

# **EVALUATION OF MOTORCYCLISTS' AND BIKERS' SAFETY ON WET PAVEMENT MARKINGS**

## **FINAL PROJECT REPORT**

by

Somayeh Nassiri, Ph.D.  
Washington State University

Sponsorship  
PacTrans

for

Pacific Northwest Transportation Consortium (PacTrans)  
USDOT University Transportation Center for Federal Region 10  
University of Washington  
More Hall 112, Box 352700  
Seattle, WA 98195-2700

In cooperation with US Department of Transportation-Research and Innovative Technology  
Administration (RITA)



## **Disclaimer**

**The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation's University Transportation Centers Program, in the interest of information exchange. The Pacific Northwest Transportation Consortium, the U.S. Government and matching sponsor assume no liability for the contents or use thereof.**

## Technical Report Documentation Page

<b>1. Report No.</b>	<b>2. Government Accession No.</b>	<b>3. Recipient's Catalog No.</b>	
<b>4. Title and Subtitle</b>  Evaluation of Motorcyclists' and Bikers' Safety on Wet Pavement Markings		<b>5. Report Date</b> 01/02/2018	
		<b>6. Performing Organization Code</b> 04-148-5301	
<b>7. Author(s)</b> Harry Rodin III, MS Student, Washington State University Somayeh Nassiri, Assistant Professor, Washington State University Mina Yekkalar, MS, Washington State University		<b>8. Performing Organization Report No.</b>	
<b>9. Performing Organization Name and Address</b> PacTrans Pacific Northwest Transportation Consortium University Transportation Center for Region 10 University of Washington More Hall 112 Seattle, WA 98195-2700		<b>10. Work Unit No. (TRAIS)</b>	
		<b>11. Contract or Grant No.</b> DTRT-13-UTC40	
<b>12. Sponsoring Organization Name and Address</b> United States of America Department of Transportation Research and Innovative Technology Administration		<b>13. Type of Report and Period Covered</b> Research	
		<b>14. Sponsoring Agency Code</b>	
<b>15. Supplementary Notes</b> Report uploaded at <a href="http://www.pacTrans.org">www.pacTrans.org</a>			
<b>16. Abstract</b> <p>In this study, three different pavement marking material types were evaluated by using a British Pendulum Tester (BPT) in dry, wet, and icy conditions. The frictional properties were recorded as a British Pendulum Number (BPN). Two different rubber sliders on the BPN were used to compare different pavement marking users: a pedestrian slip rubber (PSR) and tire slip rubber (TSR). This study included both laboratory and field testing. The pavement markings evaluated were chosen after a careful review of Washington State Department of Transportation's specifications and Washington State University's (WSU) Facilities Services common practices.</p> <p>During laboratory testing, a neat concrete slab surface was compared to waterborne paint, preformed fused thermoplastic, and cold applied pre-formed tape surfaces. Each of the surface types was evaluated under dry, wet, and icy conditions. Laboratory test results showed that the paint and thermoplastics resulted in lower BPN values than the neat concrete surface. However, the centerline striping that was tested did show higher frictional properties than the neat concrete surface because of the contours and surface macrotecture of the tested striping.</p> <p>During field testing, two locations on the WSU Pullman campus were chosen for testing in dry and wet conditions. Each location was evaluated by using the BPT, and then two bicyclists rode over the markings in a variety of ways in dry and wet conditions. The tested locations were painted markings.</p> <p>A safety scale was created for riders to evaluate the field markings. The results showed that riders generally felt safe while riding in a straight line over the pavement markings. Most of the unsafe ratings occurred during wet testing, and as cyclists turned and braked over the pavement markings. In comparing the laboratory and field testing BPN values, the laboratory values were typically higher. This was most likely due to the fact that beads were present on the laboratory markings and not on the field markings.</p> <p>From these results, the authors concluded that centerline striping showed the most promising frictional properties. Although paint and thermoplastics showed lower frictional properties than those of the neat concrete surface, the use of beads helped improve the laboratory values over the field testing values.</p>			
<b>17. Key Words</b> Friction, pavement marking, skid resistance, paint, thermoplastic		<b>18. Distribution Statement</b> No restrictions.	
<b>19. Security Classification (of this report)</b> Unclassified.	<b>20. Security Classification (of this page)</b> Unclassified.	<b>21. No. of Pages</b> 44	<b>22. Price</b> NA



## Table of Contents

Acknowledgments.....	ix
Executive Summary .....	xi
1. INTRODUCTION .....	1
1.1 Research Need .....	1
1.2 Report Organization.....	2
1.3 Pavement Marking Materials.....	2
1.3.1 Low Volatile Organic Carbon (VOC) Paint .....	3
1.3.2 Plastics .....	4
1.3.2.1 Type A – Liquid Hot Applied Thermoplastic.....	4
1.3.2.2 Type B – Preformed Fused Thermoplastic .....	5
1.3.2.3 Type C – Cold Applied Preformed Polymer Tape.....	6
1.3.2.4 Type D – Liquid Cold Applied Methyl Methacrylate (MMA).....	8
1.3.3 Other Materials .....	9
1.3.3.1 Epoxy .....	9
1.3.3.2 Polyurea .....	9
1.3.3.3 Modified Urethane.....	10
1.3.3.4 Profiled Thermoplastic.....	10
2 PAVEMENT MARKING FRICTIONAL PROPERTIES.....	11
2.1 Literature Review.....	11
2.2 Project Scope .....	14
3 METHODOLOGY.....	17
3.1 Slab Specimen Preparation .....	17
3.2 Friction Evaluation Method.....	20
3.3 Laboratory Testing.....	21
3.4 Field Testing .....	21
4 TEST RESULTS.....	27
4.1 Laboratory Testing.....	27
4.2 Field Testing .....	31
4.3 Comparison between Laboratory and Field BPN Values .....	34

5. CONCLUSIONS AND RECOMMENDATIONS ..... 37

    5.1 Conclusions.....37

    5.2 Recommendations for Future Research.....38

6. REFERENCES..... 39

APPENDICES ..... 42

## List of Figures

Figure 1.1: Cross-section of 3M™ Stamark™ Pavement Marking Tape Series 380 (3M and Stamark 2013). _____	7
Figure 3.1: (left) Application of waterborne paint on slab surfaces, (right) application of glass beads on the slab surface. _____	18
Figure 3.2: Twelve slabs cast and painted in preparation for friction testing. _____	18
Figure 3.3: Slab surface markings for a) paint with beads, b) thermoplastic with beads, and c) cold-applied preformed tape _____	19
Figure 3.4: a) The BPT apparatus and b) a close snapshot of the BPN values on the machine. _____	20
Figure 3.5: a) Testing location one on Lincoln Drive and b) testing location two on Olympia Avenue. _____	22
Figure 3.6: Dry testing using the mountain bike at Test Site 1 by a) the BPT, b) rider one, and c) rider two. Wet testing at Test Site 2 by d) the BPT, e) rider one, and f) rider two. _____	24
Figure 3.7: Wet testing using the mountain bike at Test Site 1 by a) the BPT, b) rider one, and c) rider two. Wet testing at Test Site 2 for d) the BPT, e) rider one, and f) rider two. _____	25
Figure 3.8: Wet testing using the road bike by rider one at a) Test Site 1 and b) 2. _____	26
Figure 4.1: Laboratory testing of different pavement markings under three surface conditions using the a) PSR and b) TSR. _____	29
Figure 4.2: Comparison of laboratory and field testing on painted markings. _____	34

## List of Tables

Table 3.1: Mixture design for slab specimens cast from ready-mix concrete. _____	17
Table 4.1: Recommended minimum BPN values in wet testing conditions (from Asi, 2005). _	27
Table 4.2: Statistical analysis using a 95 percent confidence interval. _____	30
Table 4.3: Field evaluations on a bike, riding in a straight line over a painted pavement marking. _____	32
Table 4.4: Field evaluations on a bike, turning over a painted pavement marking. _____	33
Table 4.5: Statistical comparison of laboratory testing and field testing. _____	35



## **Acknowledgments**

Thank you to PacTrans for funding this project. Undergraduate workers who helped with the laboratory work are also acknowledged, as well as the bike riders who volunteered to conduct the field tests in this study.



