Development of Improved Procedures for Removing Temporary Pavement Markings during Highway Construction

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ABSTRACT

During highway construction, temporary pavement markings are a common necessity as is their subsequent removal. Current methods to remove markings have often been unsatisfactory, leaving pavement scarring that can be mistaken for a line. The objective of this study was to develop a methodology for removing temporary pavement markings that would not adversely affect the pavement and would leave no trace of the marking. Two experimental methods, such as modified slurry-seal coat and modified sand-seal coat, were developed and tested. A modified sand-seal coat procedure was selected as the best method. Cost analysis to estimate the expense of the modified sand-seal application was performed. A draft specification for covering existing pavement markings with a sand-seal coat was developed as an optional method.

INTRODUCTION

Background

Highway construction frequently involves modification to the existing pavement markings. During construction, maintenance of traffic plans typically consists of numerous phases, each requiring different routing of the traffic through the work zone. Existing thermoplastic markings must be removed and replaced by temporary markings indicating the new lanes. Temporary markings must also be removed and replaced as different maintenance of traffic phases is implemented.

Mechanical removal of the existing markings by water blasting or by grinding is the methods most often used for marking removal. Both methods are relatively expensive, however, frequently do not produce satisfactory results. Mechanical removal frequently results in pavement scarring, which can be a serious problem. The pavement scars can easily be mistaken for pavement markings at night under wet pavement conditions or during the day when the sun is at a low angle to the pavement.

Work zone safety is a key concern during highway construction. Safe navigation through a highway construction work zone places extraordinary demands upon the motorist. The construction activities and lighting can be a distraction at the time the motorist is negotiating temporary lane shifts and/or detours. Clearly, it is essential that the motorist not be confused or distracted by pavement markings that have not been properly removed. Furthermore, the nature of pavement construction presents problems for the maintenance of the temporary markings. Adjacent paving operations often result in the tracking of asphalt over the newly installed markings. Trucks involved in the paving operations can track the tack coat material over the open lanes and seriously distort the pavement markings. Emergency closures on major roadways, such as interstates, present additional challenges. Pavement markings must be removed quickly and effectively. The current mechanical removal methods are not satisfactory for emergency situations.

Objectives

Temporary markings must be removed and replaced as different phases of maintenance of traffic are implemented. The objective of this study was to develop a methodology for removing temporary pavement markings that would not adversely affect the pavement and would leave no trace of the marking. The method must remove all traces of the markings and leave no pavement scaring so as not to mislead the motorist.

LITERATURE REVIEW

Removal of Pavement Markings

There are several methods that have been commonly used in all states (*1*): chemical methods, excess-oxygen burning, grinding, high-pressure water jet, hot-compressed air-burning, hydro-blasting, and sandblasting. Each method produces an unsatisfactory result. Most removal methods still either damage the road or create delineation problems that confuse and distress the motorist. The most common problem is the scars left by removal processes on the pavement surface. These scars can be misinterpreted as pavement markings and can precipitate vehicle accidents, especially under wet weather conditions at night. In all states, the choice of removal method is generally left to the project contractor. For the removal of temporary pavement markings, the *Manual on Uniform Traffic Control Devices* (MUTCD) states, "Pavement marking obliteration shall leave a minimum of pavement scars and shall remove old marking material. Painting over existing pavement markings with black paint or spraying with asphalt shall not be accepted as a substitute for removal or obliteration (*2*)." In accordance with the MUTCD, the Florida Department of Transportation (FDOT) specifications for the removal of existing pavement markings provide guidelines for contractors and engineers as follows (*3*):

- Where a detour changes the lane use or where normal vehicle paths are altered during construction, remove all existing pavement markings that will conflict with the adjusted vehicle paths.
- Do not over-paint.
- Remove existing pavement markings using a method that will not damage the surface texture of the pavement and which will eliminate the previous marking pattern regardless of weather and light conditions.

As stated in the specifications, unwanted markings on the roadway must be removed without damaging the pavement surface. However, it is not easy to remove the makings without damaging the surface texture materials when contractors try to peel off the pavement markings. Thus, a method of covering up the markings may be a good alternative without using paint materials.

