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Development of Improved Procedures for Managing Pavement Markings During FDOT Highway Construction Projects

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16. Abstract

The removal of temporary pavement markings is a common necessity during highway construction operations. Current methods of marking removal 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. Several experimental methods were developed and tested. A modified seal coat procedure was selected as the best method. This document reports on the research activity and test results.

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CHAPTER ONE

INTRODUCTION

1.1 Research Background

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

Current FDOT specifications do not allow the use of paint to cover or mark out existing pavement markings. Mechanical removals of the existing markings by water blasting or by grinding are the methods most often used for marking removal. However both methods are relatively expensive and frequently do not produce satisfactory results. Mechanical removal frequently results in pavement scarring. The scarring can be a serious problem. The pavement scars can easily be mistaken for pavement markings with wet pavement conditions at night or with the sun at the right angle to the pavement.

Work zone safety is a key concern. Safely navigating 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 must negotiate temporary lane shifts and/or detours. Clearly, it is essential that the motorist not be confused or distracted by pavement markings, which 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 deteriorate 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.

1.2 Research Objectives

The overall goal of this research is to study the removal of pavement markings and to develop improved methods for removing temporary markings. The method must remove all traces of the markings and leave no pavement scaring so that the motorist cannot be misled.

1.3 Research Methodology

The approach adopted by the research team was to investigate the feasibility of covering the pavement marking rather than attempting to remove the markings from the pavement surface. This research studied the application of seal coating method for the removal of pavement markings and developed an appropriate method. This study applied manufacturer's seal coat materials to cover pavement markings according to their specification. The friction evaluation plan was developed and performed after seal coat applications. The FDOT's Pavement Friction unit (Locked-Wheel Skid Trailer) and the British Pendulum Tester were used for the seal-coated surface friction tests. Field tests were performed in three different test sites: Camp Blanding, SR 121, and SR 26 Highway work zone. Three different test approaches were developed in order to find most suitable method. Finally, the test results are analyzed on the point of evaluating the suitability and performance of the seal coating removal method.

In addition, this research also investigated removable marking tapes for the removal of pavement markings. 3M Removable Black Line Mask and ATM Black-Out Tape were installed at the SR 26 test site and their performances are evaluated.

CHAPTER TWO

LITERATURE REVIEW

The literature review involved the examination of *ASTM standard specification,* the book *Hot Mix Asphalt Materials, Mixture Design and Construction*, technical reports, published articles, and other reports and studies. The review was limited to the reported experiences and research results in terms of the removal of pavement markings, seal coating, and friction test to develop and evaluate improved procedures for the removal of pavement marking during highway construction projects.

2.1 The Removal of Pavement Markings

The FDOT specifications on pavement marking removal provide guidelines for contractors and engineers as follows (FDOT, 1996):

- Where a detour changes the lane use or where normal vehicle paths are altered during construction, all existing pavement markings that will be in conflict with the adjusted vehicle paths shall be removed
- The removal may be accomplished by any method without damaging the pavement surface texture materials and which will eliminate the previous marking regardless of weather and light conditions
- The method of over-painting is not allowed

As shown in the specifications, unwanted markings on the roadway must be removed clearly without damaging the pavement surface. However, it is not easy to remove the makings without damaging the surface texture materials when contractors try to use a method to peel off the pavement markings. Therefore, a method to cover up the markings might be a good alternative if not using paint material.

Ellis et al. (1999) reviewed the current pavement marking removal methods and suggested the best management practices in highway construction work zones. There have been seven methods most commonly used in all states: Chemical Methods, Excess-Oxygen Burning, Grinding, High-Pressure Water Jet, Hot-Compressed Air-Burning, Hydro-blasting, and Sandblasting. Each method has an unsatisfactory result in certain situations. Most removal methods still leave some degree of damage to the road, or create delineation problems that confuse and distress the motorist. The most well known problem is the scars left by removal processes on the pavement surface. These scars can be misinterpreted as pavement markings and can cause car accidents especially under wet weather conditions at nighttime. The summary of physical problems for the removal methods is shown in Table 2-1. According to their investigation, Ultra-High Pressure Low Volume Water Blasting was the best removal method. The authors also studied other state DOT agencies' specifications for the removal of pavement markings. However, none of the states had specific removal method requirements. The choice of the removal method is up to the project contractor in all states. The only requirement in the specifications is the resulting of the surface conditions after removal.

Table 2-1. Physical Problems of Current Removal Methods

Removal Methods	Physical Problems
Chemical Methods	Chemical damage to the pavement
Grinding	Resulting Scars
Water Blasting	Removes aggregates
Hot Compressed-Air Burning	Creating a scar and damaging pavement
Excess-Oxygen Burning	Scars bonded by obliterated paint and beads
Hydro-blasting	Resulting Scars Scouring and polishing surface aggregate
Sandblasting	Damaging the pavement
Motor Grader	Tremendous damage to the pavement
Black Paint	Wears off fairly quickly

Recently, an alternative method has been tried by Pew and Thome (2000). They studied the Laser Removal method of pavement paint markings sponsored by the Transportation Research Board (IDEA Program). The authors developed “a mobile highway paint removing system” using pulsed laser. The high-powered laser system they developed through their experiments showed successful results. The researchers found that the type of paint affected the paint removal efficiency in the test. Finally, the authors concluded that additional field tests are needed to create an effective system and the developed system should be optimized in order to operate as efficiently as possible on the road. As the authors concluded, more research should be done to use this method for the real world. In addition, the cost-effectiveness of this method should be evaluated and compared with others for the commercial purpose.

Various methods have been tried for the removal of pavement markings so far. It is, however, still a challenging issue during highway construction projects. Therefore, more research efforts should be made to improve and find more efficient removal process.

2.2 Seal Coating

Seal coating is well known as a relatively inexpensive maintenance method used for highway pavement surface, which improves pavement texture, and waterproofs asphalt surface. Seal coating information for maintenance activities can be found in *Hot Mix Asphalt Materials, Mixture Design and Construction* (Robert et al., 1996). Seal coating is a broad topic as a thin pavement surface treatment. Seal coating may or may not be covered with aggregate. For instance, fog seal is an application of diluted asphalt emulsion with no cover aggregate; slurry seal is a mixture of emulsified asphalt and fine aggregate in the form of slurry; and chip seal and sand seal are one or more applications of asphalt covered with a thin aggregate, which should be rolled immediately. The size or type of covered aggregate distinguishes chip seal from sand seal. For example, the aggregates for chip seal are made up of crushed stone, gravel, or slag; the aggregates for sand seal are either natural sand or rock screenings (Mouaket et al. 1992).

The purpose of maintenance decides the type of seal coating. 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 on 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 a seal against air and water intrusion.

Especially, sand seals are well known as low-cost treatments and for use on low volume rural roads or residential streets. Therefore, applying seal coating for the removal of pavement markings on the roadway can be a good way to cover up unwanted markings and make them invisible without damaging the pavement surface if safety and cost-effectiveness are satisfied.

The construction sequence for sand seal coat is introduced in *Hot Mix Asphalt Materials, Mixture Design and Construction* (Robert et al., 1996) as follows:

1. Set up traffic control. A detour is preferred.
2. Clean the surface to remove dirt and other loose materials. This is an extremely important step since the asphalt will bond to whatever is at the surface. If the chip seal is to have a long life, it is imperative that the asphalt forms a strong bond with the road surface and not the debris on the surface.
3. Apply the asphalt binder to the surface at the specified rate and temperature using a calibrated asphalt distributor.
4. Spread the aggregate at the specified rate evenly over the surface immediately after the asphalt binder is applied. The aggregate spreader should be properly calibrated prior to starting work. Avoid excessive application of aggregate because of the tendency of traffic to roll the excess aggregate against that aggregate penetrating the asphalt layer and dislodging it. This dislodgement problem is especially acute during the first few hours that the treated road is open to traffic.

5. Immediately roll the aggregate to push it through the asphalt binder and to seat it firmly against the underlying layer. The aggregate should be rolled preferably with a pneumatic roller; however, a steel roller can be used. Spreading and rolling of the aggregate should be completed before the emulsified asphalt, if used, breaks to ensure adequate bond to retain the aggregate. The pneumatic roller is better suited for pressing the aggregate against the underlying layer than the steel-wheeled roller, especially if the surface being repaired has high spots, since the steel-wheeled roller bridges over the low spots and does not compact aggregates below the plane surface between the high spots. The steel-wheeled roller may also tend to break the aggregate particles.

Table 2-2. Typical Construction Problems and Solutions

Problems	Solutions
Streaking of asphalt	The spray nozzles should be adjusted at the proper angle The spray bar should be set at the proper height to provide either double or triple overlap as required by the specification
Low application rate of asphalt binder	Proper settings on the distributor truck Proper evaluation and adjustment for dryness of existing surface Use of more absorptive aggregate than anticipated in design
Excessive aggregate loss	Applying appropriate aggregate Do not delay application of aggregate Do not apply dust, dirty aggregate Do not use damp or wet aggregate Apply sufficient amount of asphalt binder to hold the aggregate Do not delay compaction Do not open the treated roadway to traffic too soon

The typical construction problems and their solutions are also recommended in *Hot Mix Asphalt Materials, Mixture Design and Construction* (Robert et al., 1996). The summary of problems and solutions are shown in Table 2-2.

The study of seal coating practice was performed by Scott (1986). The author investigated common defects in seal coat application and indicated several factors that affect construction quality of seal coats as follows:

- Aggregate
- Asphalt
- Condition of surface
- Atmospheric conditions
- Construction method
- Equipment used

The author also pointed typical defects that happen in seal coating process as follows:

- Streaked appearance
- Bleeding and flushing
- Loss of aggregate
- Surface breaks and poor adhesion to road surface
- Washboarding
- Transverse and longitudinal joint defects

Scott (1986) talked about the above defects in detail. Streaked appearance defect is mainly related to the condition of the distributor and the adjustment of its nozzle. The uniformity of asphalt film thickness should be maintained for seal coating quality. Figure 2-1 shows the effect of varying nozzle angle and the effect on the lateral distribution. Influence of spray bar height is shown in Figure 2-2. Asphalt viscosity and aggregate spread rate are also considered to cause streaking of asphalt.

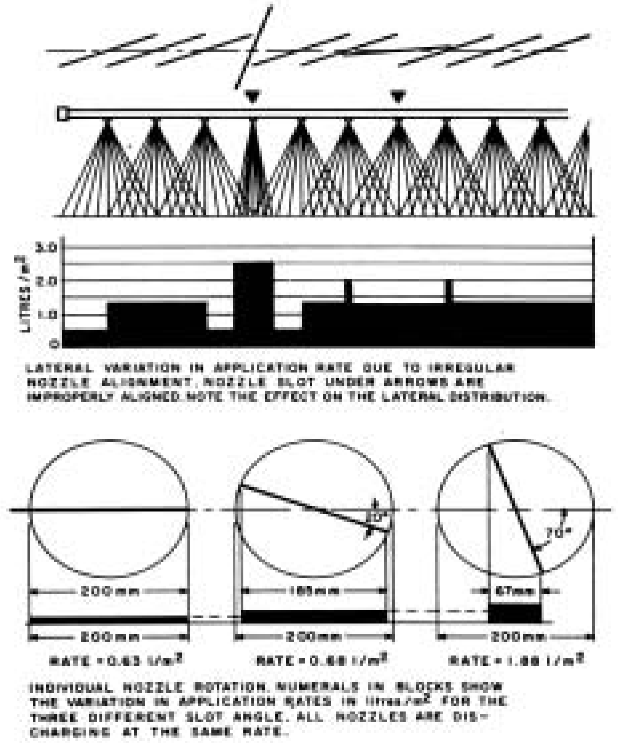

Figure 2-1. The Effect of Varying Nozzle Angle (Scott, 1986)

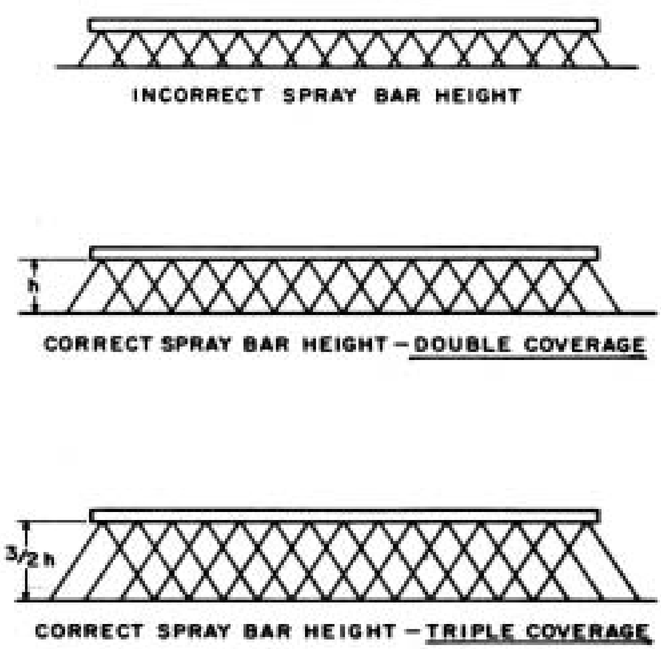

Figure 2-2. Influence of Spray Bar Height (Scott, 1986)

Loss of aggregate is mainly caused by "insufficient asphalt application rate or insufficient compaction". The author also emphasized that "Compaction should occur as close as possible to the aggregate spreader while the asphalt is in the most fluid state. Rolling speed should not exceed 5 km/hr and aggregate application rate should be slow enough". Bleeding and flushing and Washboarding are caused by an excessive asphalt application rate and an excessive asphalt emulsion application rate respectively. Other problems can be minor or major depending on situations.