## **Executive Summary**

In this study, three different pavement marking material types were evaluated by using a British Pendulum Tester (BPT) in dry, wet, and icy conditions. The frictional properties were recorded as a British Pendulum Number (BPN). Two different rubber sliders on the BPN were used to compare different pavement marking users: a pedestrian slip rubber (PSR) and tire slip rubber (TSR). This study included both laboratory and field testing. The pavement markings evaluated were chosen after a careful review of Washington State Department of Transportation's specifications. In addition, the common practices of Washington State University's (WSU) Facilities Services were considered in performing an evaluation of local practices and materials.

During laboratory testing, a neat concrete slab surface was compared to waterborne paint, preformed fused thermoplastic, and cold applied pre-formed tape surfaces. Each of the surface types was evaluated under dry, wet, and icy conditions. Laboratory test results showed that the paint and thermoplastics resulted in lower BPN values than the neat concrete surface. However, the centerline striping that was tested did show higher frictional properties than the neat concrete surface because of the contours and surface macrotexture of the tested striping. By using statistical analysis at a 95 percent confidence interval, the differences between each of the markings and the neat concrete surfaces were shown to be significant (for both increases and decreases of the BPN).

During field testing, two locations on the WSU Pullman campus were chosen for testing in dry and wet conditions. Each location was evaluated by using the BPT, and then two bicyclists rode over the markings in a variety of ways in dry and wet conditions. The tested locations were painted markings.

A safety scale was created for riders to evaluate the field markings. The results showed that riders generally felt safe while riding in a straight line over the pavement markings. Most of the unsafe ratings occurred during wet testing, and as cyclists turned and braked over the pavement markings. In comparing the laboratory and field testing BPN values, the laboratory values were typically higher. This was most likely due to the fact that beads were present on the laboratory markings and not on the field markings.

From these results, the authors concluded that centerline striping showed the most promising frictional properties. Although paint and thermoplastics showed lower frictional properties than those of the neat concrete surface, the use of beads helped improve the laboratory values over the field testing values. Future work should include field testing on a larger variety of pavement marking types. Through more testing, a better understanding and correlation between BPN values and rider safety can be determined in evaluating pavement markings.

# 1. Introduction

## 1.1 Research Need

The application of road surface markings on paved roadways provides drivers, cyclists, and pedestrians with guidance to enhance their ability to navigate the road. Pavement markings are critical in guiding road users in properly using traffic lanes; however, they may lead to catastrophic crashes for motorcyclists and bikers when the markings are wet or icy. Large pavement markings are becoming prevalent to minimize confusions on high-volume routes or in urban areas with mixed road users. Large symbols are painted on the pavement surface, typically at mid-lane locations, and extend across the lane in some cases. The intention is that the symbols be easily visible to road users and thus reduce drivers' response time and help them focus on driving safely. Other pavement markings such as crosswalks, divider single and double lines, and edge lines are used to guide road users in properly using and sharing lanes. In addition, in many urban areas bicycle lanes are painted in distinct colors for more protection and attention from nearby drivers and other riders. The users of protected bike lanes have found the colors effective at keeping cars from entering their lanes. However, riders also find painted areas slick when wet, especially when they corner and brake ([bostonbiker.com](http://bostonbiker.com)).

The aim of the present study was to empirically investigate the frictional properties of different pavement markings in comparison to a neat pavement surface under different surface conditions, including wet and icy conditions. Emphasis was placed on providing objective and statistical comparisons by adhering to controlled laboratory test conditions. In addition, a qualitative ,complementary riding evaluation was conducted to compare the results of the laboratory test method to observations of two cyclists riding on dry and wet paving markings.

## 1.2 Report Organization

A wide variety of pavement marking materials is available on the market, and markings are specified in state agencies' specifications. These materials vary in application method and conditions, durability, and cost, among other factors. A brief overview of common pavement marking materials is provided in the section below.

In Chapter 2 of this report, a review of the literature pertaining to the scope of this study regarding the frictional properties of various pavement markings is provided. Chapter 2 also includes a discussion of the scope of the present study. Chapter 3 presents details of the methodology followed in the laboratory and in the field. The details of the testing, results, and findings from both series of laboratory and field testing, as well as statistical comparisons, are discussed in detail in Chapter 4, followed by concluding remarks and recommendations for future research.

## 1.3 Pavement Marking Materials

According to the Washington State Department of Transportation's (WSDOT) Standard Specifications, the most common pavement marking material types are as follows (WSDOT 2016):

- Low volatile organic carbon (VOC) paint
  - Low VOC solvent-based paint
  - Low VOC waterborne paint, and temporary pavement marking paint
- Plastics
  - Type A – Liquid hot applied thermoplastic
  - Type B – Pre-formed fused thermoplastic
  - Type C – Cold applied pre-formed tape, and

- Type D – Liquid cold applied methyl methacrylate
- Other Materials
  - Epoxy, polyurea, modified urethane, ceramic buttons, profiled thermoplastic, contrast markings, heated-in-place thermoplastic, retroreflective raised pavement markings, and stones

Each of the pavement marking materials is briefly described in the succeeding sections.

### *1.3.1 Low Volatile Organic Carbon (VOC) Paint*

Some of the most inexpensive marking materials applied on roadways are paints consisting of three main components: pigments, resins (binders), and water (solvents). Pigments may contain other additives such as UV stabilizers, fillers, and retroreflective glass beads, which bring the color pigments to the required level for marking travel lanes, parking lots, and special-purpose spaces such as disabled parking, loading zones, and time-restricted parking. Although pigments and resins are mixed with both water (water-based paints) and solvents (solvent-based paints), water-based paints are typically more environmentally friendly, easier to work with, and safer for workers than solvent-based paints (Lopez 2004, WSDOT 2013).

Because of environmental concerns, WSDOT specifications require paints to comply with regulatory levels of VOC, including mercury, lead, chromium, toluene, chlorinated solvents, hydrolysable chlorine derivatives, ethylene-based glycol ethers and their acetates, and any other waste material designated hazardous by the Environmental Protection Agency (WSDOT 2013). In addition to their lower environmental effects, humidity has negligible effect on water-based paints because this type of paint begins to set as a result of evaporation of ammonia and a drop in pH. Paint is applied right after the pavement installation and usually lasts 9 to 36 months before color fading occurs, depending on factors such as paint thickness, traffic

volume, pavement surface roughness, and environmental conditions. To achieve maximum paint-pavement bonding and consequently higher durability, it is essential that paints be applied on pavement surfaces that are free of dust, contaminants, poorly adhered existing markings, glass beads, curing compound, and moisture. The pavement and air temperatures must also be at least 40°F for application (FHWA 2010, Jun-Taek et al. 1999, Lopez 2004).

Paints have a decreased performance in less than three months on coarse roadway surfaces and on roads with high annual average daily traffic (AADT). Therefore, their use should be limited to low-volume roadways under normal conditions. This type of pavement marking is commonly used in low-volume traffic, urban areas such as the Washington State University campus, and therefore it was included in the testing program in this study. The details of the test program are discussed in Section 2.2 of Chapter 2.

### *1.3.2 Plastics*

#### *1.3.2.1 Type A – Liquid Hot Applied Thermoplastic*

Thermoplastic marking materials consist of four components: binder, pigment, glass beads, and filler material—usually calcium carbonate, sand, or both. The mixture of plasticizer and resins that keep the other ingredients together is solid at room temperature and liquid when heated. The popularity of thermoplastic markings can be attributed to their immediate use, acceptable retro-reflectivity, and low cost. In addition, when properly formulated for a given roadway surface and correctly applied, thermoplastic pavement markings can provide durability that far surpasses that of standard requirements. However, because thermoplastic materials are sensitive to the variables involved with application—such as material composition, application procedure, roadway surface, traffic, and environmental conditions—they may not be the most reasonable choice for certain situations. Thermoplastic markings are well suited for their



application on asphalt surfaces, especially hot mix asphalt (HMA) surfaces, because of their thermal bond development with the asphalt via heat fusion. On portland cement concrete (PCC) surfaces, the bond formation is the result of liquid thermoplastic seeping into the pores of the surface and developing a tight mechanical bond after cooling. In this case, a considerable portion of thermoplastic materials can seep into the voids between the aggregate, resulting less material on the top of the aggregate than on impermeable surfaces. Because lack of materials on the pavement surface leads to accelerated wear of the thermoplastic and premature bead loss, greater thermoplastic thicknesses may sometimes be necessary. The thermal properties of the thermoplastic binder and the roadway surface, the porosity of the surface, air temperature, and surface moisture are important factors affecting the long-term performance of thermoplastic markings. To ensure a proper rate of cooling, pavement and air temperatures must be at least 50°F and 55°F, respectively. Thermoplastics are also highly susceptible to moisture-associated bonding failures. Because of this sensitivity to environmental changes (especially alkyd materials), thermoplastic materials may not be the best material for pavement markings in regions with high humidity or susceptibility to dew formation during times that would affect striping operations (Lopez 2004, Montebello & Schroeder 2000).

