

Slurry Seal Quality Construction

State-of-the-Practice

Nevada Department of Transportation Maintenance Division, 1263 S. Stewart St. Carson City, NV 89712

TECH BRIEF

This document is a brief technical summary on slurry seal preservation treatments which is included in a larger report, ***State-of-the-Practice in Chip Seal, Slurry Seal, Micro Surfacing and Thin Lift Asphalt Overlay Construction Quality Assurance*** (Report No. 715-15-050). This Tech Brief provides information on slurry seal specifications and construction practices. It then summarizes the state-of-the-practice elements that could lead to quality construction.

Introduction

Slurry seal “consists of a mixture of emulsified asphalt, well-graded crushed aggregate, mineral fillers, additives and water that is properly proportioned, mixed, and uniformly spread on a properly prepared surface.”⁽¹⁾ This Tech Brief summarizes the specification and construction state-of-the-practice for three agencies: the California Department of Transportation (Caltrans), the City of Columbus, Ohio, and the Virginia Department of Transportation (VDOT). The agencies were selected based on agency experience, construction volume, and reported performance. All of these elements were determined using surveys and interviews. The standard slurry seal specifications for these agencies are summarized and compared.⁽²⁻⁴⁾ Additionally, two case studies are presented.

Slurry Seal Pre-Construction Considerations

The actual pre-construction considerations are beyond the scope of this study. However, these considerations are the first step in achieving a well-performing slurry seal treatment. These include project selection based on pavement condition, pavement age, traffic, and climate. Such considerations should be used in a decision matrix or decision tree to determine which preservation treatment is the appropriate treatment to use on a particular pavement.

Slurry Seal Specifications

Caltrans, City of Columbus, and VDOT appear to have effective specifications and special provisions for slurry seal treatments. The general slurry seal specification summary for the three agencies is presented in Table 1.

Materials.

All three agencies specify a quick-set emulsion. Caltrans specifies a polymer-modified cationic quick-set emulsion (PMCQS-1h). All three agencies specify similar aggregate gradation types. These gradations follow the International Slurry Surfacing Association's (ISSA's) recommended gradation guidelines, with some minor variations present in the sieve size ranges. Additionally, Caltrans does not specify a percent passing range for No. 50 and No. 100 sieves.

Caltrans and the City of Columbus both use the ISSA gradation type naming convention (Type I, II, III), whereas VDOT uses separate identifiers (Type A, B, C). Caltrans specifies Maximum Aggregate Sizes (MAS) for the slurry types of No. 4, 3/8 inch, and 3/8 inch for the Type I, II, and III slurry seals, respectively. The City of Columbus and VDOT specify MAS values of 3/8 inch for their three slurry seal types.

Caltrans and City of Columbus use similar materials quality tests—namely, Sand Equivalent and L.A. Abrasion, whereas VDOT uses Soundness, Void Content, Organic Impurities and Deleterious Materials, which may aid in the use of a durable, non-reactive and long-lasting aggregate.

Mix Design and Verification.

All three agencies require the Contractor to provide the mix design for approval. The mix design material proportions are specified in terms of dry weight of aggregate.

Caltrans and the City of Columbus both specify the ISSA mix design method and verification tests. Caltrans specifies the asphalt binder percentage in terms of emulsion: 15-20% for Type I, 12-18% for Type II, and 10-15% for Type III. City of Columbus specifies using the recommended materials proportion ranges stated in the ISSA design standard: 10.0-16.0% residual asphalt for Type I, 7.5-13.5% residual asphalt for Type II, 6.5-12% residual asphalt for Type III, 0-3.0% mineral filler for all three types, and water and additives as needed.