In addition, more research efforts were made to seal coating implementation and seal coat performance. Despite increasingly using seal coating, there are no specific guidelines for the implementation of seal coating. Therefore, the Indiana Department of Transportation wanted to develop a decision-making guideline to help its staff and to make seal coating practices consistent. Mouaket et al. (1992) developed a decision-making process model that suggests a preferred solution of probable problems. The developed decision tree model manages seal coating activities considering the pavement serviceability index, skid resistance, road roughness, pavement age, and average daily traffic. The authors also stated six major factors that affect seal coating quality as follows:

- Ambient conditions during and after construction: air and pavement temperature, moisture, and wind
- Surface preparation before seal coating: whether the pavement is clean and dry or whether it is open, flushing, patched, or shaded
- Materials: type and grade of asphalt; method of storing and handling of asphalt; type, size, and condition of cover aggregates; and application rates
- Equipment: distributor spray bar height, nozzle orientation with respect to the bar, spray tip size and cleanliness, and pump condition; spreader gates and auger roller condition
- Operation coordination: pre application preparation; control of material application and rolling during the operation; traffic control and brooming of excess aggregates after the rolling

- Postsealing inspections: checking of aggregate embedment into asphalt; application of fog seal to compensate for low asphalt application rate or correction of situations in which there is too much asphalt; and reinforcement of weight restrictions

Roque et al. (1991(a)) studied the performance of a seal coat and found that emulsion application and aggregate retention rates were one of the most critical factors. They also recommended seal coat curing time during construction phase as follows:

- No more than 2 hr of traffic control needs to be specified after construction before seal coat is open to traffic.
- However, it is unclear whether traffic control of less than 2 hr can be allowed. Therefore, for lack of more detailed information, 2-hr traffic control should be the minimum allowed before opening a seal coat to traffic.

In addition to curing time, brooming or sweeping time is also important for seal coat performance. In order to reduce loss of aggregate, Scott (1986) recommended an appropriate time to start brooming as follows:

- Brooming should be delayed as much as possible to allow the asphalt to harden and reduce the risk of sweeping out embedded stones.
- Graded aggregate on low-volume roads, need not be broomed the day the seal is applied because there is some benefit in traffic compaction.
- On higher volume roads, flying stones cause too much damage to vehicles, and light brooming should be started as soon as possible. Usually this can be done within 4 hr, depending on temperature and humidity.
- Chip seals with rubber asphalt can usually be broomed in 4 hr with no danger of stone loss.

During seal coat application, cover material not captured by bituminous material should be considered and measured for an appropriate seal coat design. The whip-off amount of aggregate was measure by Roque et al. (1991(b)). The authors collected and calculated all loose aggregate within test area by brooming the pavement surface approximately 20 to 50 minutes after aggregate was rolled. They concluded that the assumption of 10 percent whip-off for design purposes was reasonable.

2.3 Friction Test

Good skid resistance of paved surfaces is one of the most important safety requirements in all states. Friction test is performed in order to measure the skid resistance of paved surfaces. ASTM Method E-274 is most commonly used for the friction test. It is also recommended for the measurement of skid resistance and pavement texture by AASHTO (1976). According to *ASTM Standards Manual*, the test method of measuring skid resistance is given as (ASTM E-274, 1999):

1. The test apparatus consists of an automotive vehicle with one or more test wheels incorporated into it or forming part of a suitable trailer towed by a vehicle. The apparatus contains a transducer, instrumentation, a water supply and proper dispensing system, and actuation controls for the brake of the test tire.
2. The test apparatus is brought to the desired test speed. Water is delivered ahead of the test tire and the braking system is actuated to lock the test tire. The resulting friction force acting between the test tire and the pavement surface and the speed of the test vehicle are recorded with the aid of suitable instrumentation.
3. The skid resistance of the paved surfaces is determined from the resulting force or torque and reported as a skid number (SN), which is determined from the force as required to slide the locked test tire at a stated speed, divided by the effective wheel load and multiplied by 100.

The Federal Highway Administration provides testing program for pavement skid resistance in the skid accident reduction program (1980). Skid resistance measurement is particularly advised in this report as follows:

- Skid resistance measurements should be made with a calibrated locked-wheel skid tester using ASTM E 274 method or an acceptable alternative method.
- Locations such as intersections and sharp curves which are not easily measured with the locked-wheel skid tester at the standard speed of 40 mph should be tested

at the lower speed. Such tests should be supplemented with texture measurements to permit extrapolation of available skid resistance to operating speed.

- Alternative methods of measuring pavement friction properties may be used provided the correlated well with the locked-wheel skid tester.

Guiding minimum skid resistance has been a critical issue to the State Highway Agencies. Kummer and Meyer (1967) studied frictional requirements for main rural highways funded by AASHTO and published under the National Cooperative Highway Research Program (NCHRP) Report 37. NCHRP Report 37 recommended minimum interim skid numbers with various mean traffic speeds and a skid number of 37 as the minimum and tentative requirement for main rural highway pavement friction (see Table 2-3). This skid number is based on measurement with a skid trailer in accordance with ASTM Method E-274 at the speed of 40 mph. The authors compared the minimum requirements for main rural highways with the guidelines used by State highway departments (see Table 2-4).

Table 2-3. Recommended Minimum Interim Skid Numbers (Kummer and Meyer, 1967)

Mean Traffic Speed (MPH)	Skid Number[a]	
	SN[b]	SN_{40}[c]
0	60	-
10	50	-
20	40	-
30	36	31
40	33	33
50	32	37
60	31	41
70	31	46
80	31	51

[a] Skid Numbers in accordance with ASTM E-274 Method of Test.

[b] SN = Skid Number, measured at mean traffic speeds.

[c] SN_{40} = Skid Number, measure at 40 mph, including allowance for the skid number reduction with speed using a mean gradient of G= 0.5

Table 2-4. Comparison of Minimum Friction Requirements for Main Rural Highways with the Guidelines Currently Used By State Highway Departments (Kummer and Meyer, 1967)

	SKID TRAILERS		STOPING DISTANCE CAR		BRITISH PENDULUM TESTER
AGENCY	SN	SPEED (MPH)	SDN	SPEED (MPH)	BPN
Arkansas	-	-	-	-	45
Connecticut	-	-	43	30 or 40	-
Florida	-	-	40	40	-
Georgia	-	-	-	-	50
Kenturcky	-	-	45	30	-
Louisiana	-	-	-	-	55
Maryland	-	-	47	40	-
Michigan	40	40	-	-	-
Mississippi	40	40	40	-[1]	-
New York	32	30	-	-	-
N. Carolina	-	-	45	-[1]	-
Pennsylvania	40	35	-	-	-
Tennessee	40	40	-	-	-
Taxas	35	40	-	-	-
Virginia	35	40	40	40	-
Recommendation	37	40	46	46	60

[1] Not stated, presumably 40 mph

Halstead (1993) surveyed various state highway agencies about their present practices concerning skid-resistant surfaces and summarized the criteria for applying friction surfaces. The survey results also provide guidelines for appropriate skid numbers. Most of the state highway agencies suggested a range of skid number between 30 and 40 for Interstate or all highways for which the speed limit was larger than 40 miles per hour (65 km/h). Twelve of the 16 agencies suggested a number between 35 and 40 for the same conditions. A skid number between 25 and 40 was suggested for urban and rural low-speed area (less than 40 mph) and relatively low traffic (less than 3000 average daily traffic). In conclusion, the survey shows different guidelines for minimum skid numbers among state highway agencies.

Table 2-5. Type of Friction Tester and Manufacturer (Dahir and Gramling, 1990)

Type of Tester	Number of Testers
K.J. Law Locked-Wheel Skid Trailer	38
Locked-Wheel Skid Trailers (built by the agencies using them)	13
Cox & Sons Locked-Wheel Skid Trailer	3
Locked-Wheel Skid Trailer Meeting AASHTO Specifications	2
FMC Locked-Wheel Skid Trailer	2
Solitest Locked-Wheel Skid Trailer	3
Mu Meter	4
British Pendulum Tester	1
Other	6

Dahir and Gramling (1990) studied the 72 friction testers used by 56 agencies testing in accordance with ASTM standards and classified them by types in order to update the information about roadway friction test. The questionnaire items cover accident records, vehicle inspection, friction testing, pavement surface, etc. According to the survey result on the friction testing, most of the agencies have a friction-testing program that they use. The summary of the upgraded information on wet-pavement accident factors and friction tests was useful. The K.J. Law Locked-Wheel Skid Trailer was the most popular tester for the pavement friction test in this survey (see Table 2-5). Most of the agencies use ASTM Method E 274 with ribbed tires and some agencies use both smooth tires and ribbed tires for the friction test.

The British Pendulum Tester (BPT) can be used either in the field or in the laboratory. However, most of highway agencies did not use the British Pendulum Tester for the highway pavement friction test in the United States. It can be used for special cases in which other dynamic test is not available. According to ASTM Standard E 303 (1998), its operation is specified as follows:

1. This test method consists of using a pendulum-type tester with a standard rubber slider to determine the frictional properties of a test surface.
2. The test surface is cleaned and thoroughly wetted prior to testing.
3. The pendulum slider is positioned to barely come in contact with the test surface prior to conducting the test. The pendulum is raised to a locked position, then released, thus allowing the slider to make contact with the test surface.
4. A drag pointer indicates the British Pendulum (Tester) Number (BPN, over a range of zero to 140). The greater the friction between the slider and the test surface, the more the swing is retarded, and the larger the BPN reading. Four swings of the pendulum are made for each test surface.

The British Pendulum Test can also be used for evaluating skid resistance of traffic marking materials. The minimum skid resistance requirement is stated in the FDOT Specifications as follows: “The surface of the stripes and markings shall provide a minimum skid resistance value of 35 BPN (British pendulum Number) when tested in accordance with ASTM E 303.” The British Pendulum tester will be used for the friction evaluation at Camp Blanding in this research because the test site has a limited space.

Recently, NCHRP Synthesis 291 (2000) summarizes pavement friction measurement methods and other considerations in friction testing. In the report, full-scale friction measuring devices are classified by four basic types: “locked wheel, side force, fixed slip, and variable slip”. The report provides notation information on reporting locked wheel friction test results as follows:

- SN{Test Speed} followed by *R* for ribbed tire of *S* for the smooth tread tire.
- Test speed expressed in kilometers/hour should be enclosed in parentheses (e.g. the value of SN40R is equivalent to SN(64)R.)
- AASHTO terminology for the locked wheel uses the term “friction number” (FN) in place of skid number (SN).

According to interview with the FDOT friction evaluation engineers, the desired level of the minimum friction requirement is the skid number of 35 (SN 35) based on the Locked-Wheel Friction test at the speed of 40 mph in the State of Florida. The Pavement Systems Evaluation Section of the State Materials Office provides information about testing equipment in detail in their research report (2001). Testing equipment of the FDOT fiction evaluation is called a “Pavement Friction unit” which collects friction data in accordance with ASTM E 274-97. The detail descriptions and Calculations are given in the report as follows (2001):

- Each friction unit is composed of a truck, water tank, friction trailer and mobile data recorder.
- Measured values are taken representing the friction force on a locked test wheel as it is dragged over a wetted pavement surface under constant load and constant speed.
- The Friction Number at 40 mph using a standard ribbed tire (FN_{40R}) is calculated as follows:

  $$FN_{40R} = (F/W) \times 100$$

  Where: F and W are numerical factors for horizontal force (F) applied to the test tire at the tire-pavement contact patch and dynamic vertical load (W) on test wheel.

This Pavement Friction unit will be used for the friction evaluation test in this research by the FDOT friction evaluation engineers.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

This research studied the application of seal coating method for the removal of pavement markings and developed an appropriate method. This study involved the application of manufacturer's seal coat materials to cover pavement markings according to their specification. The friction evaluation plan was developed and performed after seal coat applications. The FDOT's Pavement Friction unit (Locked-Wheel Skid Trailer) and the British Pendulum Tester were used for the seal-coated surface friction tests. Field tests were performed in three different test sites: Camp Blanding, SR 121, and SR 26 Highway work zone. Three different test approaches were developed in order to find most suitable method. Finally, the test results are analyzed on the point of evaluating the suitability and performance of the seal coating removal method. In addition, research team also investigated removable marking tapes for the removal of pavement markings. 3M Removable Black Line Mask and ATM Black-Out Tape were installed at the SR 26 test site and their performances were evaluated.

The overview of research methodology is shown as in the following flow chart in Figure 3-1. Specific test plans are described in Table 3-1. As shown in Table 3-1, three different removal methods were performed in this research: Seal coating method frequently used in parking lot maintenance according to manufacturer's specifications were tested at Camp Blanding and SR121. Based on the test result analysis of seal coating method, modified sand seal coat method was developed and tested at SR 26 highway work zone. Removable marking tape method was also tested at SR 26 highway work zone. The term "Seal Coating" means a type of slurry seal and is distinguished from "Modified Sand Seal Coat" in this study. The following sections were covered with each method: Seal coating method in section 3.2, modified sand seal coat method in section 3.3, and removable marking tape method in section 3.4.