Although thermoplastics are well known for their long-term performance, it is recommended to apply primers and give them proper curing time. Similar to paints, keeping pavement surfaces free from dust, contaminants, poorly adhered existing markings, glass beads, curing compound, and moisture is crucial (Federal Highway Administration 2010, Lopez 2004).

#### *1.3.2.2 Type B – Preformed Fused Thermoplastic*

Preformed thermoplastic pavement markings are manufactured thermoplastics that are ready to place on the pavement surface by using a propane heat torch to heat the pavement. The

preformed thermoplastic markings usually last between three and six years. The considerable durability and cost-effective service life of Type B thermoplastic markings make pre-formed fused thermoplastics one of the most common markings for applications such as intersections, stop lines, legends, crosswalks, arrows, bike lane symbols, and accessibility symbols. In addition, they are not easily damaged by snowplows because they are melted into the surface (FHWA 2010, Lopez 2004).

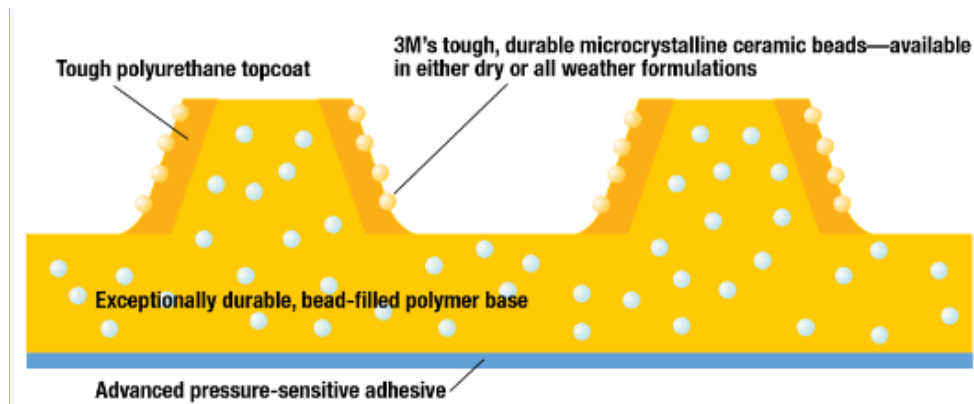
#### *1.3.2.3 Type C – Cold Applied Preformed Polymer Tape*

Type C is cold-applied, preformed pavement marking material that is supplied in continuous rolls in various lengths and widths. This marking tape can be applied on new HMA during the final rolling process, existing HMA pavement surfaces, and PCC pavements. However, the use of a surface primer or adhesive is sometimes recommended by the tape manufacturer, especially in areas that have a high numbers of turning movements or weaving over the strip. One of the most important advantages of pre-formed tape is that unlike sprayed or extruded materials, they require little or no equipment to apply. In addition, the roadway is open almost immediately after installation with minimum curing time because tire traffic over the tape installation will strengthen the bond (Lopez 2004).

While tapes have a significantly higher initial cost than most other materials, their service lives are usually superior to most other materials (including thermoplastics), often making them a cost-effective choice in locations with high traffic volumes. Preformed tapes can be classified by the expected service life and material composition. The first type is “permanent” preformed tape which is any material that bonds with the pavement surface so that it cannot be removed by hand and has a service life of at least one year. This includes any inlayed installations and thick overlaid installations that have achieved a strong bond with the surface. Permanent preformed

tapes are usually made of a plastic binder material with glass beads embedded into the surface. The other type is “temporary” preformed tape, which is used in construction zones and maintenance jobs that require temporary delineation or altered travel lanes because of its easy removability by hand without leaving any trace of a marking (Lopez 2004, Federal Highway Administration 2010).

Two commercial polymer tapes are Stamark™ Pavement Marking Tape Series 380 and Tape Series 270 ES. 3M’s microcrystalline ceramic beads create high-visibility guidance, improved roadway safety, and more resistance to harsh roadway conditions than conventional glass beads (see figure 1.1). With an easy-to-use surface preparation adhesive, Stamark Series 380 tape can be applied beyond the seasonal application dates when the temperature is 40 °F or higher, extending the effective striping season by several weeks with no specific surface preparation during the normal marking season (3M and Stamark 2013).



**Figure 0.1:** Cross-section of 3M™ Stamark™ Pavement Marking Tape Series 380 (3M and Stamark 2013).

Tape Series 270 ES, with a considerably long-lasting visibility, is ideal for interstate highways, dark rural roads, and urban streets, where nighttime reflectivity is critical. Also, its

high-profile diamond pattern improves wet reflectivity. This type of tape is mostly used on HMA and PCC pavements as long lines, edge lines, channelizing lines, stop bars, and crosswalk marking materials. Series 270 ES tape offers extended season applications because of an improved pressure sensitive adhesive (PSA) package on the bottom surface. The durability of Series 270 ES tape depends on traffic conditions, snow removal practices, application techniques, and pavement and atmospheric conditions at the time of application. The main factors that affect its performance are heavy trucks, excessive encroachment (crossover) on high AADT roadways, narrow lane width, unpaved shoulders, and snow removal and ice control techniques (3M and Stamark 2011).

#### *1.3.2.4 Type D – Liquid Cold Applied Methyl Methacrylate (MMA)*

Methyl methacrylate (MMA) is a two-component mixture of methyl methacrylate and a catalyst. MMA is a nonhazardous and durable pavement marking material that is applied cold to the pavement either at a continuously uniform thickness or with profiles following the bump pattern. MMA can be sprayed or extruded onto the pavement to form a strong bond with the pavement surface through exothermic reactions. In addition to being an environmentally friendly alternative to solvent-borne paints, MMA provides much longer service life (greater than three years) than standard traffic paint and is resistant to oils, antifreeze, and other common chemicals on the roadway surface. MMA is mostly used in cold weather climates, as the curing process does not require heating. However, the application of MMA requires special equipment (FHWA 2010, Lopez 2004).

### *1.3.3 Other Materials*

#### *1.3.3.1 Epoxy*

Epoxies contain two parts, a pigmented resin base and a catalyst, that are mixed in a specialized truck, and then heated before being sprayed onto the road surface. Epoxy materials provide exceptional adhesion to both HMA and PCC surfaces with acceptable abrasion resistance. Epoxies are exceptionally durable under various roadway conditions because of the chemical reaction that occurs when the two components are mixed, resulting in tight bonding to the pavement surface. On low- to mid-volume roadways, epoxies can provide service lives in excess of four years. Research also shows that epoxy paints are generally less sensitive to application factors than thermoplastic materials. One drawback associated with epoxies is that they often need over 40 minutes to dry. Newer formulations provide no-track drying times as low as 30 seconds (depending on weather conditions); however, these are more expensive than slow cure epoxies. Another drawback is their color instability under ultraviolet lighting, which results in fading. Epoxies also cannot be placed over markings made from other materials, limiting their use as a restripe material (FHWA 2010, Lopez 2004).

#### *1.3.3.2 Polyurea*

Similar to epoxies, polyurea is a sprayed, two-component pavement marking material that is durable with a service life of up to five years and excellent resistance to abrasion. Polyurea has excellent adhesion to all pavement surfaces and can also provide an exceptional color stability while achieving a proper bond and no-track conditions in 2 minutes or less. In addition, polyurea markings show less sensitivity to pavement surface moisture than thermoplastics and can be applied at temperatures as low as freezing. However, polyurea

materials must be applied by a special striping apparatus, limiting the number of contractors available to apply the material (Lopez 2004).