The verification tests include Consistency, Wet-Stripping, Compatibility, Cohesion, Wet-Track Abrasion, and the Loaded Wheel Test Sand Adhesion (City of Columbus only). The test result requirements for each agency are the same as those suggested in the ISSA slurry seal design standard with the following exception: the City of Columbus' maximum Sand Adhesion value is 60 g/ft², compared to the ISSA's maximum of 50 g/ft².⁽¹⁾

VDOT specifies an internally-created mix design method and mix verification tests. It requires the Contractor to conduct the mix design in a VDOT-approved laboratory. The materials proportions vary by type of slurry seal. For Type A and B slurry seal, the residual asphalt content must be between 8.0-10.5%. For Type C slurry seal, it must be between 7.0-9.5%. Mineral filler percentages are not

Table 1. Slurry Seal Specifications Summary.

Elements of Specifications ^a	Caltrans	City of Columbus	VDOT
Asphalt Binders	Emulsions—QS/CQS-1hP (PMCQS-1h).	Emulsions—QS/CQS.	Emulsions—QS/CQS-1h.
Aggregates	Sand and/or crushed rock dust.	Crushed gravel and/or stone. Sand and/or crushed rock dust.	Crushed gravel and/or stone.
Mix Design/ Verification	ISSA Mix Design Method— includes tests.	ISSA Mix Design Method— includes tests.	Agency mix design method. Agency verification tests.
Equipment and Calibration	Both equipment and calibration details.	Both equipment and calibration details.	Both equipment and calibration details.
Calendar Date/ Climate Limits	Temperature limits only.	Temperature limits only.	Temperature limits only.
Inspection	Inspection of application rates. Monitor mix consistency.	Inspection of application rates. Monitor mix consistency.	Test strip performed. Monitor mix consistency.
Opening to Traffic	Opening to traffic 1-2 hrs.	Not specified.	Not specified.
Quality Control	QC includes materials testing.	QC includes materials testing.	QC includes materials testing.
Acceptance	Acceptance includes materials testing.	Acceptance includes materials testing.	Acceptance includes materials testing.

^aInformation obtained from standard specifications, published documents, and phone interviews.

specified. Mix verification tests include the Compatibility Test and the Wet-Track Abrasion Test.

Climate and Surface Preparation.

Caltrans and VDOT specify that the surface and air temperatures must be at least 50°F and rising. The City of Columbus specifies minimum surface and air temperatures of 45°F and rising. The minimum temperatures are to ensure that the slurry seal will cure within the required time frame. Surface preparation includes cleaning the surface of all deleterious material and covering exposed roadway structures. Proper surface preparation ensures the bond of the treatment with the existing pavement.

Caltrans and the City of Columbus both specify tack coats, whereas VDOT specifies water-fogging ahead of the spreader box, if needed. These applications are applied as a part of surface preparation activities to aid in bonding the treatment to the existing

pavement. Caltrans and the City of Columbus specify diluted asphalt emulsion tack coats. Caltrans specifies using a diluted SS-1h or CSS-1h emulsion with a water-to-emulsion ratio of 3:1 applied at a rate of 0.08-0.15 gal/yd². The City of Columbus specifies any diluted emulsion applied at a rate of 0.05-0.10 gal/yd².

Equipment.

All three agencies specify equipment details for a mixer, a standard spreader box, and auxiliary equipment. Caltrans specifies that either truck-mounted or self-propelled continuous mixer may be used. If used, two truck-mounted mixers are to be provided on the jobsite. The City of Columbus specifies that only 10-ton self-propelled mixers are to be used, and two must be provided on the jobsite.

The recommended industry standard is to calibrate equipment prior to the construction of every project. Caltrans specifies that each mixing unit is to be calibrated in the presence of the

Engineer prior to construction. Caltrans specifies that up to six-month-old calibration data can be used to verify a truck-mounted mixer-spreader, provided that the Contractor uses the same truck, a requirement that is verified by giving each truck a unique identifying number. In addition, the same materials must be used and be in compliance with the authorized mix design. Finally, the Contractor must not have performed any repairs or alterations to the proportioning systems in the time after the calibration has taken place.

Caltrans specifies that the adjustable cut-off gate settings of each mixer-spreader truck must be calibrated to achieve the correct delivery rate of aggregates and emulsion per revolution of the aggregate feeder. Calibration frequency of the mixer-spreader vehicle varies between agencies from five business days to two months prior to construction. VDOT requires the Contractor to maintain calibration data for the current calendar year, using the same materials that are used on the project.