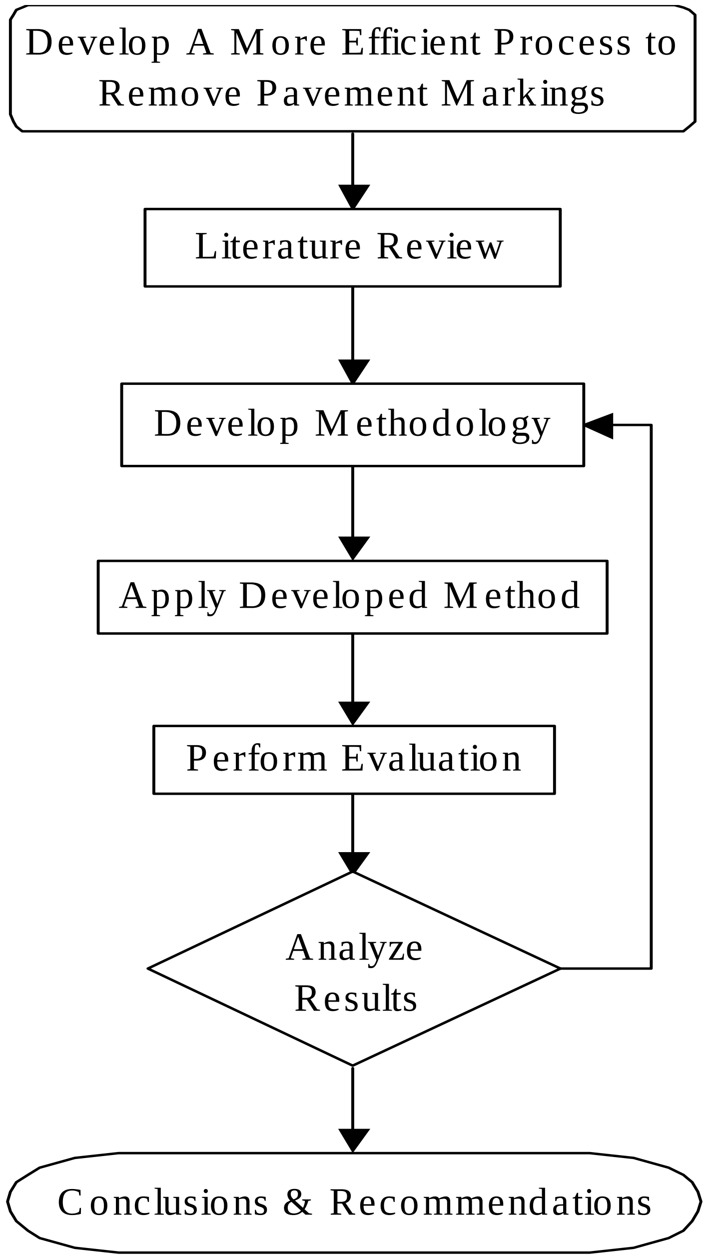

Figure 3-1. Research Performance Flow Chart

Table 3-1. Test Plan Overview

Test Site	**Camp Blanding**	**SR 121**	**SR 26 Highway Work Zone**
Removal Method	Seal Coating	Seal Coating	Modified Sand Seal Coat Removable Marking Tapes
Purpose	Feasibility Study & Friction Test	Feasibility Study & Friction Test	Suitability & Performance of the removal method
Pavement Type	Friction Course	Structural Course	Structural Course
Pavement Marking Materials	Paint	N/A	Paint
Seal Coat Materials	Three Manufacturers' Materials	Contractor's Materials (SealMaster’s)	RS-1, Masonry Sand
Seal Coating Coverage	Markings and Part of lanes	Part of lanes (Between Markings)	Whole lanes including markings
Application Equipment	Hand Spray	Rubber Squeegee	Truck Equipped Spray Bar Sand Distribution Truck
Testing Equipment	Locked-Wheel Skid Trailer British Pendulum Tester	Locked-Wheel Skid Trailer	Locked-Wheel Skid Trailer
Test Speed	20 mph	20, 30, 40, 50, 60 mph	40 mph

The photos of the Camp Blanding, SR 121, and SR 26 highway work zone test sites are shown in Figure 3-2, Figure 3-3, and Figure 3-4 respectively.

Figure 3-2. The Camp Blanding Test Site

Figure 3-3. The SR 121 Test Site

Figure 3-4. The SR 26 Test Site

3.2 Seal Coating

3.2.1. Application of Seal Coating

Three manufacturer's seal coating materials were applied with hand spray according to their specifications under clear weather conditions (Temperature 78 deg. F) at Camp Blanding on April 25, 2002. Contactor's seal coating material (SealMaster's) was installed with rubber squeegee according to the SealMaster's specifications under cloudy weather conditions (Temperature 75 deg. F) at SR 121 on June 14, 2002. The appropriate mixing rates and application rates of seal coating materials are given in the specifications (see Table 3-2 and Table 3-3). Mixing rates were similar among manufacturers even though slight differences were found. The application amount in Table 3-3 covers only one coat.

Table 3-2. Manufacturer's Mixing Rates of Seal Coating Materials

Materials	Seal Master Coal Tar Concentrate	Neyra Tarconite	GEM Seal Coal Tar emulsion
Coal Tar	1 gal.	1 gal.	1 gal.
Water	0.3 – 0.4 gal.	0.35	0.45
Additive	0.02 gal.(Polymer)	N/A	0.03 gal.(latex)
Sand (Aggregate)	3- 5 lbs.	5 lbs.	3-6 lbs.

Table 3-3. Manufacturer's Application Rates and Curing Time

Application	Seal Master	Neyra	GEM Seal
Amount	0.08 - 0.12 gal./sq. yd.	0.09 gal./sq. yd.	0.10 - 0.15 gal./sq.yd.
Drying Time	Max. 8 hours	Max. 8 hours	4 –24 hours
Curing Time	Min. 24 hours	Min. 24 hours	Min. 24 hours

Drying time and curing time are also shown in Table 3-3. Drying time depends on whether conditions. In general, contactors observe the drying condition of surface and try another application if it is touchable. Seal coating application procedures are also similar among manufacturers. For example, SealMaster's seal coating application procedures are stated in the specifications as follows (2001):

- Apply by squeegee, brush, mechanical spray, or squeegee application equipment designed specifically for such purposes.
- A minimum of two coats is recommended. The first coat of sealer must be dried completely before applying the second coat.

- Temperature must be a minimum of 50°F or rising for a period of not less than 24 hours. Do not apply when the temperature is expected to drop below 50°F in a 24-hour period or if rain is forecast within 8 hours.
- Allow final coat of pavement sealer to cure a minimum of 24 hours before opening up to traffic.

Paint marking strips was applied for the test at Camp Blanding (see Figure 3-4). Hand spray application was used for the Camp Blanding test sites and hand rubber squeegee application was used for the SR 121 test site in this study. Photos of seal coat application with hand spray at Camp Blanding and the result with two-coat application at Camp Blanding are shown in Figure 3-5 and in Figure 3-6 respectively.

Figure 3-4. Application of Paint Marking Strips at Camp Blanding

Figure 3-5. Application of Seal Coating with Hand Spray at Camp Blanding

Figure 3-6. Result with Two-Coat Application at Camp Blanding

Figure 3-7. Application of Seal Coating with Rubber Squeegee at SR 121

Figure 3-8. Result with Two-Coat Application at SR 121

Photos of seal coating application with rubber squeegee at SR 121 and the result with two-coat application at SR 121 are shown in Figure 3-7 and in Figure 3-8 respectively.

3.2.2 Friction Testing

The Camp Blanding site is a small area that consists of a 300 feet by 75 feet asphalt and Portland cement runaway. The test speed of 20 mph was the maximum that can be tested by the Locked-Wheel friction tester in the limited area. However, friction tests at various speeds were performed at SR 121 in order to observe friction variations.

Field test for the pavement friction evaluation was performed before and after application of asphalt seal coating at Camp Blanding and SR 121. Friction testing was carried out using both the British Pendulum Tester and the FDOT Pavement Friction Unit (Locked-Wheel Skid Trailer) at Camp Blanding on May 1, 2002. However, only the FDOT Pavement Friction Unit was used at SR 121 on June 20, 2002. The FDOT friction evaluation engineers performed the Locked-Wheel Skid test for this research. The number of friction tests is shown in Tables 3-4. A photo of the British Pendulum Test is shown in Figure 3-9. The friction testing by the FDOT Pavement Friction Unit is shown in Figure 3-10.

Table 3-4. Number of Friction Tests

Test	The British Pendulum Test		The Locked Wheel Test	
Test Area	Before Seal Coating	After Seal Coating	Before Seal Coating	After Seal Coating
Test Numbers	30	30	3	3

Figure 3-9. The British Pendulum Test at Camp Blanding

Figure 3-10. Friction Testing by the FDOT Pavement Friction Unit at Camp Blanding

Figure 3-11. Friction Testing by the FDOT Pavement Friction Unit at SR 121

3.2.3 Test Results and Analysis

1) Camp Blanding Test Results

The results of the Locked-Wheel Friction test on the pavement and on the markings at Camp Blanding are shown in Table 3-5 and Table 3-6 respectively. The output data from the FDOT Friction unit are also attached in Appendix A. The speed of the test trailer was 20 mph each time. The results of the British Pendulum test on the pavement and on the markings at Camp Blanding are shown in Table 3-7 and Table 3-8 respectively.

Table 3-5. Locked-Wheel Friction Test Results on the Pavement at Camp Blanding

Test No.	Skid Numbers			
	Before Seal Coating	After Seal Coating		
		Sealmaster	GEM Seal	Neyra
1	78.9	44.4	51.2	52.1
2	76.3	43.7	39.5	40.3
3	74.9	39.7	37.2	41.4
Average	77	43	43	45

Table 3-6. Locked-Wheel Friction Test Results on the Markings at Camp Blanding

Test No.	Skid Numbers			
	Before Seal Coating	After Seal Coating		
		Sealmaster	GEM Seal	Neyra
1	66.7	37.3	43.9	41.2
2	58.9	33.6	36.2	38.3
3	55.4	30.3	32.3	37.5
Average	60	34	37	39

Table 3-7. British Pendulum Test Results on the Pavement at Camp Blanding

Test No.	**Skid Numbers**			
	Before Seal Coating	**After Seal Coating**		
		Sealmaster	**GEM Seal**	**Neyra**
1	65	49	55	53
2	65	50	55	59
3	60	50	52	58
4	60	51	54	55
5	62	53	53	57
6	60	52	53	58
7	61	51	53	57
8	60	52	51	58
9	64	53	51	59
10	60	52	50	57
11	60	49	48	57
12	60	55	49	57
13	61	52	50	57
14	59	52	50	55
15	60	54	48	57
16	63	53	51	55
17	61	54	48	54
18	60	52	55	55
19	60	55	49	56
20	62	52	54	54
21	60	53	51	54
22	58	55	50	55
23	58	53	50	54
24	59	53	49	55
25	60	52	51	54
26	60	50	51	53
27	60	50	52	54
28	59	49	53	53
29	58	51	53	53
30	58	52	52	53
Average	**60**	**52**	**51**	**56**

Table 3-8. British Pendulum Test Results on the Markings at Camp Blanding

Test No.	**Skid Numbers**			
	Before Seal Coating	**After Seal Coating**		
		Sealmaster	**GEM Seal**	**Neyra**
1	47	49	50	54
2	47	52	49	56
3	48	52	49	54
4	47	52	48	53
5	45	50	49	54
6	46	49	47	53
7	45	52	46	54
8	50	55	47	51
9	50	52	46	52
10	48	54	49	53
11	48	50	49	53
12	48	51	49	52
13	46	50	46	51
14	46	52	50	52
15	44	54	50	50
16	46	48	50	55
17	49	49	50	53
18	50	49	48	53
19	47	51	48	50
20	50	52	49	51
21	46	51	49	54
22	49	52	50	50
23	47	55	50	50
24	46	52	46	51
25	45	54	46	51
26	48	52	49	49
27	45	52	48	49
28	48	49	48	48
29	44	48	50	49
30	46	48	50	49
Average	**47**	**51**	**49**	**52**

2) State Road 121 Test Results

The results of the Locked-Wheel Friction test on the pavement at SR 121 are shown in Table 3-9. The friction test was performed at the speeds of 20, 30, 40, 50, and 60 mph. The output data from the FDOT Friction unit are also attached in Appendix A.

Table 3-9. Locked-Wheel Friction Test Results on the Pavement at SR 121

Test Speed	Test Number	Skid Numbers	
		Before Sealcoat	After Sealcoat
20 MPH	1	65	44
	2	66	48
	3	66	41
	Average	**66**	**44**
30 MPH	1	57	35
	2	57	39
	3	58	41
	Average	**58**	**38**
40 MPH	1	55	39
	2	54	38
	3	48	33
	Average	**52**	**36**
50 MPH	1	46	33
	2	47	31
	3	44	34
	Average	**46**	**33**
60 MPH	1	40	34
	2	40	29
	3	43	36
	Average	**41**	**33**

3) Results Analysis

- **Camp Blanding Test**

Statistical test was performed to compare two population means. The friction test results of each manufacturer's material were compared one another. Statistical test process is attached in Appendix B. According to t-test results of the Locked-wheel tests results, there are no statistically significant friction differences among manufacturer's materials at the 0.01 level (99% confidence level) even though the result of Neyra's material is a little bit higher than others in the Locked-Wheel Friction Test. All average skid numbers evaluated by the Locked-Wheel friction tests are higher than the recommended minimum interim skid number of 40 at the speed of 20 mph referred to NCHRP Report 37. However, the FDOT does not have any minimum friction requirement for the 20 mph speed friction test. Therefore, any generalization based on the friction test results is not made herein. The t-test of the British Pendulum test results indicates that there are statistically significant friction differences among materials at the 0.01 level. The friction result of Neyra's Material is better than others. However, all materials keep much higher skid resistance on the marking than a minimum skid resistance value of 35 BPN. There are no pavement friction guidelines for the British Pendulum Test in the state of Florida because the FDOT officially use the Locked-wheel Friction test. Therefore, no generalization based on the British Pendulum test is made herein, either.

Statistical test was also performed to compare the Locked –Wheel friction test results between "before seal coating" and "after seal coating". Statistical test process is also attached in Appendix B. According to t-test results, there are statistically significant friction differences between "before seal coating" and "after seal coating" at the 0.01 level. In conclusion, decreases of skid resistance are statistically significant after seal coating at the Camp Blanding test.

The average skid numbers for the Locked-Wheel Friction Test are shown in Table 3-10. The bar chart diagram of Table 3-10 is shown in Figure 3-12.