#### *1.3.3.3 Modified Urethane*

Another two-component, durable marking material is modified urethane, which has performance characteristics similar to those of polyurea and epoxy and can be sprayed from a standard epoxy truck. This product is marketed as slightly more durable with shorter cure times (2 minutes) and better ultraviolet color stability than epoxy. With respect to cost, it appears that modified urethane is slightly more expensive than epoxy but less expensive than polyurea. A drawback of this marking material is limited experience with its application under different traffic loads and weather conditions (Lopez 2004).

#### *1.3.3.4 Profiled Thermoplastic*

Profiled thermoplastic markings are sprayed or extruded thermoplastic markings of normal thickness constructed with an alternating elevated and recessed profile at uniform spacing (often 3 ft). The purpose of the profiled pattern is to provide nighttime retro-reflectivity under wet conditions. Although profiled thermoplastics generally perform well on all types of pavement surfaces, their cost is reported to be significantly higher (up to six times as much) than standard thermoplastic materials (Lopez 2004).

## **2 Pavement Marking Frictional Properties**

### 2.1 Literature Review

Winter safety for bicyclists may be compromised on pavement markings under wet and icy conditions. Different friction levels between pavement markings and adjacent pavement surfaces can lead to potential hazards, especially for motorcyclists and pedestrians (Griffin and Reinhardt 1995). Several studies with a focus on the skid resistance of marking materials have been conducted to provide an acceptable level of skid resistance with no adverse effect on the day/night and wet night visibility of markings. The National Research Council (1996) conducted tests on 39 combinations of different types of marking materials and the underlying pavements in both the laboratory and the field. Skid resistance numbers were measured by the British Pendulum Tester (BPT) to obtain the British Pendulum Number (BPN) values, microtexture, macrotexture, static coefficient of friction, laboratory polishing, and accelerated exposure. Results showed that wet friction can vary considerably for different marking materials. The study also found that the texture of the underlying pavement is an important factor in the friction for thinner marking materials such as paints, while the wet-friction resistance of the thicker marking materials is unaffected by the texture of the underlying pavement (National Research Council 1996).

Asdrubali et al. (2013) aimed at developing a new methodology for evaluating road marking quality in terms of operational performance (visibility and skid resistance) and maintenance (durability and costs). Skid resistance measurements on road markings were evaluated by using a BPT, which provides a measurement of the frictional properties between a rubber slider (to mimic tires) and a wet road surface (values recorded as a BPN). In their study, the skid resistance measurements were taken on crosswalks, arrows, transverse markings, text,

and symbols. The results were also correlated with the performance of a vehicle with patterned tires that braked with locked wheels on a wet road at 50 km/h. A correction was applied to measurements to take into account the influence of the asphalt temperature. The study concluded that more studies should be conducted to define how the performance of markings varies with time on urban roads in order to select the appropriate material for the AADT and presence of lighting, among other factors (Asdrubali et al. 2013).

To evaluate airport pavement marking materials, five materials (two water-borne, two epoxies, and one methacrylic resin) were evaluated for conspicuity, durability, rubber build-up, color retention, friction, environmental acceptability, and cost benefits for a period of one year. Friction measurements were recorded by using the K.J. Law Runway Friction Tester (RFT). Friction data indicated that the addition of silica and/or glass beads improved the conspicuity of the markings, improved friction, and minimized rubber adherence. The epoxy materials exhibited poor friction values if a silica friction enhancement was not included in the application. Moreover, it was determined that epoxies and resins were more durable than water-borne paints in areas subject to heavy snowfall and snowplow activity, particularly when applied to Portland cement concrete surfaces (Bagot 1995).

Thew and Dabic (1999) evaluated the skid resistance of paint marking systems and the adjacent pavement surface by utilizing the BPT. They reported that the application of waterbourne intermix glass beads produced values between 9 and 13 BPN's lower than the associated roadway surface (Thew and Dabic 1999).

In another study, Richards (1997) reported that an average skid resistance of 52 BPN on pavements can be affected negatively by solvent roadmarking paint in the un-reflectorised form. According to the results, freshly applied solvent roadmarking paints had skid resistance levels of



18 to 30 BPN, which increased to 40 BPN when the pavement was exposed from wear.

However, the application of angular materials into paint marking systems with drop-on beads enhanced the life of the marking with no virtual affect on the skid resistance (Richards 1997).

In a study by Harlow (2005), the road surface texture (either smooth or coarse textured) was shown to have a significant impact on skid resistance for thin film marking. This study suggested that the skid/slip resistance of the road marking surface could be enhanced by adding angular, anti-skid aggregates by either dropping them onto the marking system or introducing them through a premix process. However, a substantial negative effect on the retroreflective properties of the added skid resistance for the marking materials was reported (Harlow 2005).

Siyahi et al. evaluated the skid resistance and other physical properties of two component road marking paints. The skid resistance values of the specimens with several additives were determined by using the BPT. In this study, additive materials such as waste glass powder, silica granules, and Lika (i.e., expanded clay) were introduced as a solution to the poor skid resistance of conventional road marking paint. According to the BPN values, the application of waste glass powder of up to 10 percent by weight of the road marking paint could increase the skid resistance and reflectivity by 21 and 40 units, respectively. The authors also observed that the additive materials caused a reduction in the abrasion resistance of the road marking paint (Siyahi et al. 2016).

Another study focused on the formulation of paintings. It found that the road paints appeared to be in worse condition, based on texture and skid resistance, despite the presence of non-skid aggregate, implying that a marking's performance may be dependent on current pavement conditions (Pasetto and Barbati 2011).

Carnaby (2002) studied the performance of marking materials on a curved road alignment under extreme traffic conditions by using accelerated wear testing. In the study, two thermoplastic markings with angular crushed quartz with large glass beads were evaluated. One of the markings contained beads with an adhesive coating applied to them, while the other one was made of uncoated beads. After only two weeks of accelerated wear traffic, the combinations using uncoated beads were considered redundant. After nine months of measurements, skid resistance improved only because of the texture provided by the ‘craters’ remaining from heavy bead loss. Also, the crushed quartz marking had not performed as well as the large and smaller ‘True Grit’ combinations. On the basis of the reported data, the performance of the uncoated bead marking was consistently better over the period; this might have been due to the increased texture provided by the “pock marks” where the uncoated beads had been dislodged from the thermoplastic. However, the “coated” bead section also maintained acceptable skid resistance. The authors concluded that by applying pavement marking treatments such as angular surface applied particles to some binder and glass bead marking systems, high levels of skid resistance might be achievable. Because these angular particles might create shadows over the surface applied glass beads and render the line invisible during night conditions, a balance between angular and spherical surface applied particles—in size, quality, quantity, ratio, and method of application—was reported to be critical in providing considerable night delineation and a high level of skid resistance (Carnaby 2002)

## 2.2 Project Scope

On the basis of the reviewed literature, WSDOT specifications for pavements markings, WSU Facilities and Services practices, and the availability of local materials and application equipment, three different marking types commonly used for a large variety of marking purposes

were chosen for evaluation in this study. These three types were waterborne paint, preformed fused thermoplastic, and preformed cold-applied tape locally used as centerline striping. All three were applied to PCC slab surfaces to accomplish the following:

- Compare the frictional properties of the three different pavement marking types to those of a neat PCC slab surface
- Evaluate the pavement markings' frictional properties under three different surface conditions: dry, wet, and icy
- Compare one pavement marking type tested in the laboratory in dry and wet conditions for cyclists in the field.