Seal Coating

Seal coating, a well known, relatively inexpensive maintenance method, is used on highway pavement surfaces to improve pavement texture and waterproof the asphalt surface (*4*). Seal coating is a broad term for thin pavement-surface treatments. Seal coating may or may not be covered with aggregate. For example, fog seal is the application of diluted asphalt emulsion with no cover aggregate; slurry seal is a mixture of emulsified asphalt and fine aggregate in slurry form; and chip seal or sand seal are one or more applications of asphalt covered with a thin aggregate, which must be rolled immediately. The size or type of aggregate distinguishes chip seal from sand seal. For instance, the aggregate for chip seal can be made up of crushed stone, gravel, or slag; the aggregate for sand seal can be either natural sand or rock screenings (*5*).

The type of seal coating depends on the purpose of maintenance (*6*). The application of fog seal is primarily as a remedial or maintenance treatment for deteriorating surfaces, sealing and rejuvenating the existing pavement surfaces; slurry seal is used to seal cracks in an asphalt surface and to improve or restore skid resistance; and chip seal and sand seal are usually used to improve the skid resistance of pavement surfaces and to improve the seal against air and water intrusion.

Friction Test

In all states, good skid resistance of paved surfaces is one of the most important safety requirements. A friction test is performed in order to measure the skid resistance of a paved surface. American Society for Testing and Materials (ASTM) standard specification E-274 is the most commonly used friction test and recommended for the measurement of skid resistance and pavement texture by American Association of State Highway and Transportation Officials (AASHTO) (*7*).

Ascertaining minimum skid resistance has been a critical issue for state highway agencies (SHAs). According to FDOT friction-evaluation engineers, the desired level of minimum friction is a friction number (FN) of 35 based on the Locked-Wheel friction test at a speed of 40 mph in Florida. The Pavement Systems Evaluation Section of the State Materials Office provides detailed information about testing equipment in their research report (*8*). The FDOT friction-evaluation testing equipment is called as a “Pavement Friction Unit.” It collects friction data in accordance with ASTM E 274-97. In this study, this pavement friction unit was used for the friction evaluation test by the FDOT friction-evaluation engineers.

The British Pendulum Tester can be used either in the field or in the laboratory. It can be used for special cases in which other dynamic tests are not available. The British Pendulum tester was used for the friction evaluation at Camp Blanding in this research because that test site has a limited space. In the United States, most SHAs do not use the British Pendulum Tester for the highway pavement friction test.

RESEARCH APPROACH

First, the research team investigated the feasibility of covering pavement markings rather than attempting to remove them from the pavement surface. The team applied coal tar-based seal coat materials mixed with natural sand to cover pavement markings according to the manufacturer’s specifications. These materials are frequently used for parking lot seal coating. The friction evaluation was performed on the seal-coated surface. The FDOT’s pavement friction unit (termed the Locked-Wheel Skid Trailer) and the British Pendulum Tester were used for the seal-coated surface friction tests. Field tests were performed to evaluate friction performance and ease of application at work sites.

Second, the team developed a modified sand-seal coating. In this step, a traditional sand-seal application was modified by increasing the asphalt temperature and by utilizing masonry sand as aggregate. The increased temperature shortened the break time for the asphalt and the angular sand in the aggregate improved the friction properties. A test area was installed at a construction project site, locked-wheel friction tests were performed to measure friction performance, and the opacity and durability of the covering were observed. The overview of the test plan is summarized in Table 1.

Modified Slurry-Seal Coat Approach

Two experimental field tests were performed. First, a field test at Camp Blanding was performed for a feasibility study of the modified slurry-seal coat approach to cover temporary paint markings. It is mainly focused on whether the modified slurry-seal coat application could cover the markings completely and make them invisible. Second, a field test at State Road (SR) 121 focused on the safety of the modified slurry-seal coat approach.