Table 3-10. Locked-Wheel Friction Test Results at Camp Blanding

Locked-Wheel Test		Average Skid Numbers	
		On the Pavement	On the Markings
Before Seal Coating		77	60
After Seal Coating	SealMaster	43	34
	GEM Seal	43	38
	Neyra	45	39

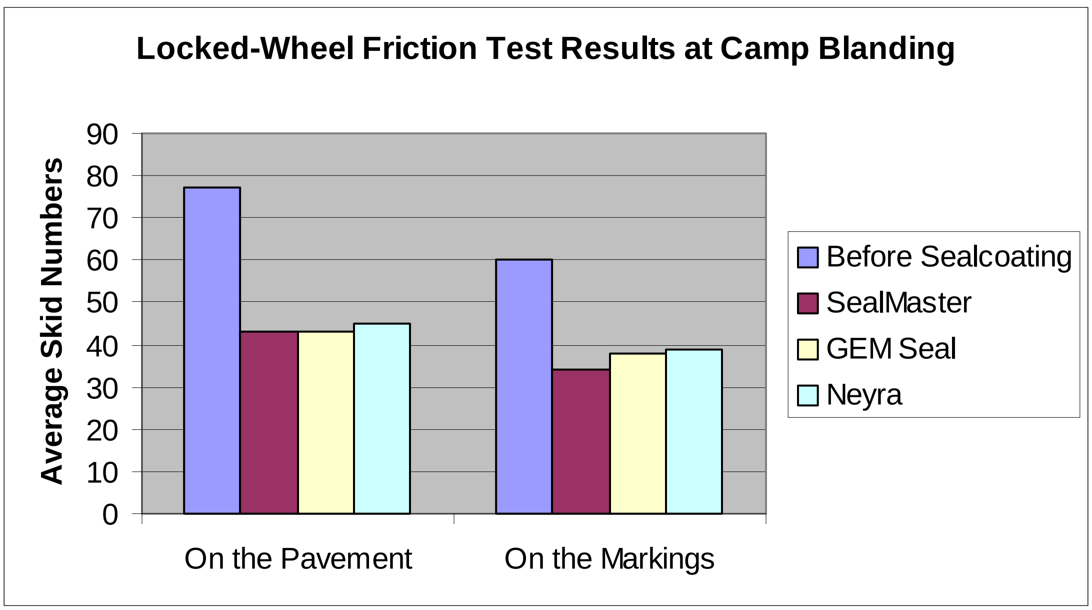

Figure 3-12. Locked-Wheel Friction Test Results at Camp Blanding

The average skid numbers of the British Pendulum Test are decreased by values of 4 to 9 on the pavement section after seal coating. However, the average skid numbers are increased by values of 2 to 5 on the marking section after seal coating. The average skid numbers for each test section are shown in Table 3-11. The bar chart diagram of Table 3-11 is shown in Figure 3-13.

Table 3-11. British Pendulum Test Results at Camp Blanding

British Pendulum Test		Average Skid Numbers	
		On the Pavement	On the Markings
Before Seal Coating		60	47
After Seal Coating	SealMaster	52	51
	GEM Seal	51	49
	Neyra	56	52

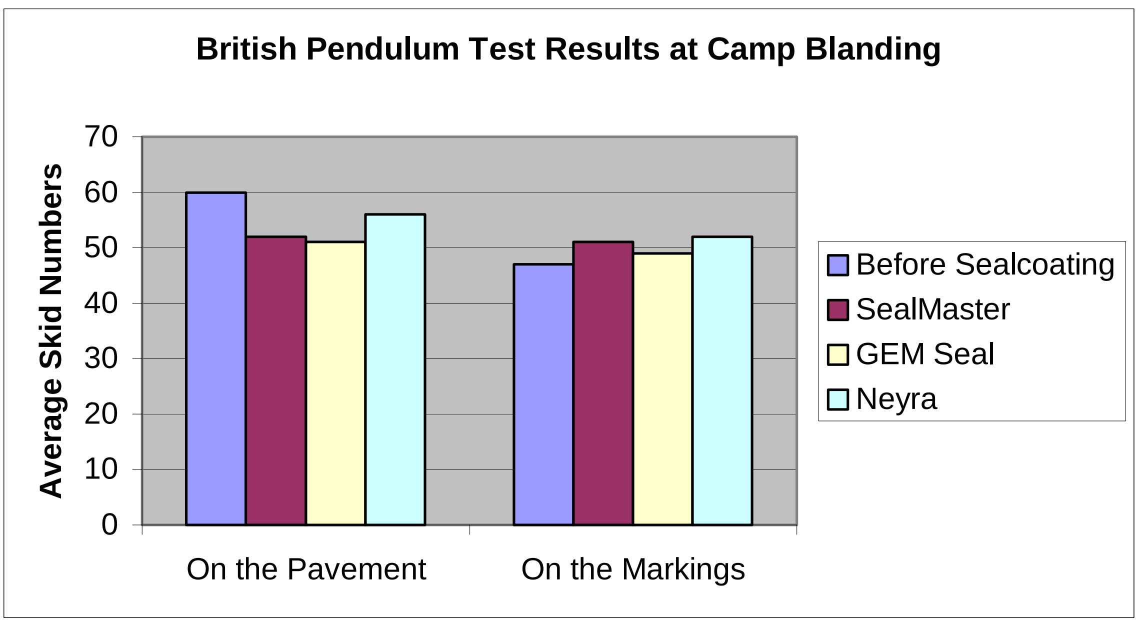

Figure 3-13. British Pendulum Test Results at Camp Blanding

- **SR 121 Test**

Statistical test was performed to compare the friction test results between “before seal coating” and “after seal coating”. Statistical test process is attached in Appendix B. According to t-test results, there are statistically significant friction differences between “before seal coating” and “after seal coating” at the 0.01 level. In conclusion, decreases of skid resistance are statistically significant after seal coating at the SR 121 test.

The average skid number at the test speed of 40 mph is decreased by a value of 16 after seal coating. However, the skid number of 36 measured at 40 mph acquired from the Locked-Wheel friction tests at SR 121 satisfies the minimum friction requirement of SN 35, which is the desired level in the state of Florida. The average skid numbers for each test speed are shown in Table 3-12. The bar chart diagram of Table 3-12 is shown in Figure 3-14. The 29% reduction of the average skid numbers after seal coating is shown in Table 3-13.

Table 3-12. Locked-Wheel Friction Test Results at SR 121

Test Speed	Skid Numbers	
	Before Seal Coating	After Seal Coating
20	66	44
30	58	38
40	52	36
50	46	33
60	41	33

Table 3-13. Skid Number Reduction Rate After Seal Coating at SR 121

Test Speed (MPH)	Skid Number Reduction (%)
20	33%
30	34%
40	31%
50	28%
60	20%
Average	**29%**

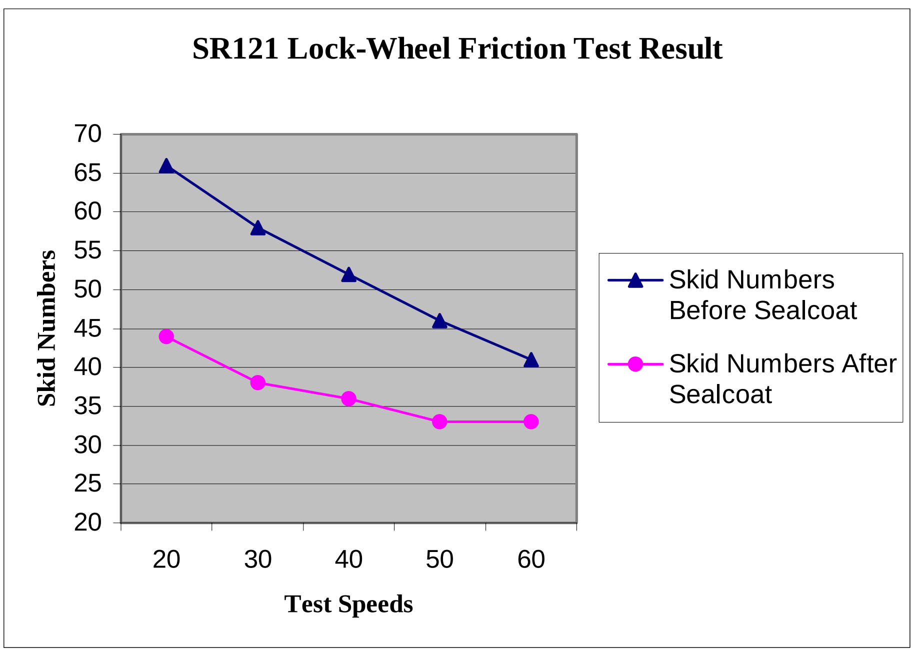

Figure 3-14. Locked-Wheel Friction Test Results at SR 121

3.3 Modified Sand Seal Coat

3.3.1 Application of Modified Sand Seal Coat

Field installation of modified sand seal coat as a method to cover traffic markings during construction sequencing was performed to test the constructability and performance of the preliminary procedure under clear weather conditions (Temperature 76 deg. F) on March 26, 2003. The developed specification is attached in Appendix C.

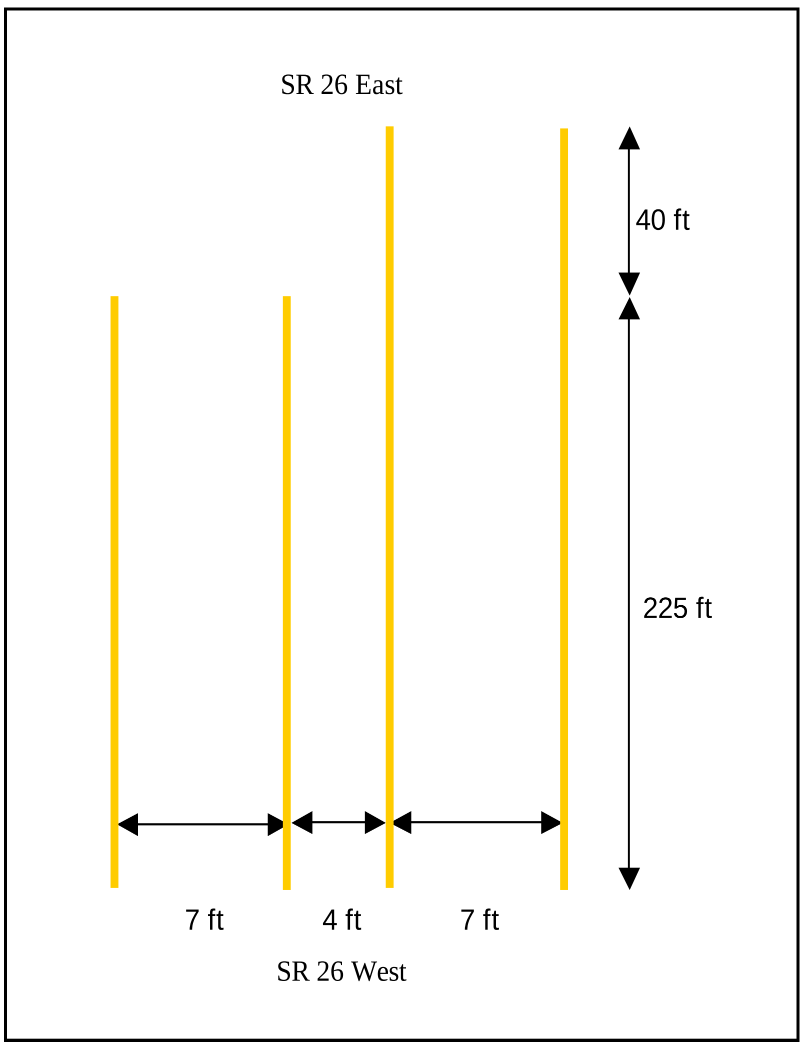

Figure 3-15. Test Area Layout at SR 26

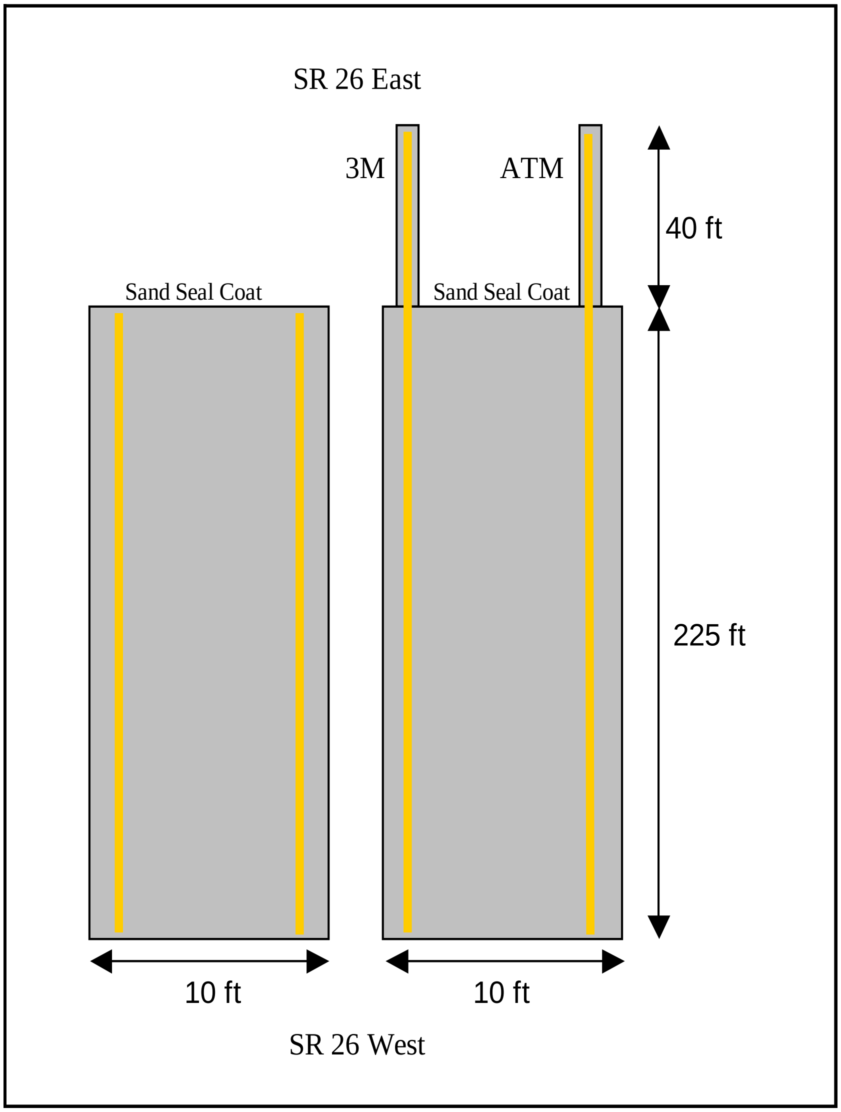

Figure 3-16. Test Application Cover Area Layout at SR 26

The existing asphalt pavement was a recently installed structural course. Four pavement marking lines were painted on the pavement for a length of approximately 75 yards. Two of the lines were extended for an additional 40 ft. Test area layout and application cover area layout at SR 26 are sketched as in Figure 3-15 and in Figure 3-16. RS-1, heated to 170 degrees, was applied by a distribution at the rate of 0.12 gal/SY. Masonry silica sand conforming to requirements of the FDOT Specification section 902 was applied at a rate of 0.08 cf/SY. Applied sand covered 175 SY more than RS-1. Application rates of modified sand seal coat are shown in Table 3-14. Sieve analysis of sample is shown in Table 3-15. Several Photos of sand seal coat application are shown in Figure 3-17 through Figure 3-22. Photos of test section pavement after sand seal application and its close up are shown in Figure 3-23 and Figure 3-24.