### 3 Methodology

#### 3.1 Slab Specimen Preparation

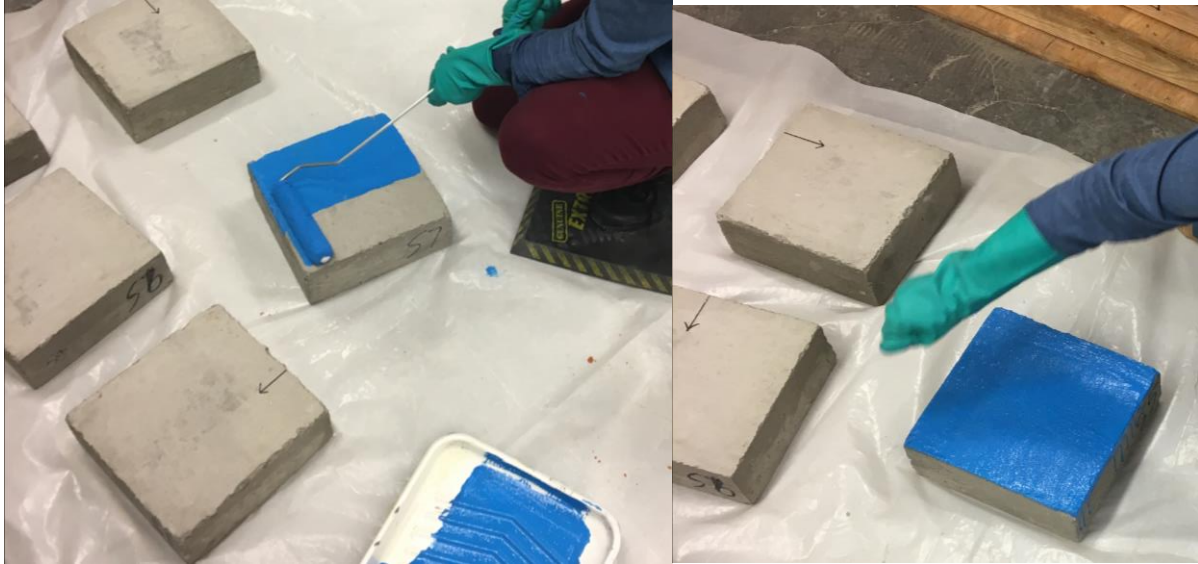
For this study, 24 concrete slabs were cast using a ready-mixed concrete purchased from Atlas Sand, Rock and Concrete in Pullman, Washington. The slabs' dimensions were 10 by 10 by 3.5 inches. The mixture design consisted of crushed and round 3/4-inch coarse aggregate (CA). In addition, Type I/II ordinary portland cement was used with Class F fly ash. The mixture design used can be seen in table 3.1

**Table 0.1:** Mixture design for slab specimens cast from ready-mix concrete.

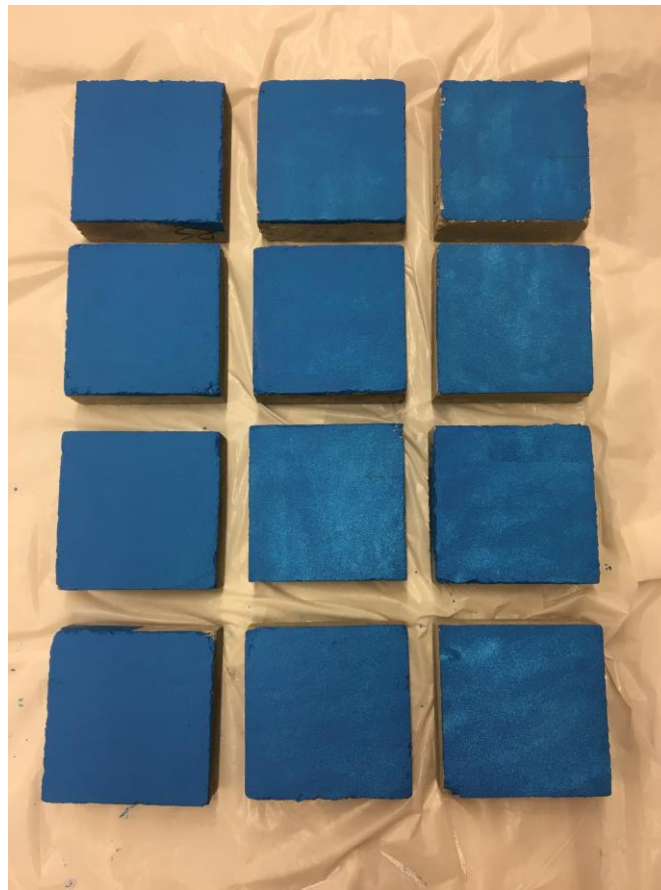
Constituent	Weight (lb/yd <sup>3</sup> )					
	3/4" Crushed CA	3/4" Round CA	Sand	Type I/II Cement	Class F Fly Ash	Water
Weight per 1 cubic yard	1,340	460	1,551	423	47	258

\*Admixture BASF MasterPozzolith 322 was used per manufacturer's recommendation.

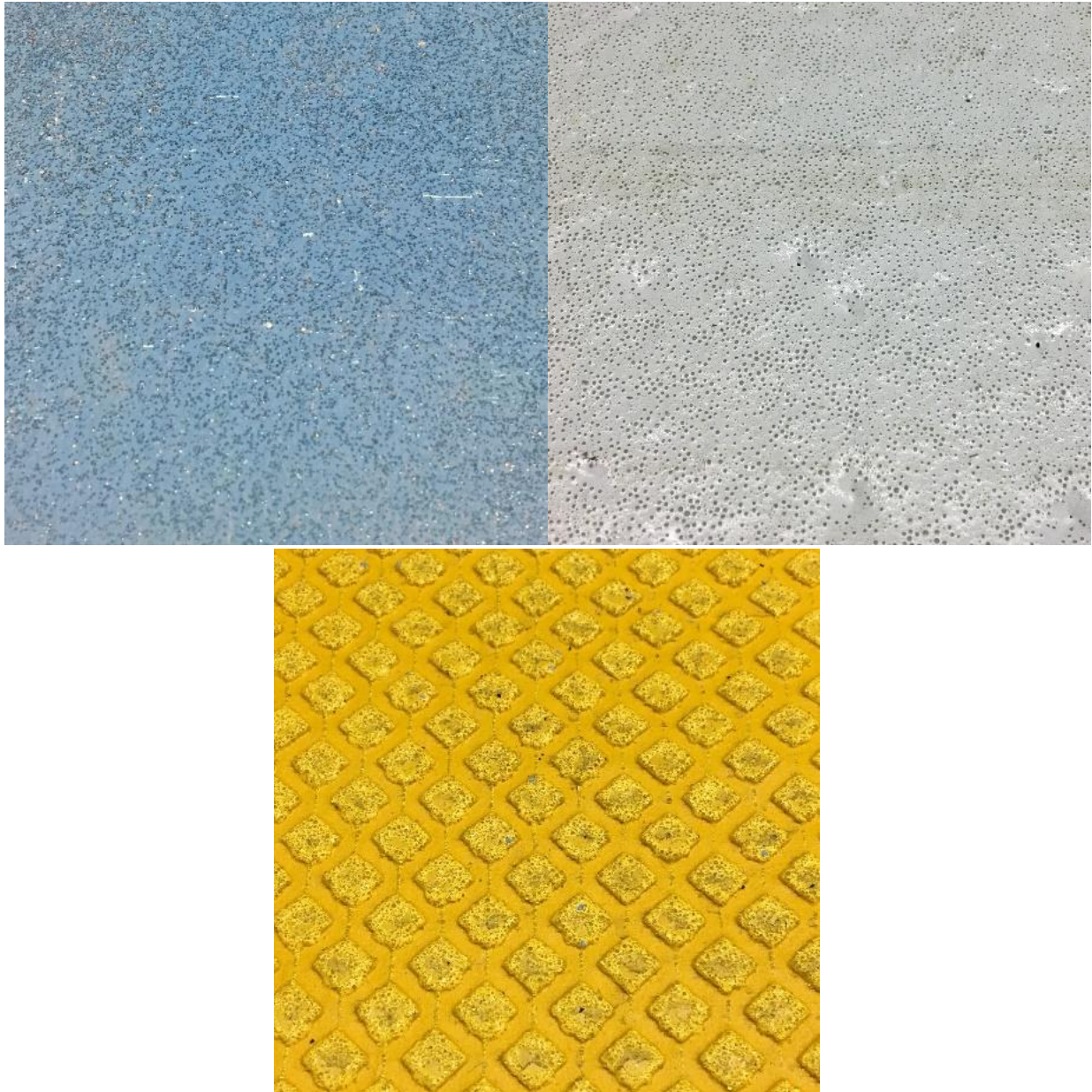
Twelve slabs were tested for frictional properties before the markings were applied. Those twelve slab surfaces were then painted with Sherwin Williams Pro Park paint and covered with Potters Highway Safety Spheres (beads). See figures 3.1 and 3.2 for pictures of the application procedure. Thermoplastic with beads was applied to the surface of six slabs, and strips of Stamark A271ES centerline striping was applied to six slab surfaces. Each of the pavement marking types can be seen in figure 3.3.