Inspection.

Table 2 shows some of the primary inspection practices that are used by the agencies. All three agencies specify that mix consistency be verified during construction. Mix consistency is an indicator of the slurry seal’s ability to be spread and cured properly. For example, excessive or inadequate emulsion content can affect the slurry seal setting time.

Caltrans and the City of Columbus further specify that the application rate be verified. Caltrans requires that the target application rate be selected within a range that is based on slurry seal type (Table 2). The field application rate must be within 10% of that selected target rate. The City of Columbus uses two ISSA standards to determine the appropriate application rates: ISSA’s TB 107, *A Method for Unit Field Control of Slurry Seal Quantities*, and ISSA TB 112, *Method to Estimate Slurry Seal Spread Rates and to Measure Pavement Macrotecture*.^(5,6) The selected target rate must be maintained within the range set in Table 2 below for that slurry seal type.

Table 2. Construction Inspection requirements.

Inspection Item	Caltrans	City of Columbus	VDOT
Calibration	Conducted five business days before construction. If truck-mounted, may use 6-month old data.	Certificate indicating calibration done in last two months.	Calibration data from current calendar year. Calibration done with same materials to be used on project.
Monitor Application Rate	Must be within 10% of target rate.	Not specified.	Not specified.
Mix Consistency	Must be homogenous and uniform with no separation.	Measured each morning prior to work per ISSA TB 106.	Must not show any liquid-aggregate separation.
Application rate ranges	Type I: 8-12 lb/yd ² Type II: 10-15 lb/yd ² Type III: 20-25 lb/yd ²	Type I: 8-12 lb/yd ² Type I: 15-17 lb/yd ² Type III: 15-22 lb/yd ²	Type A: 16 lb/yd ² minimum. Type B: 16 lb/yd ² minimum. Type C: 20 lb/yd ² minimum.

Test Strip Requirements.

The recommended industry standard is to construct test strips prior to construction for every project. Some items that a test strip checks for are:

- Check the materials proportion optimization and that the proportions are kept within job mix formula (JMF) tolerances.
- Verify the application rate.
- Check for uniformity of surface texture.
- Ensure that the equipment is in good condition.
- Ensure that the workforce is well trained.
- Check the cure time.
- Evaluate workmanship.
- Ensure proper alignment of the equipment.

Test strips should be conducted under conditions that are representative of those anticipated during construction. It should be placed using the same process and equipment to be used during construction. VDOT specifies that test strips are to be placed by the Contractor prior to beginning work to test for mix Consistency per ISSA TB 106 *Slurry Seal Consistency Template*.⁽⁷⁾ The Contractor is to supply the Engineer with the machine's calibration data at this time. Test strips are also required if any in-field adjustments are made to the mix design, to ensure that the target application rate is appropriate.

Opening to Traffic and Post-Construction Monitoring.

Caltrans specifies that the opening to traffic time is based on the Contractor's mix design. Traffic is to be allowed on the treatment within one hour of construction. The treatment must be

monitored by the Contractor for 15 days post-construction, prior to final acceptance.

The City of Columbus Inspector is responsible for opening the treatment to traffic after construction. The treatment must be monitored by the Contractor for at least 30 days post-construction before it is accepted. Any necessary repairs are to be made within seven days of being identified. The City of Columbus indicated that a new draft of the slurry seal specification will remove the 30-day requirement. This requirement will be replaced with a 1-year workmanship warranty.

VDOT specifies that the slurry seal treatment must be monitored by the Contractor until final acceptance. VDOT monitors the performance of slurry seal treatments after final acceptance at the network level.

Quality Assurance.