Table 3-14. 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/y^2	55 - 65 gal	60 gal	500 SY
Cover Material (sand)	0.076 - 0.094 ft^3/y^2	1.9 - 2.35 yd^3	2 yd^3	675 SY

Table 3-15. Sample Material Screen Test Result

Sieve Opening Size	Amount Retained (g)	Percent Retained	Percent Passing
No. 4	14.7	0.15	99.85
No. 8	120.6	1.40	98.60
No. 16	1012.7	11.89	88.11
No. 30	2749.3	40.37	59.63
No. 50	2947.2	70.90	29.10
No. 100	2054.8	92.18	7.82
No. 200	713.9	99.58	0.42
Passed	40.8	100.00	0

Figure 3-17. Photograph Showing Brooming of the Site Prior to Covering

Figure 3-18. Photograph of First Lane After Asphalt Application

Figure 3-19. Photograph of Second Lane Asphalt Application

Figure 3-20. Photograph of Sand Application

Figure 3-21. Photograph of Brooming After Sand Application

Figure 3-22. Photograph of Pavement After Brooming Sand Off

Figure 3-23. Photograph of Test Section Pavement After Sand Seal Application

Figure 3-24. Photograph Close Up of Pavement After Sand Seal Application

Figure 3-25. Photograph of Test Section Taken at Night with Vehicle Headlights Dry Pavement

3.3.2 Friction Testing and Results

Friction testing was conducted by the FDOT friction evaluation engineers on April 1, 2003. According to the friction test results, the average skid number of 44.3 measured at the 40 mph test acquired from the Eastbound and the average skid number of 43.4 measured at the same speed test acquired from the Westbound at SR 121. Both sides satisfy the minimum friction requirement of SN 35, which is the desired level in the state of Florida. Therefore, the results of the test indicate that the seal coat friction values were acceptable. Test results are enclosed in Table 3-15.

Table 3-16. Pavement Friction Test Results at SR 26

Pavement Friction Test Results
County-Section 26070, SR-26
Date: 4-01-2003

Eastbound Untreated Structural Layer				
	Mile Post	FN40R		
Begin	3.03			
	3.455	47.8		
	3.553	46.9		
	3.789	46.4		
	4.075	49.4		
Average		47.6		

Eastbound Surface Treated Structural Layer				
	Mile Post	Run 1	Run 2	Run 3
	4.282	39.6	46.6	46.8
Average		44.3		

Westbound Untreated Structural Layer				
	Mile Post	FN40R		
Begin	3.071			
	3.601	48.3		
	4.046	51.6		
	4.181	57.7		
Average		52.5		

Westbound Surface Treated Structural Layer				
	Mile Post	Run 1	Run 2	Run 3
	4.299	42.5	44.6	43.1
Average		43.4		

3.3.3 Test Result Analysis

The entire installation process for the sand seal required only about 30 minutes. The finished sand seal coating appeared to completely cover the paint markings. On the south travel lane the contractor broomed and drove over the painted lines after about 10minutes with the distributor truck in an effort to roll the section. The RS-1 had apparently not yet set. The result was that some of the sand seal was picked up by the vehicle tires. The indication is that it is important to wait until the asphalt has set before brooming. The applications rates for both asphalt and sand appeared to be correct. Friction testing indicated acceptable friction values for the treated section. Statistical test was also performed to compare the friction test results between “before sand seal coat” and “after sand seal coat”. Both Eastbound and Westbound friction test results are tested. Statistical test process is attached in Appendix B. According to t-test results, there are no statistically significant friction differences between “before sand seal coat” and “after sand seal coat” at the 0.01 level. In conclusion, decreases of skid resistance are not statistically significant after sand seal coat at the SR 26 test.

The sand seal covering method was very convenient for the contractor. The equipment used was already part of the contractor's project fleet. The asphalt was already on the project. The concrete 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 on the project site.

Durability of sand seal was measured by observation of the Sand Seal under traffic conditions. The sand seal installation was inspected on 1, 2003 at which point the installation had been subject to 30 days of traffic. The seal coating was found to be in good condition with no markings visible. Figures 3-26 and 3-27 are photos showing the condition of the Sand Seal Coating after approximately 30 days of traffic. The reported AADT for SR 26 is 48,000 (two-way).

Figure 3-26. Photograph of SR 26 Eastbound (May 1, 2003)

Figure 3-27. Photograph of SR 26 Eastbound (May 1, 2003)

3.4 Removable Marking Tapes

3.4.1 Installation of Removable Marking Tapes

3M marking covering tape (8 inch width) was applied to one of the 40ft. line extensions. The tape was applied in accordance with the manufacture's directions. A similar tape material from Advance Traffic Markings (6 inch width) was installed on the other 40ft. extension on March 28, 2003. Photos of Installation of the 3M Removable Black Line Mask Tape and the ATM Removable Polymer Tape are shown in Figure 3-28 and Figure 3-29. A Photograph Showing the consolidation of the tape with a Vehicle Tire is shown in Figure 3-30. Note that the temporary marking lines were slightly over sprayed and the

6-inch wide tape did not quite cover the entire line. Using an 8-inch wide tape would have solved this problem.

Figure 3-28. Photograph Showing the 3M Removable Black Line Mask Tape

Figure 3-29. Photograph of Installation of ATM Removable Polymer Tape

Figure 3-30. Photograph Showing the Consolidation of the Tape with a Vehicle Tire

3.4.2 Test Results and Analysis

Installation of both tape products required two people and about 10minutes each. The tapes were consolidated with a vehicle tire. However, the manufactures also suggest using a small roller. The color of the tapes was a dark black and adequately matched the color of the new asphalt. Observations of the pavement section at night under dry conditions with vehicle headlights indicated that both tapes matched the pavement and were not distinguishable as lines.

Reflectivity of the Tapes was measured by observation of the Covering Tapes Under Wet Conditions. According to researcher’s observation, the reflectivity of both tapes does not affect drivers. Figure 3-31 is a photo of a motorist view of the taped section under wet pavement conditions. The tape installation was inspected on April 30, 2003 at which point the installation had been subject to 30 days of traffic. The tapping was found to be in good condition with no markings visible.

Figure 3-31. Photograph of Test Section Taken at Night from Vehicle with Headlights

Wet Pavement

3.5 Economic Analysis

3.5.1 Estimated Cost of Modified Sand Seal Application to Cover Pavement Markings

The work activity basically involves two steps:

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

The high range of application rate for asphalt and sand have been used to develop the quantities.

The asphalt application is identical to current paving activities. Therefore the current average bid price is used to estimate the cost of asphalt application.

The application of the masonry sand is estimated using the required crew components at current hourly rates.

Note that 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 with 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.

Cost Estimate

Mobilize and Setup	Quantity	Unit	Unit Cost	Total Cost	
Broom	1	Hr.	$12.16	$12.16	
Distributor	1	Hr.	$13.55	$13.55	
Dump Truck w/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	216.67	Gals	$1.14	$247.00	
Item No. 030013 BIT MAT					$247.00
(Tack Coat)Jan-Nov 2002					
Apply Sand Seal					
Masonry Sand	5.80	CY	$24.00	$139.26	
Dump Truck w/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		Job			$706.54
TOTAL ESTIMATED UNIT COST		LF			$0.47

Figure 3-32. Seal Coat Cost Estimate

3.5.2 Estimated Cost of Tape Application to Cover Pavement Markings

The work activity basically involves two steps:

1. Sweeping the existing marking with a motorized broom.
2. Applying the covering tape.

The covering tape is available in 250 LF rolls and is manufactured with the adhesive on the bottom side of the tape. Installation requires applying the tape over the existing markings and then tamping the tape with a Roller Tamper (200 LBs). A two person crew has been used to develop the following estimated unit costs. The estimated unit cost is $1.83 per LF.

Cost Estimate

Application of Covering Tape	Quantity	Unit	Unit Cost	Total Cost	
Broom	1	Hr.	$12.16	$12.16	
Operators	1	Hr.	$38.00	$38.00	
Tape Installers	6	Hr.	$32.00	$192.00	
Covering Tape	1500	LF	$1.37	$2,055.00	
Total Direct Cost					$2,285.00
Contractor Markup					$457.00
TOTAL ESTIMATED COST		Job			$2,742.00
TOTAL ESTIMATED UNIT COST		LF			$1.83

Figure 3-33. Tape Application Cost Estimate

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

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 organic to most roadway projects.
- 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.

The covering tapes also proved to be successful. Both tape products covered the markings and were not noticeable to the motorist in dry or wet conditions. The tape covering offers the following advantages:

- No scarring of the pavement.
- Markings are completely covered and will not be mistaken as marks.
- Does not require the mobilization of specialized equipment.
- Covering is durable.
- No set or mobilization time required.
- Tape may be removed and the markings reused.
- Cost appears to be competitive with current methods and is likely to be very cost effective for small quantity applications.

4.2 Recommendations

4.2.1 Modified Sand Seal Pavement Marking Covering

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

4.2.2. Application of Covering Tape for Pavement Marking Removal

The research team recommends the adoption of the use of the covering tape as an optional method to temporarily remove pavement markings. Note that the color of the tape must match the color and shade of the asphalt pavement. The products tested worked well on new pavement but would not have been appropriate for weathered pavement. The tape may be most cost effective for relatively small removals or where there is a desire to reuse the marking. The tape also has the added advantage that it can be taken up without damaging the pavement marking, thus permitting the reuse of the marking and avoiding the cost of reapplying the markings. The use of this material should be added to the specifications and included in MOT designs. The FDOT should initiate a “Qualified Products” process for establishing approval of covering tapes.

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APPENDIX A

Locked-Wheel Friction Test Results at Camp Blanding

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                     PAVEMENT FRICTION TEST RESULTS

FILE  UF.E01      RP040L v3.14 - 09 DEC 1999      ENGLISH UNITS

COUNTY BRADFORD         ROUTE SR-000         DIR North(+) LANE 1
OPERATOR RCS        DRIVER RCS        VEHICLE UNIT 8     EQUIPMENT DOT26576/R
CO-SEC&LEG UF              FIN_NO.    0               REQ_TYPE   SPECIAL
DATE  05/01/2002        TIME  11:53:39         TIRE  Rib
AIR_TEMPERATURE      85.0°F               CONDITIONS   DAY/CLOUDY

  REF      FN    FN   SPEED SPEED  TEST
  POST     AVG   STD   AVG   STD  NUMBER
 ------- ----- ----- ----- ----- ------
   0.000 DMI_ON   *
   0.010  41.7  1.88  21.5  0.39      1
   0.121  37.3  1.44  20.6  0.34      2
   0.232  33.6  0.86  20.4  0.24      3
   0.343  30.3  2.01  21.2  0.18      4
   0.377 EVNT
   0.454  61.6  6.29  21.0  0.18      5
   0.564  75.1  1.92  21.5  0.30      6
   0.602 EVNT
   0.676  44.4  4.81  22.1  0.25      7
   0.788  43.7  5.02  20.7  0.10      8
   0.901  39.7  5.07  20.3  0.35      9
   0.936 EVNT
   0.936 EVNT
   1.009  47.0  1.13  20.8  0.09     10
   1.118  43.9  1.26  20.7  0.20     11
   1.229  36.2  1.15  20.4  0.14     12
   1.341  32.3  1.08  21.3  0.22     13
   1.377 EVNT
   1.454  51.2  2.49  20.5  0.17     14
   1.567  39.5  4.54  20.8  0.17     15
   1.678  37.2  1.07  20.7  0.07     16
   1.714 EVNT
   1.714 EVNT
   1.787  48.0  0.91  21.4  0.36     17
   1.895  41.2  1.23  20.0  0.21     18
   2.004  38.3  1.75  20.5  0.20     19
   2.114  37.5  2.92  19.7  0.14     20
   2.223  52.1  1.04  19.3  0.48     21
   2.334  40.3  1.59  20.6  0.39     22
   2.445  41.4  5.60  20.8  0.16     23
   2.495 EVNT
   2.496 EVNT
   2.548  66.7  4.40  19.9  0.06     24
   2.754  58.9  3.37  21.1  0.13     25
   2.865  55.4  1.48  20.9  0.12     26
   2.887 EVNT
   2.972  78.9  1.11  21.1  0.12     27
   3.009 EVNT
   3.080  76.3  2.30  21.0  0.35     28
   3.131 DMI_OFF