**Figure 0.1:** (left) Application of waterborne paint on slab surfaces, (right) application of glass beads on the slab surface.



**Figure 0.2:** Twelve slabs cast and painted in preparation for friction testing.

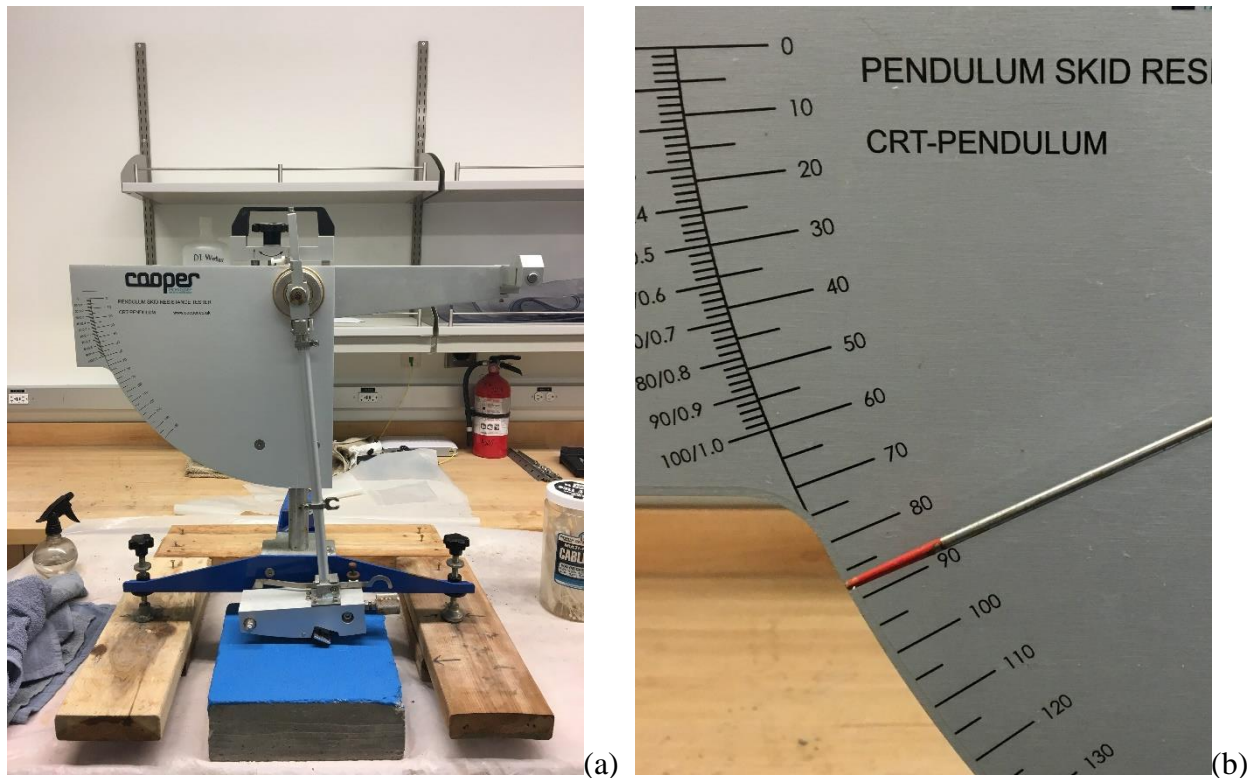


**Figure 0.3:** Slab surface markings for a) paint with beads, b) thermoplastic with beads, and c) cold-applied preformed tape.

### 3.2 Friction Evaluation Method

The frictional properties of each slab were evaluated per ASTM E303 by using a British Pendulum Tester (BPT) (figure 3.4-a). The frictional resistance values were recorded as a British Pendulum Number (BPN) (figure 3.4-b).

The BPT has a pendulum arm that swings and makes contact with the slab surface. The slab surface retards the swing and results in a BPN value for the surface friction resistance. Surfaces with better frictional properties result in higher BPN values. A rubber slider is fixed to the bottom end of the pendulum arm, which represents different tire rubber types. For this study two different sliders were used to simulate different users: a Pedestrian Slip Rubber (PSR) and a Tire Slip Rubber (TSR).



**Figure 0.1:** a) The BPT apparatus and b) a close snapshot of the BPN values on the machine.



### 3.3 Laboratory Testing

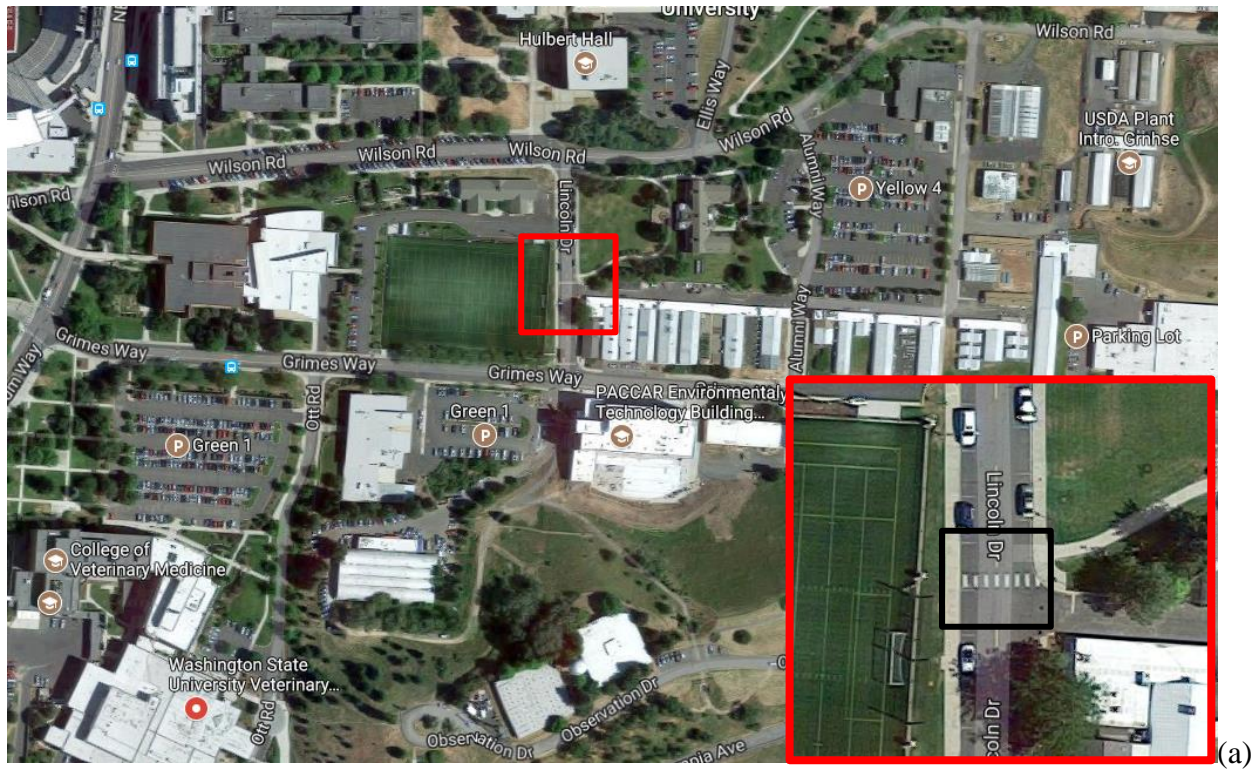
Dry, wet, and icy surface conditions were evaluated during the laboratory testing phase of this study. Dry conditions were tested after the slabs had been stored in dry laboratory conditions for 24 hours.

The slabs were then submerged in water at room temperature for 5 minutes before wet surface testing.