Caltrans specifies Contractor Quality Control (QC) testing of the individual materials prior to construction. The aggregate Moisture Content is also to be tested at a rate of once per day. If the moisture content is not controlled to within a maximum daily variation of $\pm 0.5\%$, the testing frequency is increased to once per two hours. The moisture content readings taken from the mixer-spreader's aggregate belt feeder cannot vary by more than 2% over an average of three mix "runs" (one run is three tons in size). The asphalt emulsion pump rate is monitored, and variations of more than 2% on 3 runs of 500 gallons each are not permitted and must be corrected.

The City of Columbus specifies that the Contractor conduct Mix Consistency

testing, per ISSA TB 106.⁽⁷⁾ The Contractor must also keep load-by-load records of the material quantities used and provide the city with one Cone Consistency test result per day during construction. VDOT specifies that the mix Abrasion Loss and Consistency be monitored by the Contractor during construction.

Acceptance.

Acceptance practices among the three agencies focus primarily on the quality of the overall mix, with some emphasis on individual material testing. Caltrans

accepts aggregates based on the test results for Gradation and Sand Equivalent of samples taken from stockpiles once per 300 tons or 1 day's production, whichever is less. The City of Columbus accepts the surface preparation, materials quantities, and the final treatment based on visual appearance. VDOT accepts the complete slurry seal based on test results for Asphalt Content and Mix Consistency. Table 3 and Table 4 display the primary QC and Acceptance testing practices specified by all three agencies.

Table 3. Contractor Quality Control Sampling & Testing Requirements.

Test Type	Caltrans	City of Columbus	VDOT
Mix Design (Pre-Production)	May use mix design within previous 12 months.	One JMF, submitted prior to production.	One JMF, submitted prior to production.
Aggregate Moisture Content	Measured once per day. Monitored every 2 hours if not controlled to $\pm 0.5\%$ variation.	Not specified.	Not specified.
Abrasion Loss	Not specified.	Not specified.	Continuous monitoring.
Mix Consistency	Not specified.	Once per day, using ISSA TB 106	Continuous monitoring.
Asphalt Binder Pump Rate	Measured once per 500 gal.	Not specified.	Not specified.

Table 4. Agency Acceptance Sampling and Testing Requirements.

Test Type	Caltrans	City of Columbus	VDOT
Production Gradation	Once per 300 tons or 1 day's production.	Not specified.	Not specified.
Sand Equivalent	Once per 300 tons or 1 day's production.	Not specified.	Not specified.
Asphalt Content	Not specified.	Not specified.	Checked prior to production and once per 25,000 yd ² of slurry seal mix during production.
Mix Consistency	Not specified.	Not specified.	Frequency not specified. Failures require adjustments.
Surface Preparation Approval	Not specified.	Prior to beginning construction.	Not specified.
Wet-Track Abrasion	Not specified.	Not specified.	Frequency not specified. Failures require adjustments.

Case Study: City of Columbus Slurry Seal Projects

The City of Columbus provided documentation for the purposes of developing a case study based upon its city-wide preservation program. The projects included in this case study were all constructed from August 2016 to November 2016 and included 18 locations around the city. Slurry seal was placed on 209 street segments with a total project quantity of 560,000 yd². The traffic volumes on these two-lane streets is low.

The City of Columbus provided several types of construction records, including mix design records, inspection records, and yield reports. The inspection records that were provided were for asphalt content and gradation.

The JMF and verification test results are shown in Table 5. All of the test results were within the specification tolerances.

The slurry seal used in the JMF is Type II, consisting of 3/8-inch MAS limestone aggregate, 1.0% Portland cement, 13.0% CQS-1h emulsion (8.8% asphalt residual), 11% water, and 0.02% of an unspecified additive.

The inspection during construction showed that the residual asphalt content was within the JMF tolerance range. Inspection of the aggregate gradation showed that only the percent of materials passing the No. 200 sieve (P₂₀₀) was outside of the JMF tolerance. The Contractor documented one yield report on the first day of construction. The yield report covered 18,501 yd², with an emulsion content of 13.3%, residual asphalt content of 8.3%, and aggregate rate of 16.0 lb/yd².

Six inspectors were on the jobsite on different days throughout construction. The primary inspection item that was recorded was the material quantity placed on the roadway each day.