Field Test at Camp Blanding

Under clear weather conditions (78° F), three seal coat materials were applied using a hand sprayer according to manufacturer's specifications. Two coats are applied on a friction course pavement type. A photo of seal coating application with a hand sprayer is shown in Figure 1(a). The Camp Blanding site is a small area that consists of a 300 by 75 ft. asphalt and Portland cement runway. In this limited area, a maximum speed of 20 mph could be tested by the Locked-Wheel friction tester. The field tests for pavement friction evaluation were performed before and after application of each of the seal coatings. Friction testing was carried out using both the British Pendulum Tester and the Locked-Wheel Skid Trailer. The FDOT friction evaluation engineers performed the Locked-Wheel skid test as shown in Figure 3(a).

Results and Analysis of Field Test at Camp Blanding. Two seal coating applications covered the paint markings completely and made them invisible. The results after applying two coats are shown in Figure 1(b). The results of the friction tests are shown in Table 2. The British Pendulum test was repeated 30 times for each material. The speed of the test trailer was 20 mph for each time.

The average skid value of the British Pendulum test is decreased by 7 after applying the seal coating, while the average friction number of the Locked-Wheel test is decreased by 33. Because the Locked-Wheel test results indicated that there was a significant decrease after seal coating, more research was needed to evaluate the skid resistance of the seal-coated surface.

Field Test at SR 121

The seal coating material was applied with a rubber squeegee according to manufacturer A's specifications under cloudy weather conditions (75° F). Two coats were applied on a structural course pavement type. A photo of seal coating application is shown in Figure 2(a).

Friction tests at various speeds were performed at SR 121 in order to observe friction variations. Field tests for the pavement friction evaluation were performed before and after application of seal coating. Friction testing was carried out using the FDOT pavement friction unit. The FDOT friction evaluation engineers performed the Locked-Wheel skid test, as shown in Figure 3(b).

Results and Analysis of Field Test at SR 121. The results for two-coat applications are shown in Figure 2(b). The results of the Locked-Wheel friction test on the treated surface are shown in Figure 4. The friction test was performed at speeds of 20, 30, 40, 50, and 60 mph.

A friction number of 36 measured at 40 mph obtained from a Locked-Wheel friction test satisfies the minimum friction requirement of FN 35, which is the desired level in the state of Florida. The test results, however, showed a 29% reduction in the average friction numbers after applying seal coating. The average friction number at a test speed of 40 mph was decreased by 16 after seal coating. Decrease of skid resistance seemed to be significant after seal coating. Thus, more research efforts were needed to improve the skid resistance of the seal-coated surface for greater safety.

Modified Sand-Seal Coat Approach

To improve the friction properties of seal-coated surfaces and shorten the process time, a modified sand-seal coat approach was developed. The field test at SR 26 focused on the safety of the treated surface, the covering efficacy, and the covering durability.

Field Test at SR 26

Field installation of modified sand-seal coat as a method to cover traffic markings during construction sequencing was performed to test the application and performance of the preliminary procedure under clear weather conditions (76° F). The revised specifications are shown in Figure 9.

The existing asphalt pavement was a recently installed structural course. Four pavement marking lines were painted on the pavement for a length of 75 yards. Both the paint marking layout and the application coverage layout of the test area are sketched in Figure 5. Bituminous material, RS-1, heated to 170° F was applied at a distribution rate of 0.12 gal/yd^2. The cover material, masonry silica sand, conforming to requirements of the FDOT specifications section 902 (titled Fine Aggregate), was applied at a rate of 0.08 ft^3/yd^2. Applied sand covered 175 yd^2 more than RS-1. Application rates of modified sand-seal coat are shown in Table 3. Photos of the sand-seal coat application are shown in Figure 6.

Results and Analysis of Field Test at SR 26. The sand-seal coat application covered the paint markings completely and made them invisible. Photos of test section pavement after sand-seal coat application are shown in Figure 6. Friction testing was conducted by the FDOT friction evaluation engineers. The friction test results showed that an average friction number of 44.3 (eastbound) and 43.4 (westbound) measured at 40 mph. Both sides satisfy the minimum friction requirement of FN 35, which is the desired level in the state of Florida. Thus, the results of the test indicate that the sand-seal coat friction values were acceptable. Test results are presented in Table 4.