 Left Wheel   N  =  26   M  =  48.5   SD =  13.44   H  =  78.9   L  =  32.3
```

PAVEMENT FRICTION TEST RESULTS

FILE UF.E02 RP040L v3.14 - 09 DEC 1999 ENGLISH UNITS

COUNTY BRADFORD ROUTE SR-000 DIR North(+) LANE 1
OPERATOR RCS DRIVER RCS VEHICLE UNIT 8 EQUIPMENT DOT26576/R
CO-SEC&LEG UF FIN_NO. 0 REQ_TYPE SPECIAL
DATE 05/01/2002 TIME 11:55:05 TIRE Rib
AIR_TEMPERATURE 85.0°F CONDITIONS DAY/CLOUDY

REF POST	FN AVG	FN STD	SPEED AVG	SPEED STD	TEST NUMBER
0.000	DMI_ON				
0.010	74.9	1.92	20.6	0.10	1
0.043	DMI_OFF				

Left Wheel N = 1 M = 74.9 SD = 0.00 H = 74.9 L = 74.9

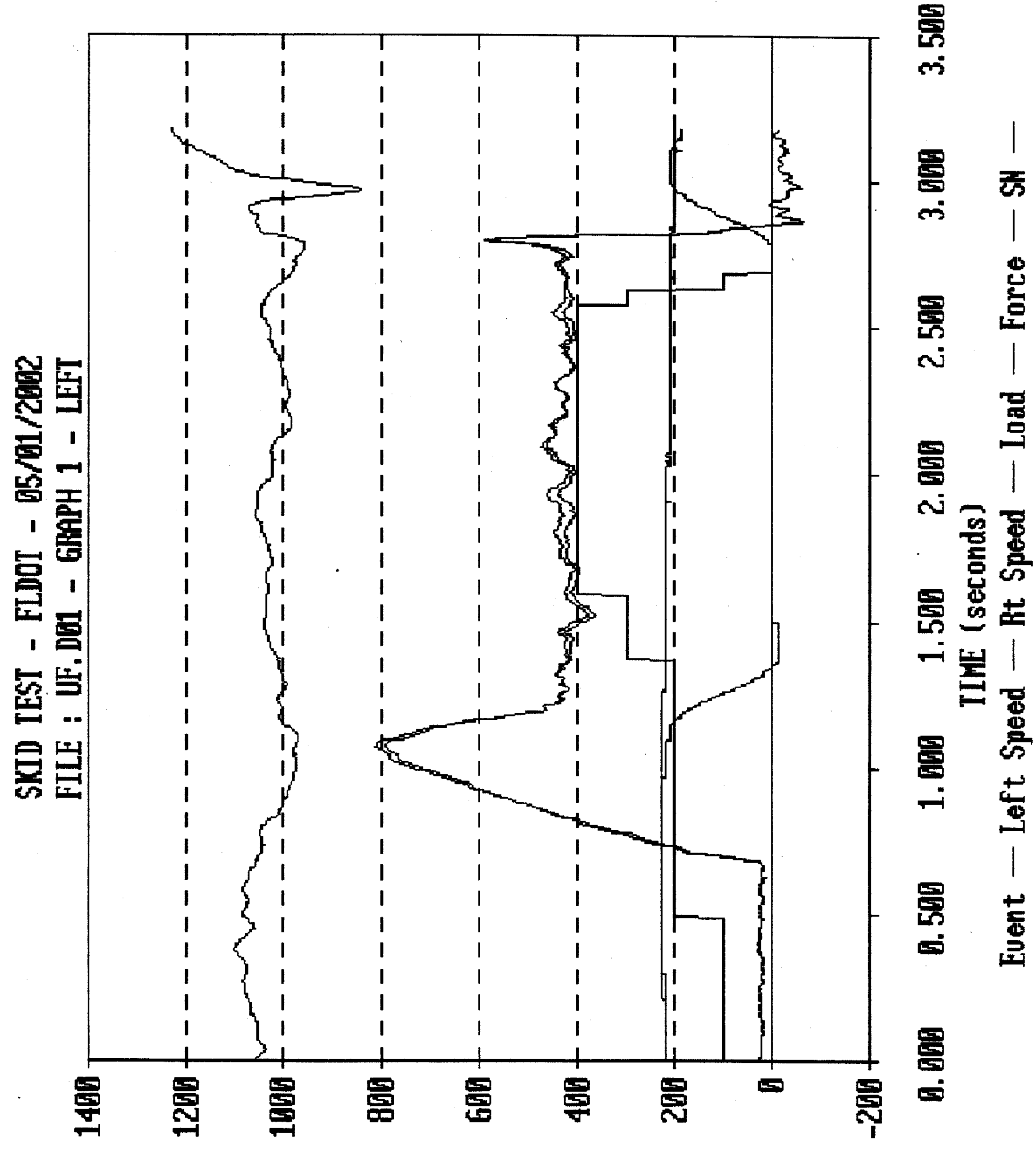
PAVEMENT FRICTION TEST RESULTS

FILE UF.E03 RP040L v3.14 - 09 DEC 1999 ENGLISH UNITS

COUNTY BRADFORD ROUTE SR-000 DIR North(+) LANE 1
OPERATOR RCS DRIVER RCS VEHICLE UNIT 8 EQUIPMENT DOT26576/R
CO-SEC&LEG UF FIN_NO. 0 REQ_TYPE SPECIAL
DATE 05/01/2002 TIME 12:07:35 TIRE Rib
AIR_TEMPERATURE 85.0°F CONDITIONS DAY/CLOUDY

REF POST	FN AVG	FN STD	SPEED AVG	SPEED STD	TEST NUMBER
0.000	DMI_ON				
0.010	79.3	0.74	20.8	0.09	1
0.116	79.7	1.68	19.8	0.23	2
0.230	77.1	1.54	19.3	0.15	3
0.340	73.8	1.01	20.0	0.20	4
0.449	73.2	0.92	19.7	0.14	5
0.558	74.3	0.78	20.0	0.51	6
0.588	EVNT				
0.589	EVNT				
0.676	50.8	2.22	22.6	0.10	7
0.787	55.0	2.63	19.2	0.30	8
0.894	57.1	4.66	20.8	0.20	9
0.937	EVNT				
1.000	49.6	1.21	20.3	0.05	10
1.108	54.4	1.86	21.4	0.13	11
1.216	53.8	3.31	20.0	0.18	12
1.246	EVNT				
1.417	48.9	1.66	20.5	0.31	13
1.529	56.3	2.74	20.2	0.24	14
1.643	59.8	1.69	20.5	0.06	15
1.672	DMI_OFF				

Left Wheel N = 15 M = 62.9 SD = 11.73 H = 79.7 L = 48.9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1.500
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2.500
3.000
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TIME (seconds)
Event — Left Speed — Rt Speed — Load — Force — SN —

Locked-Wheel Friction Test Results at SR 121

PAVEMENT FRICTION TEST RESULTS

FILE 26100SPR.E01 RP040L v3.14 - 09 DEC 1999 ENGLISH UNITS

COUNTY ALACHUA ROUTE SR-121 DIR North(+) LANE 1
OPERATOR RCS DRIVER RCS VEHICLE UNIT 8 EQUIPMENT DOT26576/R
CO-SEC&LEG 26100 FIN_NO. 00000 REQ_TYPE SPECIAL REQUEST
DATE 06/20/2002 TIME 10:16:22 TIRE Rib
AIR_TEMPERATURE 80.0°F CONDITIONS DAY/CLOUDY

REF POST	FN AVG	FN STD	SPEED AVG	SPEED STD	TEST NUMBER
0.000	DMI_ON				
3.673	EVNT				
3.673	EVNT				
4.222	65.1	1.91	20.9	0.08	1
4.260	44.3	1.28	21.2	0.08	2
4.309	66.0	1.37	20.3	0.19	3
4.410	EVNT				
4.412	EVNT				
4.820	66.3	1.77	20.7	0.11	4
4.858	47.9	1.24	20.8	0.21	5
4.906	67.6	1.55	20.6	0.08	6
5.041	EVNT				
5.043	EVNT				
5.441	64.6	2.22	20.7	0.34	7
5.480	40.7	0.76	20.5	0.09	8
5.525	67.2	0.90	20.1	0.04	9
5.609	EVNT				
5.611	EVNT				
6.055	56.8	2.18	30.4	0.09	10
6.093	34.8	1.06	30.2	0.03	11
6.140	57.4	1.75	29.8	0.07	12
6.274	EVNT				
6.275	EVNT				
6.657	58.3	1.44	29.1	0.33	13
6.695	38.7	1.80	30.5	0.05	14
6.743	61.1	1.20	29.8	0.12	15
6.857	EVNT				
6.860	EVNT				
7.276	60.5	1.39	30.4	0.12	16
7.313	40.7	1.52	30.8	0.16	17
7.359	62.0	1.65	29.6	0.05	18
7.482	EVNT				
7.484	EVNT				
7.672	55.2	0.81	39.3	0.05	19
7.728	52.5	8.20	38.6	0.05	20
7.765	54.0	1.44	38.2	0.15	21
7.826	EVNT				
7.914	48.2	2.20	39.7	0.07	22
7.951	38.5	1.32	40.8	0.11	23
7.999	49.1	1.83	40.0	0.22	24
8.102	EVNT				
8.104	EVNT				
8.353	37.7	2.39	38.5	0.21	25
8.451	EVNT				
8.476	EVNT				
8.547	52.3	0.89	39.5	0.42	26
8.583	33.1	0.83	41.5	0.12	27

8.626	48.1	1.25	40.3	0.09	28
9.448	EVNT				
9.874	34.3	6.14	58.6	0.10	29
10.011	EVNT				
10.348	DMI_OFF				

Left Wheel N = 29 M = 51.8 SD = 11.13 H = 67.6 L = 33.1

PAVEMENT FRICTION TEST RESULTS

FILE 26100SPR.E02 RP040L v3.14 - 09 DEC 1999 ENGLISH UNITS

COUNTY ALACHUA ROUTE SR-121 DIR North(+) LANE 1
OPERATOR RCS DRIVER RCS VEHICLE UNIT 8 EQUIPMENT DOT26576/R
CO-SEC&LEG 26100 FIN_NO. 00000 REQ_TYPE SPECIAL REQUEST
DATE 06/20/2002 TIME 10:19:16 TIRE Rib
AIR_TEMPERATURE 80.0°F CONDITIONS DAY/CLOUDY

REF POST	FN AVG	FN STD	SPEED AVG	SPEED STD	TEST NUMBER
0.000	DMI_ON				
0.031	40.2	1.80	60.0	0.06	1
0.173	28.7	5.95	59.8	0.11	2
0.577	DMI_OFF				

Left Wheel N = 2 M = 34.4 SD = 8.15 H = 40.2 L = 28.7

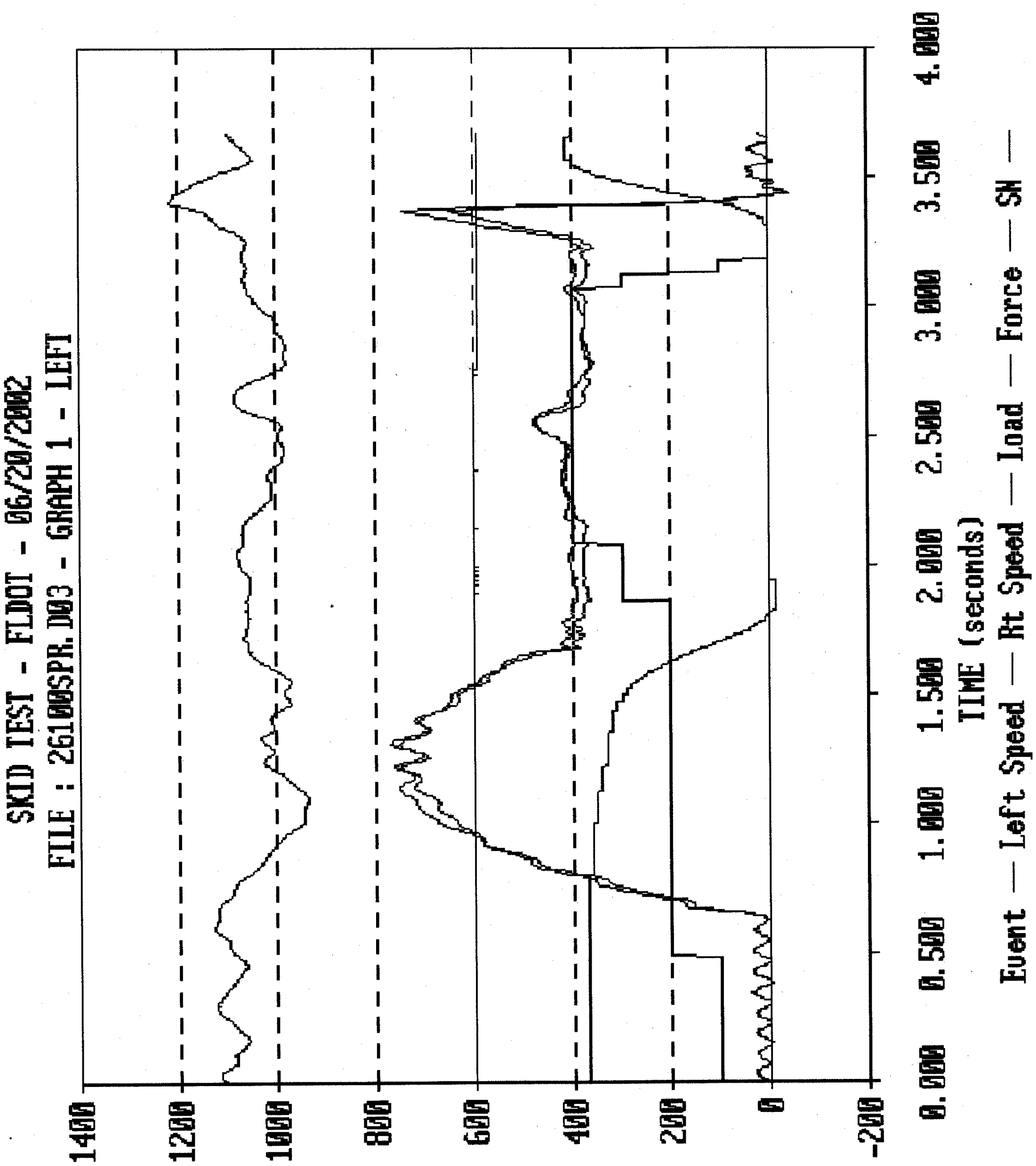
PAVEMENT FRICTION TEST RESULTS

FILE 26100SPR.E03 RP040L v3.14 - 09 DEC 1999 ENGLISH UNITS