A walk-in environmental chamber was used for icy conditions. The slabs and a tank of water were stored in the chamber at 14°F (-10°C) for two hours. Next, the slabs were submerged in water for five minutes and were then removed from the water tank. The slabs were then left in the chamber for 30 minutes to allow for ice crystals to form on the surface; at that point the slab surfaces were tested with the BPT inside the chamber.

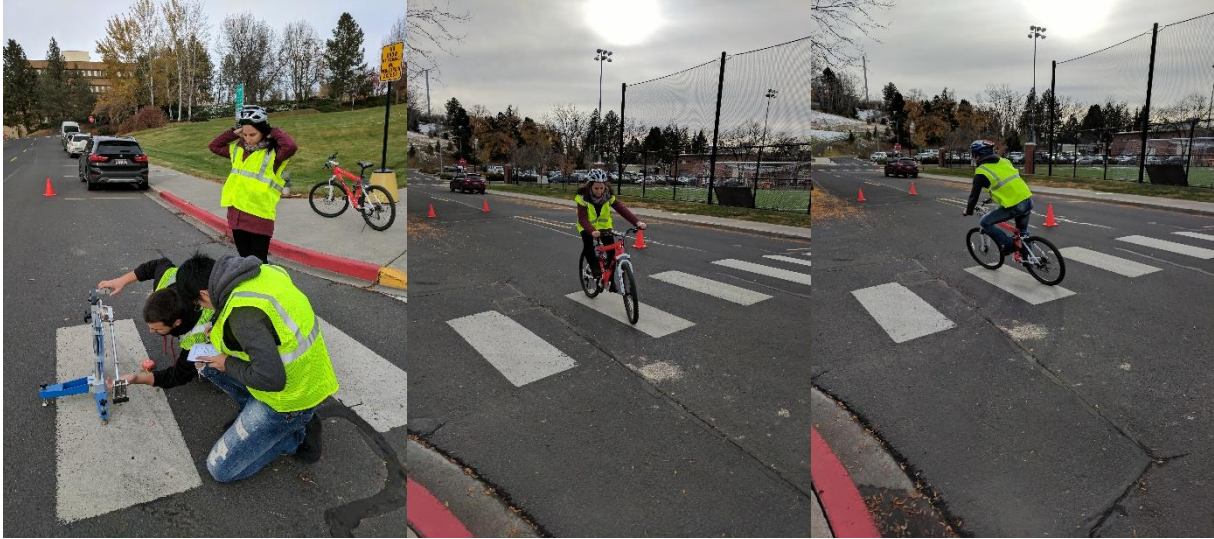
### 3.4 Field Testing

Two locations on the WSU Pullman campus were chosen for field testing under dry and wet conditions. In both cases, painted crosswalk markings without beads were evaluated. Test Site 1 was located on Lincoln Drive (figure 3.5-a) and Test Site 2 was located on Olympia Avenue (figure 3.5-b). Both locations were on flat pavement to eliminate the effects of slope on the BPN measurements. The locations were also in low traffic areas and the markings were in relatively good condition. Traffic cones were used to guide the traffic stream onto the adjacent lane. One young male cyclist and one female were chosen to perform the field evaluations.



**Figure 0.2:** a) Test Site 1 on Lincoln Drive and b) Test Site 2 on Olympia Avenue.

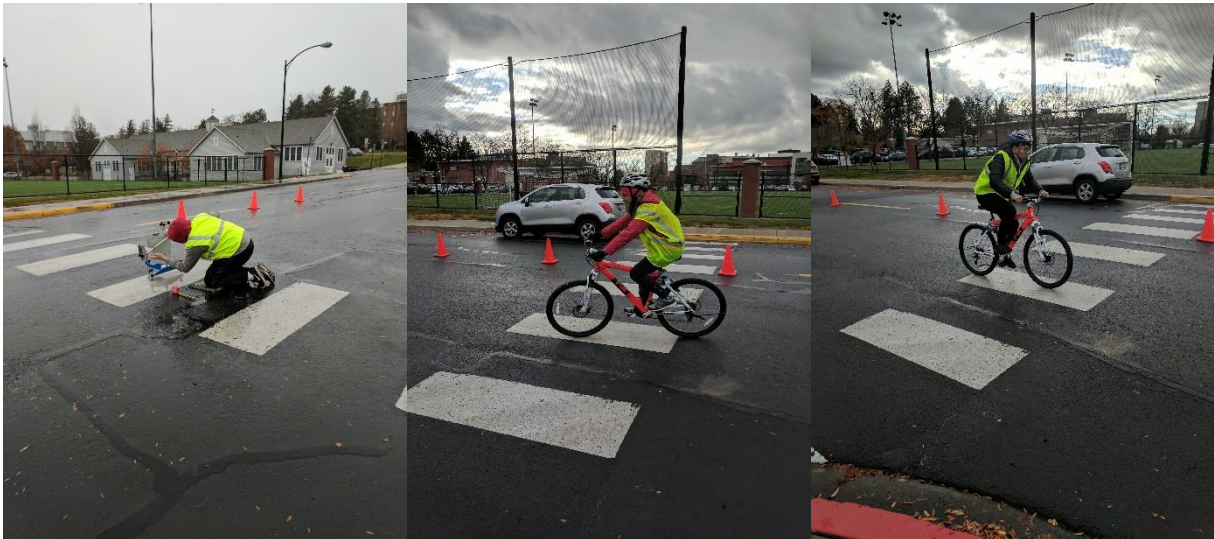
At each location, the BPN of the marking was also recorded with the TSR by bringing the BPT to the test site. The marking at each location was then tested by the cyclists. The markings were tested with the cyclists riding in a straight line with and without braking. The markings were also tested while the cyclists were turning with braking and without braking. These field evaluations were performed by each of the two riders. Rider one was a female rider who used a mountain bike only. The second rider was male and was able to conduct the tests once riding a mountain bike and on a second day riding a road bike to include the effects of tire type. The road bike tests were only performed in wet conditions. Each test was an average of three rides. Test Site 1 testing can be seen in figure 3.6, and Test Site 2 testing can be seen in figure 3.7. Testing by Rider 2 using the road bike can also be seen in figure 3.8.



(a)

(b)

(c)



(d)

(e)

(f)

**Figure 0.3:** Dry testing using the mountain bike at Test Site 1 by a) the BPT, b) rider one, and c) rider two. Wet testing at Test Site 2 by d) the BPT, e) rider one, and f) rider two.



(a)

(b)

(c)



(d)

(e)

(f)

**Figure 0.4:** Wet testing using the mountain bike at Test Site 1 by a) the BPT, b) rider one, and c) rider two. Wet testing at Test Site 2 for d) the BPT, e) rider one, and f) rider two.



(a)



(b)

**Figure 0.5:** Wet testing using the road bike by rider one at a) Test Site 1 and b) 2.

## 4 Test Results

### 4.1 Laboratory Testing

According to specifications by Asi (2005), the minimum allowable BPN values can be established for three different roadway categories. The classifications are separated by road type and can be seen in table 4.1. Categories A and B are more critical than Category C and therefore are associated with higher BPN thresholds. All three thresholds were used during the analysis of the test results in this study to provide references for the frictional performances of the three pavement markings.

**Table 0.1:** Recommended minimum BPN values in wet testing conditions (from Asi, 2005).

Category	Site Description	Minimum BPN (wet conditions)
A	Difficult sites <ul style="list-style-type: none"><li>• Roundabouts</li><li>• Bends with radius less than 150m on unrestricted roads</li><li>• Gradients, 1 in 20 or steeper, of lengths greater than 100m</li><li>• Approaches to traffic lights on unrestricted roads</li></ul>	65
B	Motorways, trunk and Class 1 roads and heavily trafficked roads in urban areas (carrying more than 200 vehicles per day)	55
C	All other sites	45

As discussed previously, three different pavement markings were evaluated in dry, wet, and icy conditions. Each marking was compared to neat PCC slabs that were used for a control during testing. For each marking, six slabs were included in the testing to account for any variability in the surface texture of the slabs/marking in the experiment. Furthermore, each of the six slabs was tested four times using the BPT to obtain reliable and repeatable measurements. The average of the four repeats was used in the study. The average of all six slabs per marking

using the PSR and TSR rubber sliders can be seen in figure 4.1-a and figure 4.1-b, respectively. The standard deviation of the six slabs is shown using error bars.