The entire installation process for the sand-seal coat required approximately 30 minutes. The finished sand-seal coating appeared to completely cover the paint markings. On the eastbound travel lane the contractor swept and drove over the painted lines after about 10 minutes with the distributor truck in an effort to roll the section. Because the RS-1 had not yet set, some of the sand-seal coat was picked up by the vehicle tires. This indicates that it is important to wait until the asphalt has set before brooming (sweeping). The applications rates for both asphalt and sand appeared to be correct. Friction testing indicated acceptable friction values for the treated section.

The sand-seal covering method was very convenient for the contractor. The equipment used was already part of the contractor's project fleet. Also, the asphalt was already at the project site and the masonry sand was picked up at a nearby batch plant. The contractor said that if they were to use this method routinely, they would have the sand available at the project site.

Durability of sand-seal coating was measured by observation of the sand-seal coating under traffic conditions. The sand-seal coating installation was inspected after being subjected to 30 days of traffic. The sand-seal coating was found to be in good condition with no underlying markings visible. Figures 8 shows the condition of the sand-seal coating after 30 days of traffic. The reported average annual daily traffic for SR 26 is 48,000 vehicles (two-way).

COST ANALYSIS

For the cost estimate of the modified sand-seal application to cover pavement markings, the work activity involves two steps:

1. Application of asphalt with an asphalt distributor;
2. Application of masonry sand with a truck equipped with a spreader.

The actual rates of application of asphalt and sand were used to develop the quantities. The asphalt application is identical to the current asphalt paving process. Therefore, the current average bid price is used to estimate the cost of asphalt application. The application cost of the masonry sand is estimated using the required crew components at current hourly rates.

The estimate is based upon a section of one lane width by 1500 LF. In some situations, more than one marking line may be covered by a single pass, which would reduce the unit cost. Also, the cost per unit is expected to be quantity sensitive. Greater quantities should result in lower unit costs. The estimated probable cost is $0.47 per LF. A detailed cost estimate of sand seal-coat is shown in Table 5.

CONCLUSIONS

The first method, modified slurry-seal coating, adequately covered the pavement markings and obtained satisfactory friction test results. The main drawback to this method was that several hours of set time was required before traffic could be allowed on the treated pavement. Additionally, the coal tar-based seal coating material is not normally found at typical asphalt paving project sites.

The second method, modified sand-seal coating, provided exceptional performance with regard to friction, coverage, and durability. Additionally, the materials and equipment required for installation are normally found at paving project sites. Cost estimates indicate that the modified sand-seal coating can be installed at less cost than that incurred in current water blasting and grinding removal methods.

The sand-seal covering proved to be a practical and successful method for covering temporary pavement markings. The sand-seal covering method offers the following advantages:

- No scarring of the pavement,
- Markings are completely covered and will not be mistaken as marks,
- Materials and equipment required are already present at most roadway project sites,
- Does not require the mobilization of specialized equipment,
- Installation requires only 30 to 40 minutes of lane closure,
- Covering is durable,
- Asphalt paving may be placed directly over the covering,
- Sand-seal covering is less costly than current grinding or blasting methods.

RECOMMENDATIONS

The research team recommends the adoption of the modified sand-seal covering method as an optional method to remove temporary pavement markings. The draft specification (see Figure 9) should be added to construction contracts and a new pay item covering this work should be developed. The method should be included in Maintenance of Traffic designs. In addition to being a good technical solution, this method also promises significant economic savings over current methods.