COUNTY ALACHUA ROUTE SR-121 DIR North(+) LANE 1
OPERATOR RCS DRIVER RCS VEHICLE UNIT 8 EQUIPMENT DOT26576/R
CO-SEC&LEG 26100 FIN_NO. 00000 REQ_TYPE SPECIAL REQUEST
DATE 06/20/2002 TIME 10:34:52 TIRE Rib
AIR_TEMPERATURE 80.0°F CONDITIONS DAY/CLOUDY

REF POST	FN AVG	FN STD	SPEED AVG	SPEED STD	TEST NUMBER
0.000	DMI_ON				
0.036	39.7	2.96	59.6	0.10	1
0.177	36.0	6.37	60.2	0.15	2
0.259	43.1	1.81	59.1	0.10	3
0.362	EVNT				
0.362	EVNT				
1.018	EVNT				
1.317	46.4	2.10	49.7	0.08	4
1.457	32.5	6.09	50.4	0.30	5
1.523	46.6	1.88	48.8	0.12	6
2.604	43.7	1.80	49.4	0.05	7
2.741	31.4	2.24	49.1	0.07	8
2.797	46.6	1.56	49.2	0.05	9
2.908	EVNT				
3.889	43.3	0.78	50.8	0.14	10
4.031	34.0	6.59	50.1	0.08	11
4.098	45.4	1.42	49.6	0.06	12
4.221	DMI_OFF				

Left Wheel N = 12 M = 40.7 SD = 5.77 H = 46.6 L = 31.4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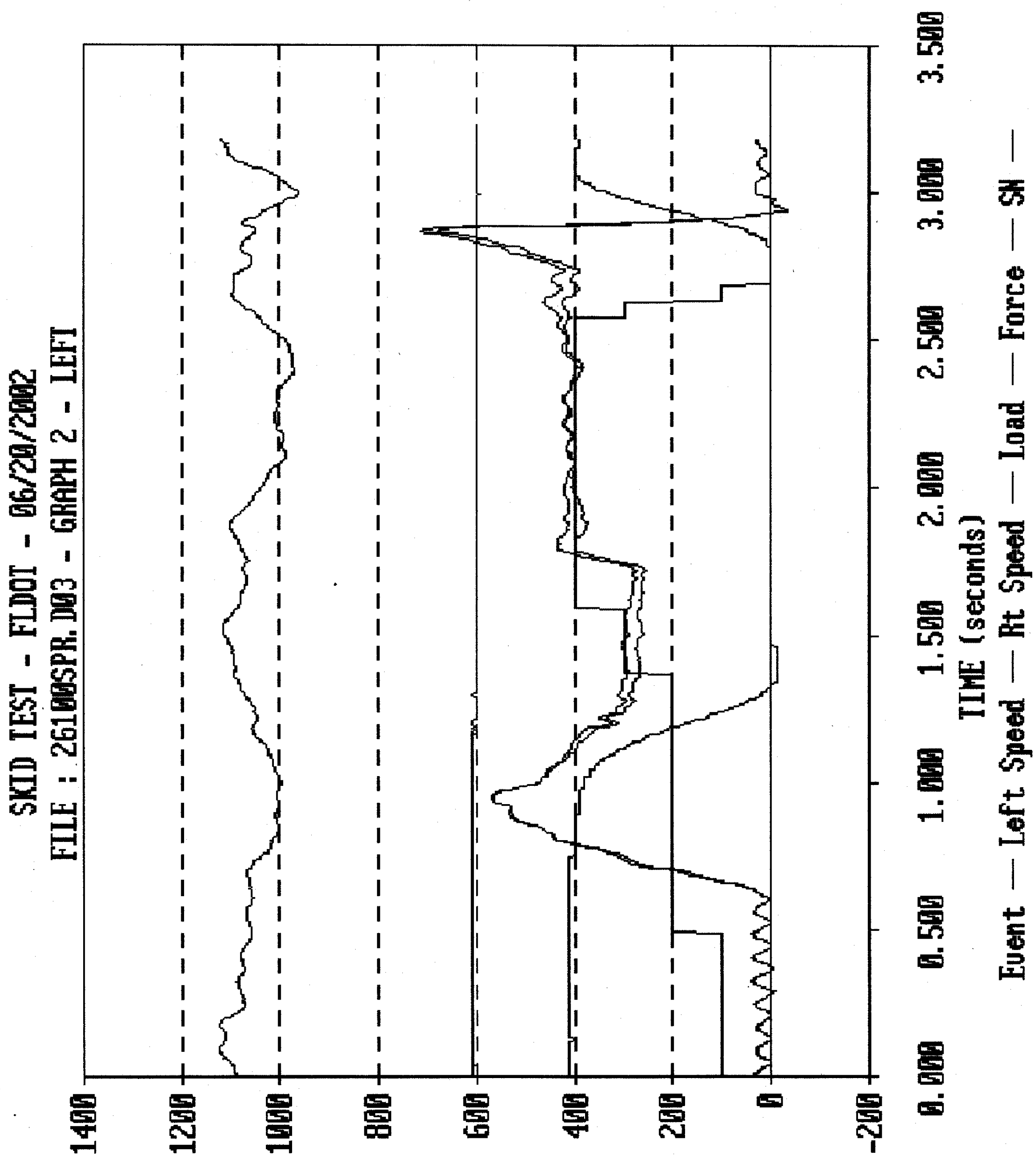
TIME (seconds)
Event — Left Speed — Rt Speed — Load — Force — SN —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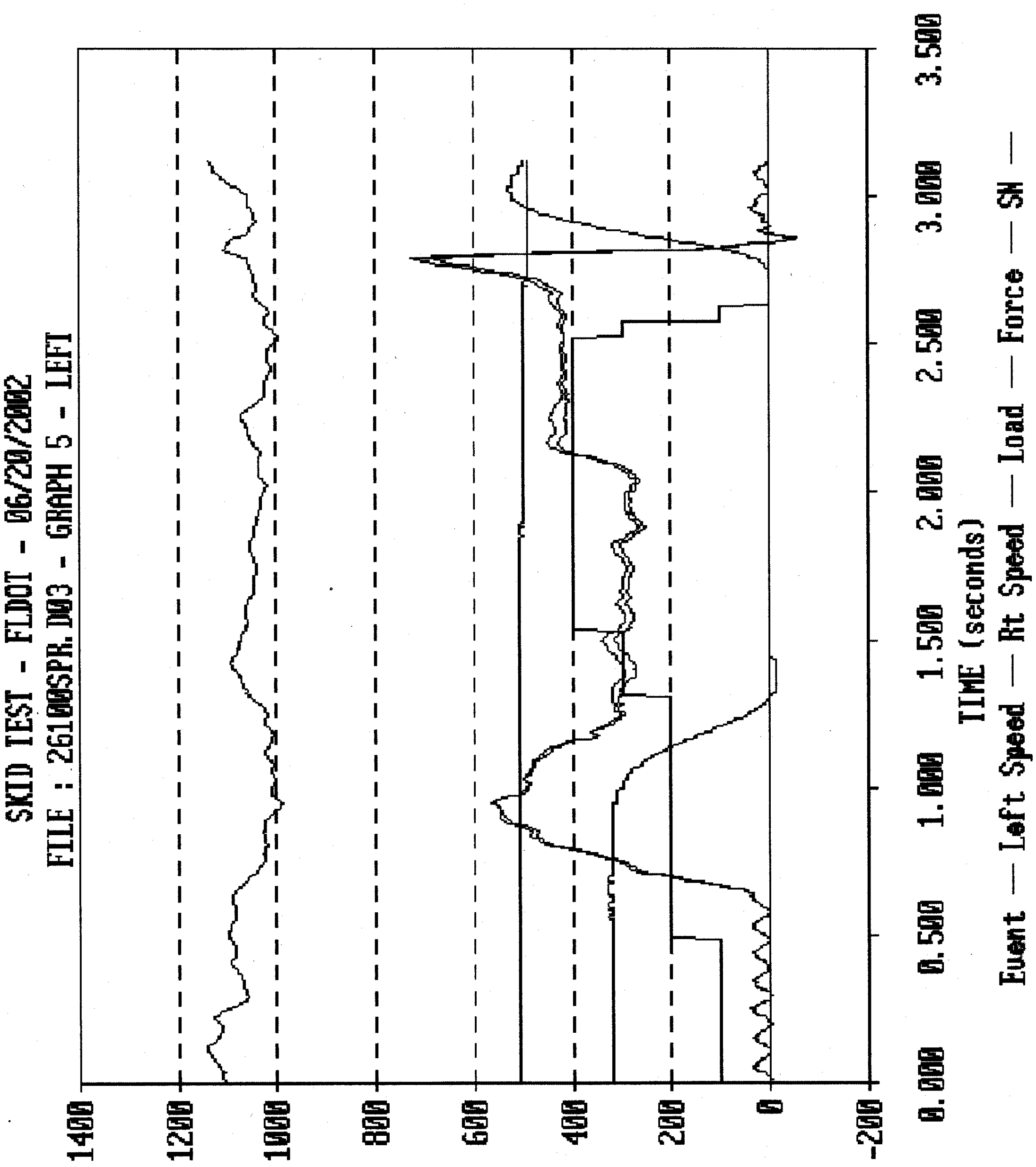
TIME (seconds)
Event — Left Speed — Rt Speed — Load — Force — SN —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1.500
2.000
2.500
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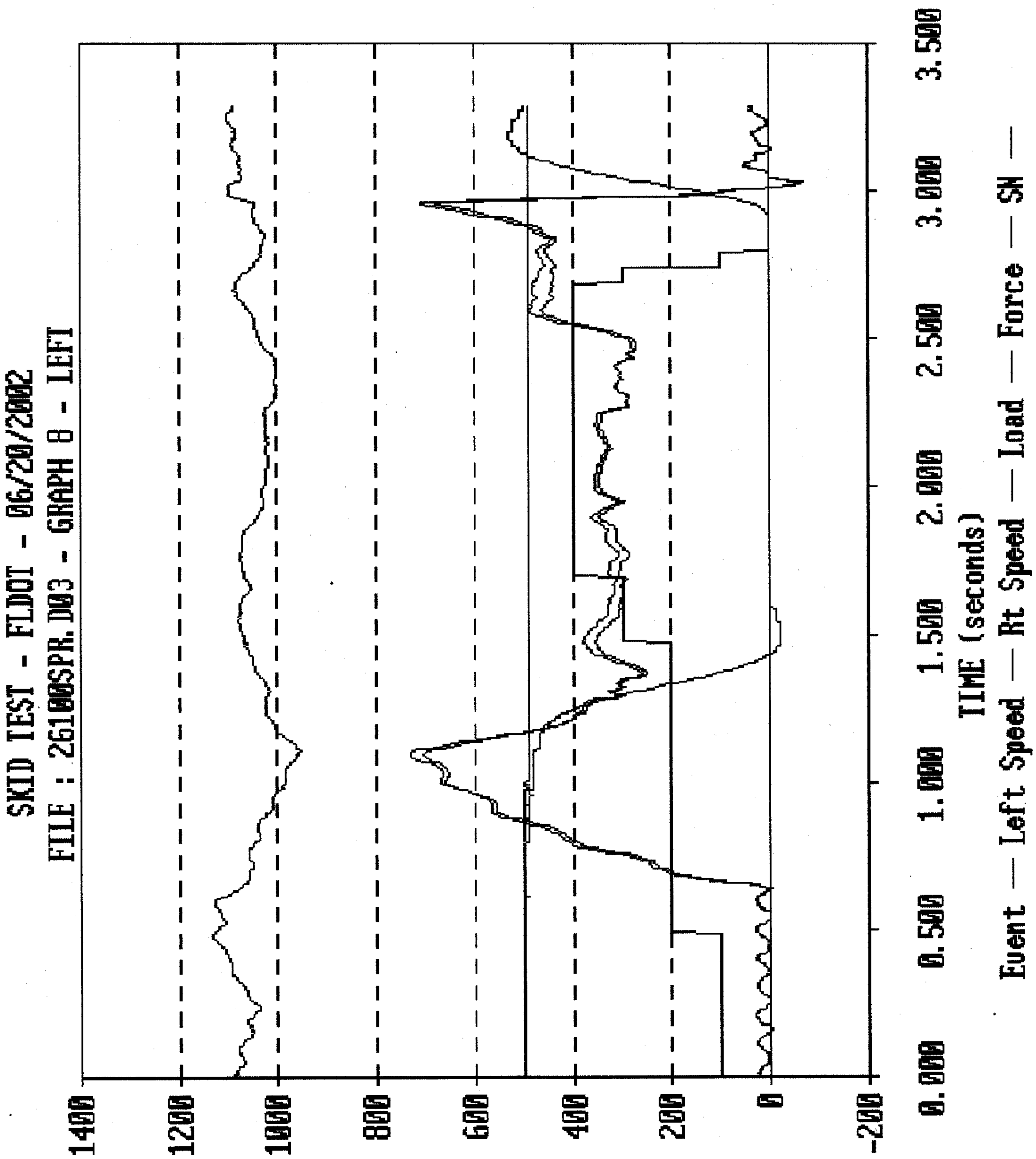
3.500
TIME (seconds)
Event — Left Speed — Rt Speed — Load — Force — SN —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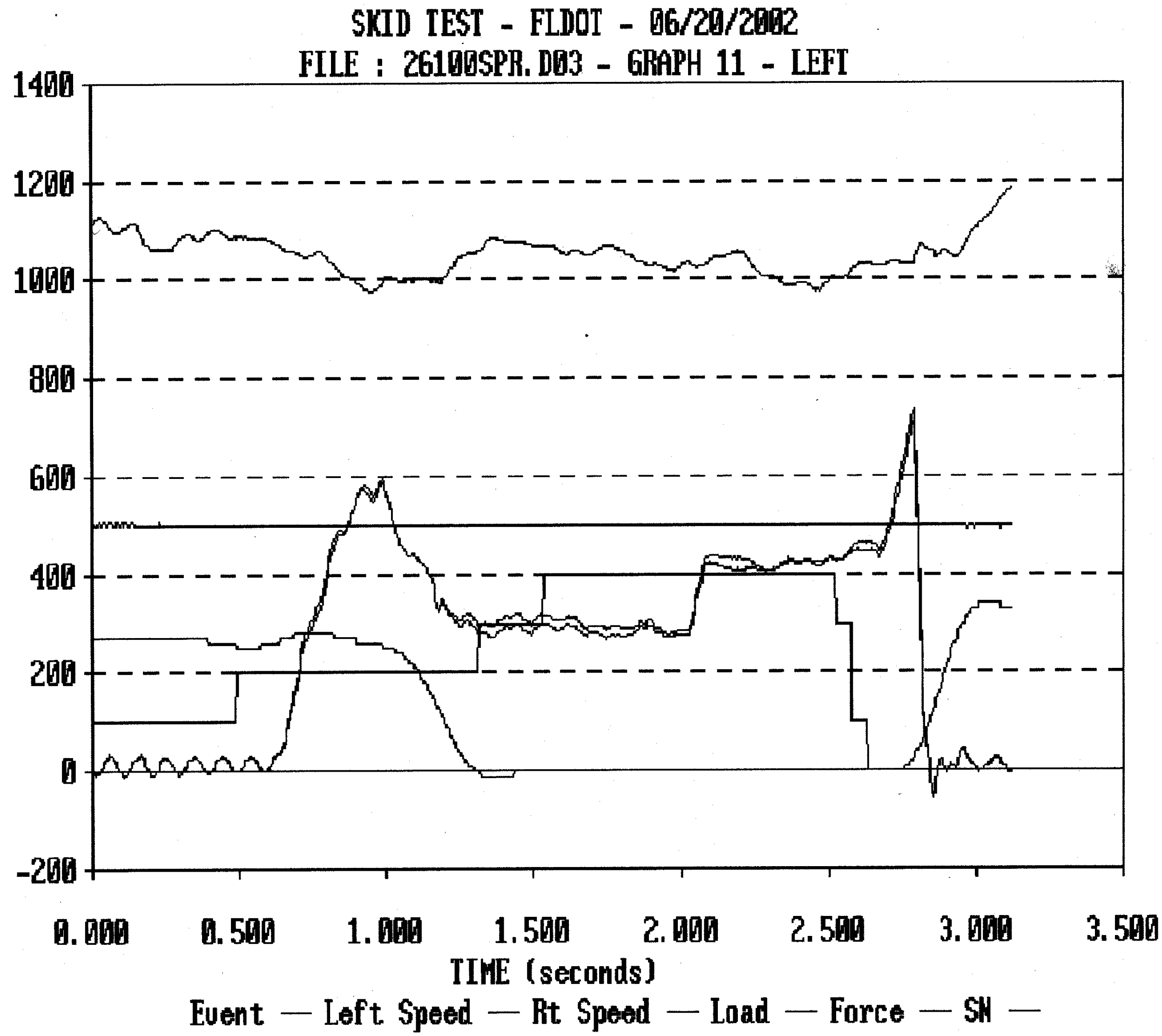
TIME (seconds)
Event — Left Speed — Rt Speed — Load — Force — SN —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2.000
2.500
3.000
3.500
TIME (seconds)
Event — Left Speed — Rt Speed — Load — Force — SN —

APPENDIX B

Test of Hypothesis concerning two population means

CASE 2

- Two small independent samples
- The populations are normally distributed
- The population variances are unknown, but are assumed to be equal

CASE 3

- Two small independent samples
- The populations are normally distributed
- The population variances are unknown, but are assumed to be equal
- $S_1^2 / S_2^2 > 4$

Statistical Test for BPT Test Results at Camp Blanding

Pavement

Ho: $y_1=y_2$ (99%)

t-test

Case 2	Neyra	GEM Seal
n	30	30
y	55.53	51.37
s	1.91	2.11
s2	3.64	4.45

Pooled Estimate	$S_p^2 =$	4.0420
Test Stat.	t =	8.0267
Critical Value	$t_{0.005,58} =$	2.66
Conclusion:	Reject Ho at 0.01 level	

Case 2	Neyra	Sealmaster
n	30	30
y	55.53	51.97
s	1.91	1.73
s2	3.64	3.00

Pooled Estimate	$S_p^2 =$	3.3178
Test Stat.	t =	7.5837
Critical Value	$t_{0.005,58} =$	2.66
Conclusion:	Reject Ho at 0.01 level	

Case 2	Sealmaster	GEM Seal
n	30	30
y	51.97	51.37
s	1.73	2.11
s2	2.9989	4.4471

Pooled Estimate	$S_p^2 =$	3.7230
Test Stat.	t =	1.2043
Critical Value	$t_{0.005,58} =$	2.66
Conclusion:	Do not reject Ho at 0.01 level	

Markings

Ho: $y_1=y_2$ (99%)

t-test

Case 2	Neyra	GEM Seal
n	30	30
y	51.80	48.50
s	2.06	1.43
s2	4.23	2.05

Pooled Estimate	$S_p^2 =$	3.1431
Test Stat.	t =	7.2091
Critical Value	$t_{0.005,58} =$	2.66
Conclusion:	Reject Ho at 0.01 level	

Case 2	Neyra	Sealmaster
n	30	30
y	51.80	51.20
s	2.06	2.02
s2	4.23	4.10

Pooled Estimate	$S_p^2 =$	4.1655
Test Stat.	t =	1.1386
Critical Value	$t_{0.005,58} =$	2.66
Conclusion:	Do not reject Ho at 0.01 level	

Case 2	Sealmaster	GEM Seal
n	30	30
y	51.01	48.50
s	2.11	1.43
s2	4.45	2.05

Pooled Estimate	$S_p^2 =$	3.2491
Test Stat.	t =	5.3942
Critical Value	$t_{0.005,58} =$	2.66
Conclusion:	Reject Ho at 0.01 level	

Statistical Test for Locked-Wheel Trailer Test Results at Camp Blanding

Ho: $y_1=y_2$ (99%)

Pavement

Data

Test No.	Neyra	GEM Seal
1	52.1	51.2
2	40.3	39.5
3	41.4	37.2
Average	44.6	42.6

t-test

Case 2	Neyra	GEM Seal
n	3	3
y	44.60	42.63
s	6.52	7.51
s^2	42.49	56.36

Pooled Estimate	$S_p^2 =$	49.4267
Test Stat.	t =	0.3426
Critical Value	$t_{0.005,4} =$	4.604
Conclusion:	Do not reject Ho at 0.01 level	

Test No.	Neyra	Sealmaster
1	52.1	44.4
2	40.3	43.7
3	41.4	39.7
Average	44.6	42.6

Case 3	Neyra	Sealmaster
n	3	3
y	44.60	42.60
s	6.52	2.54
s^2	42.49	6.43

Test Stat.	t =	0.4953
d.f.	v =	2.5918
Critical Value	$t_{0.005,2} =$	9.9925
Conclusion:	Do not reject Ho at 0.01 level	

