project:

- This pilot project's performance reviews should continue to verify the long-term performance of the various strategies. The pilot chip seal should continue to be monitored at regular intervals over a 7-year period to determine the long-term performance of the four strategies. Crack mapping should be repeated within PESs as well as other forms of distress.
- Life expectancy should be quantified for the four chip seal strategies from future distress data.
- Caltrans should lower the binder application rates or practice construction in cooler weather to prevent the observed bleeding of the double chip seals with or without a paving mat or PRF.
- A future pilot project may use an existing double chip seal as a Stress-Absorbing Membrane Interlayer (SAMI) for an HMA paving project. This could eliminate Caltrans' standard practice of removing chip seal prior to re-paving.
- A new Caltrans Standard Specification, or Caltrans Standard Special Provision, should be developed for a particular double chip seal treatment based on minimizing long-term pavement distress. A particular treatment strategy could be confirmed from the four treatment strategies used in this pilot project.

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