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LIST OF FIGURES

TABLE 1 Test plan overview

Test site	Camp Blanding	SR 121	SR 26 Highway work zone
Research approach	Modified Slurry-seal coat	Modified Slurry-seal coat	Modified Sand-seal coat
Purpose	Feasibility study; visibility, friction test	Feasibility study; friction Test	Safety, suitability, and durability
Pavement type	Friction course	Structural course	Structural course
Pavement marking materials	Paint	N/A	Paint
Seal-coat materials	Coal tar, natural sand	Coal tar, natural sand	RS-1, masonry sand
Seal-coating coverage	Markings and part of lanes	Part of lanes (between markings)	Whole lanes, including markings
Application equipment	Hand sprayer	Rubber squeegee	Asphalt distribution truck, sand distribution truck, brooming truck
Testing equipment	Locked-Wheel Trailer, British Pendulum Tester	Locked-Wheel Trailer	Locked-Wheel Trailer
Trailer test speed (MPH)	20	20, 30, 40, 50, 60	40

TABLE 2 Friction test results at Camp Blanding

Seal-coating treatment	Locked-Wheel Test (average FN)	British Pendulum Test (average BPN)
Untreated	77	60
Manufacturer A materials	43	52
Manufacturer B materials	43	51
Manufacturer C materials	45	56

TABLE 3 Modified sand-seal coat application rates at SR 26

Materials	Application rate	Appropriate amount	Used amount	Covered area
Bituminous material	0.11 - 0.13 gal/yd^2	55 - 65 gal	60 gal	500 yd^2
Cover material	0.076 - 0.094 ft^3/yd^2	1.9 - 2.35 yd^3	2 yd^3	675 yd^2

TABLE 4 Pavement friction test results at SR 26

Treatment	Location	Mile post	FN40R	Average FN
Untreated structural layer	**Eastbound**	3.455	47.8	47.6
		3.553	46.9	
		3.789	46.4	
		4.075	49.4	
	Westbound	3.601	48.3	52.5
		4.046	51.6	
		4.181	57.7	
Surface-treated structural layer	**Eastbound**	4.282	39.6	44.3
		4.282	46.6	
		4.282	46.8	
	Westbound	4.299	42.5	43.4
		4.299	44.6	
		4.299	43.1	

TABLE 5 Cost estimate of modified sand-seal coat application

Work activity		Quantity	Unit	Unit cost	Total cost
Mobilize and setup	Broom	1	hr	$12.16	$12.16
	Distributor	1	hr	$13.55	$13.55
	Dump truck with spreader	1	hr	$51.99	$51.99
	Operators	2	hr	$38.00	$76.00
	Total direct cost	-	-	-	$153.70
	Contractor markup	-	-	-	$30.74
Asphalt application	Asphalt at current bid average item no. 030013 BIT MAT (Tack Coat) Jan-Nov 2002	216.67	gal	$1.14	$247.00
Sand application	Masonry sand	5.8	yd3	$24.00	$139.26
	Dump truck with spreader	1	hr	$51.99	$51.99
	Operators	1	hr	$38.00	$38.00
	Total direct cost	-	-	-	$229.25
	Contractor markup	-	-	-	$45.85
TOTAL ESTIMATED COST		1	Job	$706.54	$706.54
TOTAL ESTIMATED UNIT COST		1500	LF	$0.47	$706.54

(a) Seal coating application by a hand sprayer

(b) Results after two-coat application

FIGURE 1 Modified slurry-seal coat application at Camp Blanding.

(a) Seal coating application with a rubber squeegee

(b) Results after two-coat application

FIGURE 2 Modified slurry-seal coat application at SR 121.

(a) Friction test at Camp Blanding

(b) Friction test at SR 121

FIGURE 3 Friction testing by the FDOT pavement friction unit.