Table 5. JMF for City of Columbus Type II Slurry Seal Projects

Slurry Mix Properties	Results at 13% Emulsion	Specification, Type II
Mix time @ 77°F (25°C), TB113	250 seconds	120 seconds minimum
Mix time @ 100F (37.7°C), TB113	44 seconds	Not specified.
Cohesion @ 30min, TB139	17 N kg-cm	12 N kg-cm minimum
Cohesion @ 60min, TB139	23 N kg-cm	20 N kg-cm minimum
Water Resistance Test, 30 min	Pass	Pass
WTAT 1 hour, TB100	3.3 grams/ft ²	75 grams/ft ² maximum
Cone Consistency Flow	3 cm	2.5-3.5 cm
Set Time Blotter Test	Pass	Pass
Coating Test	99%	90% minimum
Excess Asphalt/Sand Adhesion, TB109	24.7 grams/ft ²	60 grams/ft ² maximum
Gradation		
Passing 3/8 inch	100%	100%
Passing No. 4	99%	90-100%
Passing No. 8	79%	65-90%
Passing No. 16	54%	45-70%
Passing No. 30	36%	30-50%
Passing No. 50	25%	18-30%
Passing No. 100	20%	10-21%
Passing No. 200	14.7%	5-15%

Key practices that led to quality City of Columbus projects included:

- Overall project size.
 - A total of 560,000 yd² of slurry seal was placed.
 - Proper consistency between street segment conditions.
- Requiring a mix design.
- Requiring quality assurance during construction.
 - Aggregate testing and residual asphalt content verification.
 - Continuous presence of on-site inspectors.
 - Routine checks of material quantities.
- Providing a near-continuous operation using two slurry seal trucks.
 - Placing of a large and consistent quantity of material each day.

Case Study: VDOT Slurry Seal Project

VDOT provided documentation for the purposes of developing a case study based upon slurry seal treatment construction that was performed on ten individual routes, all of which are two-lane rural roads. Placement began in March 2014 and ended in May 2014.

VDOT was able to provide several types of construction records, including mix design records, mix test reports, and inspection reports. The inspection reports that were provided were for application rate and asphalt content.

A JMF for a Type B slurry seal mix that was prepared on February 26, 2014 was provided. Table 6 presents the mix design proportions for this JMF. A Type C mix was also used, although VDOT was not able to provide that

documentation. Mix design requirements include submitting Form TL-127—*Statement of Asphalt Concrete or Central-Mix Aggregate Job Mix Formula*, Compatibility by Schulze-Breuer, and the Wet Track Abrasion test results.⁽⁸⁾ The Type B mix was a 3/8-inch MAS granite aggregate with 1.0% hydrated lime, 8.5%±1.5% CQS-1h emulsion, and cement mineral filler as needed.

VDOT provided mix property laboratory tests on Form TL-50—*Report on Asphalt Concrete Mixtures*.⁽⁹⁾ Also included were five test reports for the Type B slurry seal, ranging from sample dates of March 21 to May 4. All reports list 20,000 yd² as the amount of slurry seal that is represented by each sample. The VDOT special provision requires that samples represent a maximum of 25,000 yd² at the start of production, and can be reduced to one sample per 50,000 yd² when the mix is determined to be consistent. The tested residual asphalt content ranged from 7.1% to 8.0% for the first three samples and jumped to 9.3% and 9.8% for the last two samples, all of which were within the JMF tolerance range. The P₂₀₀ values ranged from 13.0% to 14.6%, which were on the high side of the target range of 5% to 15%.

An aggregate application rate report dated March 31 for the Type B slurry seal showed that the aggregate application rate was 15.4 lb/yd² that is lower than the required minimum of 16 lb/yd².