Statistical Test for Locked-Wheel Trailer Test Results at Camp Blanding

Ho: $y_1=y_2$ (99%)

Markings

Data

Test No.	Neyra	GEM Seal
1	41.1	43.9
2	38.3	36.2
3	37.5	32.3
Average	39.0	37.5

t-test

Case 2	Neyra	GEM Seal
n	3	3
y	38.97	37.47
s	1.89	5.90
s^2	3.57	34.84

Pooled Estimate	S_p^2 =	19.2083
Test Stat.	t =	0.4192
Critical Value	$t_{0.005,4}$ =	4.604
Conclusion:	Do not reject Ho at 0.01 level	

Test No.	Neyra	Sealmaster
1	41.1	37.3
2	38.3	33.6
3	37.5	30.3
Average	39.0	33.7

Case 3	Neyra	Sealmaster
n	3.0	3
y	44.60	42.60
s	6.52	2.54
s^2	42.49	6.43

Test Stat.	t =	0.4953
d.f.	v =	2.5918
Critical Value	$t_{0.005,2}$ =	9.9925
Conclusion:	Do not reject Ho at 0.01 level	

Statistical Test for Locked-Wheel Trailer Test Results at Camp Blanding

Ho: $y_1=y_2$ (99%)

Pavement

Data

Test No.	Before	GEM Seal
1	78.9	51.2
2	76.3	39.5
3	74.9	37.2
Average	76.7	42.6

t-test

Case 2	Before	GEM Seal
n	3	3
y	76.70	42.63
s	2.03	7.51
s^2	4.12	56.36

Pooled Estimate	S_p^2 =	30.2417
Test Stat.	t =	7.5870
Critical Value	$t_{0.005,4}$ =	4.604
Conclusion:	Reject Ho at 0.01 level	

Test No.	Before	Sealmaster
1	78.9	44.4
2	76.3	43.7
3	74.9	39.7
Average	76.7	42.6

Case 2	Before	Sealmaster
n	3	3
y	76.70	42.60
s	2.03	2.54
s^2	4.12	6.43

Pooled Estimate	S_p^2 =	5.2750
Test Stat.	t =	18.1840
Critical Value	$t_{0.005,4}$ =	4.604
Conclusion:	Reject Ho at 0.01 level	

Test No.	Before	Neyra
1	78.9	52.1
2	76.3	40.3
3	74.9	41.4
Average	76.7	44.6

Case 2	Before	Neyra
n	3	3
y	76.70	44.60
s	2.03	6.52
s^2	4.12	42.49

Pooled Estimate	S_p^2 =	23.3050
Test Stat.	t =	8.1438
Critical Value	$t_{0.005,4}$ =	4.604
Conclusion:	Reject Ho at 0.01 level	

Statistical Test for Locked-Wheel Trailer Test Results at SR 121

Ho: $y_1 = y_2$ (99%)

Pavement

Data

20 MPH

Test No.	Before	After
1	65.1	44.3
2	66.0	47.9
3	66.3	40.7
Average	65.8	44.3

t-test

Case 2	Before	After
n	3	3
y	65.80	44.30
s	0.62	3.60
s^2	0.39	12.96

Pooled Estimate	$S_p^2 =$	6.6750
Test Stat.	$t =$	10.1920
Critical Value	$t_{0.005,4} =$	4.604
Conclusion:	Reject Ho at 0.01 level	

30 MPH

Test No.	Before	After
1	56.8	34.8
2	57.4	38.7
3	58.3	40.7
Average	57.5	38.1

Case 2	Before	After
n	3	3
y	57.50	38.07
s	0.75	3.00
s^2	0.57	9.00

Pooled Estimate	$S_p^2 =$	4.7867
Test Stat.	$t =$	10.8787
Critical Value	$t_{0.005,4} =$	4.604
Conclusion:	Reject Ho at 0.01 level	

40 MPH

Test No.	Before	After
1	55.2	38.5
2	54.0	37.7
3	48.2	33.1
Average	52.5	36.4

Case 2	Before	After
n	3	3
y	52.47	36.43
s	3.74	2.91
s^2	14.01	8.49

Pooled Estimate	$S_p^2 =$	11.2533
Test Stat.	$t =$	5.8537
Critical Value	$t_{0.005,4} =$	4.604
Conclusion:	Reject Ho at 0.01 level	

Statistical Test for Locked-Wheel Trailer Test Results at SR 121

Ho: $y_1 = y_2$ (99%)

Pavement

Data

50 MPH

Test No.	Before	After
1	46.4	32.5
2	46.6	31.4
3	43.7	34.0
Average	45.6	32.6

t-test

Case 2	Before	After
n	3	3
y	45.57	32.63
s	1.62	1.31
s^2	2.62	1.70

Pooled Estimate	$S_p^2 =$	2.1633
Test Stat.	$t =$	10.7695
Critical Value	$t_{0.005,4} =$	4.604
Conclusion:	Reject Ho at 0.01 level	

60 MPH

Test No.	Before	After
1	40.2	34.3
2	39.7	28.7
3	43.1	36.0
Average	41.0	33.0

Case 2	Before	After
n	3	3
y	41.00	33.00
s	1.84	3.82
s^2	3.37	14.59

Pooled Estimate	$S_p^2 =$	8.9800
Test Stat.	$t =$	3.2696
Critical Value	$t_{0.005,4} =$	4.604
Conclusion:	Do not reject Ho at 0.01 level	

Statistical Test for Locked-Wheel Trailer Test Results at SR 26

Ho: $y_1=y_2$ (99%)

Data

Eastbound

Test No.	Before	After
1	47.8	39.6
2	46.9	46.6
3	46.4	46.8
4	49.4	-
Average	47.6	44.3

t-test

Case 2	Before	After
n	4	3
y	47.63	44.33
s	0.71	4.10
s^2	0.50	16.81

Pooled Estimate	$S_p^2 =$	8.6583
Test Stat.	$t =$	1.4647
Critical Value	$t_{0.005,5} =$	4.032
Conclusion:	Do not reject Ho at 0.01 level	

Westbound

Test No.	Before	After
1	48.3	42.5
2	51.6	44.6
3	57.7	43.1
Average	52.5	43.4

Case 2	Before	After
n	3	3
y	52.53	43.40
s	4.77	1.08
s^2	22.74	1.17

Pooled Estimate	$S_p^2 =$	11.9567
Test Stat.	$t =$	3.2350
Critical Value	$t_{0.005,4} =$	4.604
Conclusion:	Do not reject Ho at 0.01 level	

APPENDIX C

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 ^{o}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 60ºF [15ºC] 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.