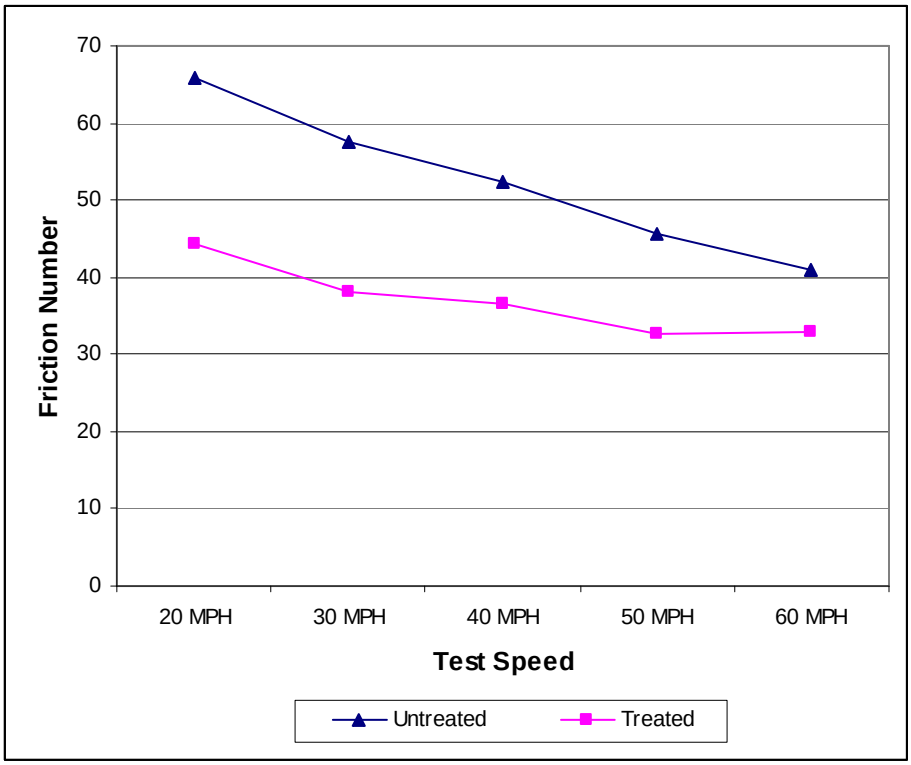
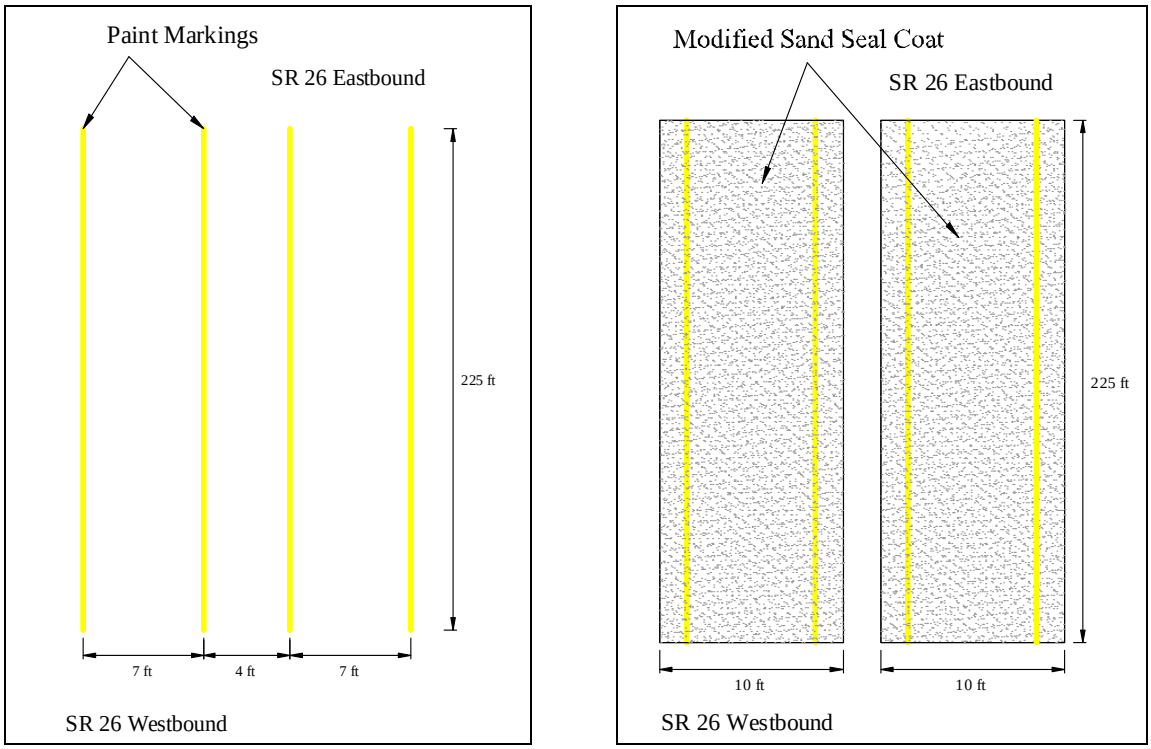


FIGURE 4 Friction test results at SR 121.