VDOT provided nine mix property test reports for Type C slurry seal, ranging from sample dates of April 8 to May 15. Six of the reports list sample size

Table 6. JMF for VDOT Type B Slurry Seal Project

Material Type	Mix Design JMF	Specification, Type B
Residual Asphalt	7.0-10.0%	8.0-10.5%
Mineral Filler	1.0%	Not specified.
Gradation		
Passing 3/8 inch	100%	100%
Passing No. 4	94%	70-95%
Passing No. 8	65%	45-70%
Passing No. 16	45%	32-54%
Passing No. 30	34%	23-38%
Passing No. 50	26%	16-29%
Passing No. 100	17%	9-20%
Passing No. 200	9.1%	5-12%

quantities from 70,000-170,000 yd². The residual asphalt content for the nine reports ranged from 6.4% to 7.6%. The JMF’s residual asphalt content range for Type C slurry was 5.7-8.7%.

Ten aggregate application rate reports were provided from April 8 to May 19 for the Type C slurry seal mix. The application rate for the reports ranged from 19.4 lb/yd² to 21.9 lb/yd². The specification requires a minimum target rate of 20 lb/yd², so some of the reports showed that the application rates were lower than the requirement.

Key practices that led to a quality VDOT project included:

- Overall project size.
 - Ensure a consistent mix.
- Requiring a mix design.
- Requiring quality assurance during construction.
 - Aggregate testing and residual asphalt content verification.
 - Routine checks of mix application rates.
- An onsite certified technician.
 - Monitor mix consistency.
 - Make changes as needed.

State-of-the-Practice

The recommended state-of-the-practice for slurry seal preservation treatments includes:

- Selecting quality asphalt binder and aggregate materials.
 - Quick-set asphalt emulsion.
 - Durable aggregates.
 - ISSA aggregate property tests are specified along with agency-specific tests.
- Performing a slurry seal mix design for the materials to be used during construction.
 - The ISSA method is a common slurry seal mix design standard.
- Calibrating equipment with the materials to be used during construction.
 - Recommended prior to every project.
- Proper surface preparation, including using a tack coat.
 - Achieve a clean surface to obtain bond between pavement surface and slurry seal.
- Constructing a test strip.
 - Recommended to be done on every project, under conditions similar to those that are anticipated during construction.
- Enforcing appropriate climatic conditions during construction.

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- Minimum surface and air temperatures.
 - No impending precipitation within, typically, the next 24 hours to 72 hours.
 - Continuously monitoring the asphalt content and application rate of slurry seal mix during construction.
 - Ensuring proper curing prior to opening the treatment to traffic.
 - Requiring Contractor's QC testing during construction.
 - Aggregate moisture content, asphalt binder property, residual asphalt binder content, and mix consistency.
 - Requiring agency Acceptance sampling and testing during construction.
 - Emulsion and residual asphalt binder properties, residual asphalt binder content, mix consistency, and mix proportions.
 - Testing of mix proportions requires measuring the actual quantities of emulsion and aggregates used. If measured, they could be direct pay items. This can be challenging because of the need for weigh scales at the project. Thus, emphasizing the need for proper and frequent calibration if scales are not practically available.

An additional consideration that can support quality slurry seal construction is the use of qualified personnel for:

- Conducting slurry seal mix designs.
- Constructing slurry seal treatments.
- Inspecting slurry seal during construction.
- Field testing the slurry seal mix and materials.

Additional Information

For additional information, contact this project's principal investigator Elie Y. Hajj, Ph.D. at the University of Nevada, Reno.

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7. ISSA TB 106—*Slurry Seal Consistency Template*, International Slurry Surfacing Association, 2015, 2 pp.
8. Form TL-127—*Statement of Asphalt Concrete or Central-Mix Aggregate Job Mix Formula*, Virginia Department of Transportation, Sept. 2016.
9. Form TL-50—*Report on Asphalt Concrete Mixtures*, Virginia Department of Transportation, Sept. 2016.

Additional Reference

ISSA, *MA-1 Inspector's Manual: 2010 Edition*. This document covers slurry seal and micro surfacing materials, mix design, equipment calibration in the field, sampling at the site, inspection responsibilities and procedures, safety, surface preparation, stockpiling procedures, problems that may occur, their potential causes, solutions to those problems, and other suggestions.

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