(a) Paint marking layout (b) Sand-seal coat covering area layout

FIGURE 5 Modified sand-seal coat test layout at SR 26.

(a) Brooming of the site prior to covering

(b) Asphalt application

(c) Cover material application

(d) Brooming cover material

FIGURE 6 Modified sand-seal coat practice at SR 26.

(a) Pavement after brooming off sand

(b) Close-up of treated surface

(c) New paint markings on treated surface

(d) Test section taken at night with vehicle headlights on dry pavement

FIGURE 7 Results of modified sand-seal coat application at SR 26.

(a) Westbound SR 26

(b) Eastbound SR 26

(c) Test section taken at night with vehicle headlights on wet pavement

FIGURE 8 Results for modified sand-seal coat after 30 days of traffic.

COVERING EXISTING PAVEMENT MARKINGS WITH SAND SEAL COAT

311-1 Description.

Cover Existing pavement markings with a sand seal coat composed of bituminous material applied in one application and covered with sand cover material applied in a single application.

311-2 Proportioning.

Use the approximate proportions for the sand seal coat as follows:

Bituminous Material..... 0.11 - 0.13 gal/yd2 [0.5 to 0.6 L/m2]

Cover Material .....0.076 - 0.094 ft3/yd2 [0.0026 to 0.0032 m3/m2]

The Engineer will designate the actual spread for each material.

311-3 Materials.

311-3.1 Bituminous Material: Meet the following requirements:

Asphalt Cement, Viscosity Grade AC-30.....916-1

Emulsified Asphalt, Grade RS-1.....916-4

During the months of November through April, use emulsified asphalt. During the remaining months of the year, use asphalt cement or emulsified asphalt, unless asphalt cement is specified. Asphalt to be heated to 170 °F prior to application.

311-3.2 Cover Material: Use masonry sand per fine aggregate as provided in 902. The Contractor may use local sand if it meets the above requirements. Obtain the Engineer's approval of the sand. Engineer will have discretion to adjust application rates.

311-4 Weather Limitations.

Do not apply bituminous material when the air temperature in the shade and away from artificial heat is less than 60°F [15°C] at the location where the application is to be made, or when weather conditions or the surface conditions are otherwise unfavorable.

311-5 Construction Methods.

311-5.1 Application of Bituminous Material: Meet the requirements as specified for bituminous surface treatments in 310-9.

311-5.2 Application of Cover Material: Apply sand uniformly at the rate designated by the Engineer. If the Engineer considers it necessary for the proper distribution of the spread, lightly broom after asphalt breaks.

311-6 Method of Measurement.

311-6.1 Bituminous Material: The quantity to be paid for will be the volume, in gallons [liters], applied on the road and accepted, determined as provided in 300-8.

311-6.2 Cover Material: The quantity to be paid for will be the volume, in cubic yards [cubic meters], applied on the road and accepted, determined by measurement, in loose volume, in truck bodies.

311-7 Basis of Payment.

Prices and payments will be as specified for bituminous surface treatment in 310-15, except that the cover material will be paid for under Sand Cover Material.

Payment will be made under:

Item No. 300- 1- Bituminous Material - per gallon.

Item No. 2300- 1- Bituminous Material - per liter.

Item No. 311- 1- Sand Cover Material - per cubic yard.

Item No. 2311- 1- Sand Cover Material - per cubic meter.

FIGURE 9 Draft specification of modified sand-seal coat method for FDOT highway construction projects.