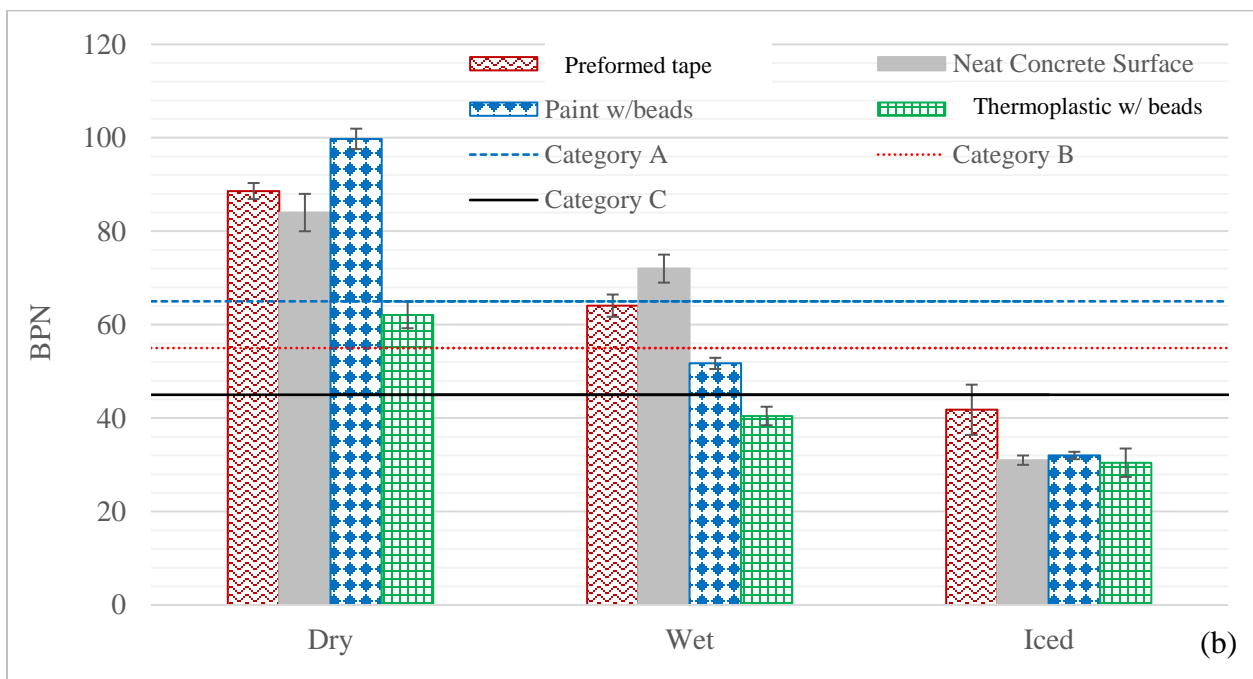
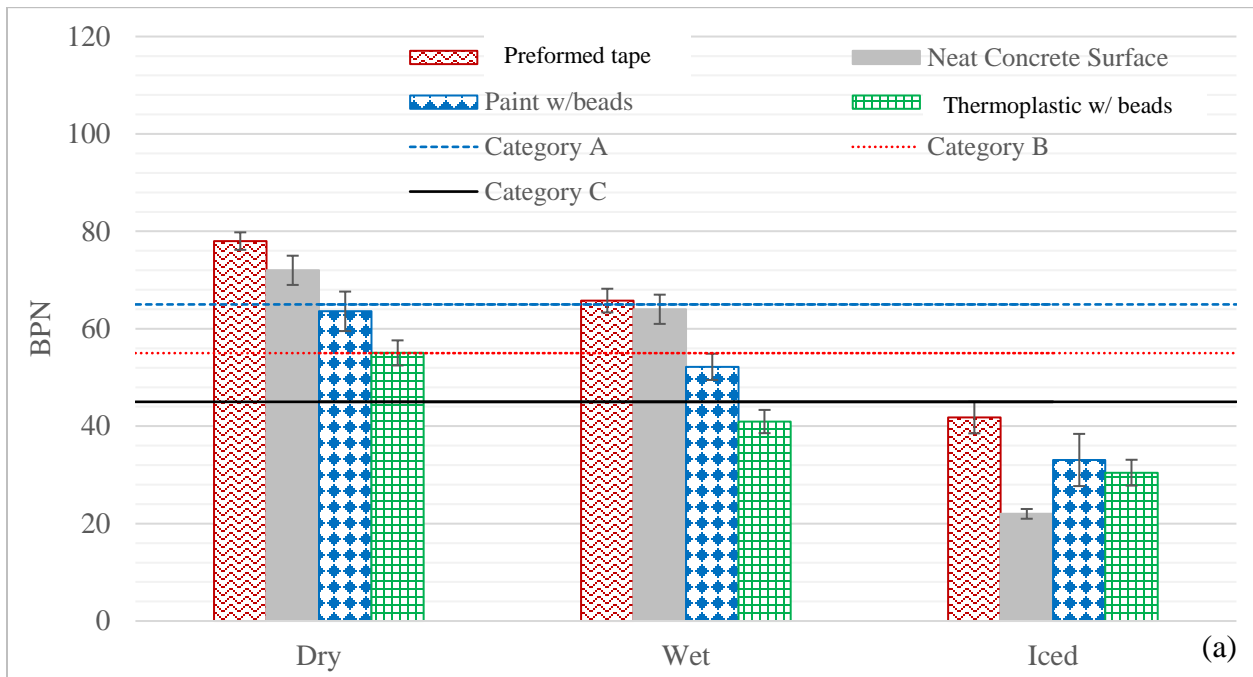
On the basis of both figures, the preformed tape showed higher BPN values than the neat PCC and the other two marking types under most conditions, which is most likely due to the contours and macrotexture of the striping surface. On the other hand, the thermoplastic with beads showed a lower BPN under all three conditions than the other two marking types. Both the paint and thermoplastic resulted in BPN values that were lower than the control for most testing conditions, demonstrating that the pavement markings reduced the frictional properties of the pavement.

For both the PSR and TSR, the thermoplastic performance in wet conditions was below the threshold for Category C in table 4.1, while the paint was just below the threshold of Category B. The preformed tape, however, resulted in values around the Category A threshold during wet testing. On the basis of these results, careful consideration is required in selecting a pavement marking type, depending on the category of the roadway section described in table 4.1, especially when thermoplastic marking materials are used. It should be noted that only one type of paint and thermoplastic materials was included in this study. More testing to include materials from a wide range of manufacturers would add more reliability to the conclusions drawn on the basis of the data in figure 4.1.

As expected, under icy conditions, all the BPN values were below the Category C threshold. The control showed lower BPN values than the paint and thermoplastic markings. These results highlight the significance of anti- and deicing treatments on pavement areas with markings. Future studies can focus on the effectiveness of various types of treatments on



different pavement marking types. These results showed that different pavement marking types may not be appropriate for use on certain roadways.



**Figure 0.1:** Laboratory testing of different pavement markings under three surface conditions using the a) PSR and b) TSR.

Using the collected data, a statistical analysis was conducted to establish the significance of the differences in BPN values for each of the marking types relative to the neat PCC surfaces (table 4.2). Paired t-tests were performed using a 95-percent confidence interval (a P-value of less than 0.05 implies a significant difference). There were many statistically significant differences between the neat PCC surfaces and the pavement markings. The test data using the TSR had more relevance to the focus of cyclists’ safety. For the TSR category, both the paint and thermoplastic markings showed significantly lower frictional properties than the neat pavement surface. These differences showed that pavement markings do have a significant effect on the frictional properties of pavements under different surface conditions. Future studies can focus on evaluating the significance of the beads and the required frequency of their application.

**Table 0.2:** Statistical analysis using a 95 percent confidence interval.

Marking Type	P-value comparing each marking type BPN values to neat concrete surfaces					
	PSR			TSR		
	Dry	Wet	Icy	Dry	Wet	Icy
Paint w/beads	0.000	0.000	0.000	0.000	0.000	0.111
ThermoPlastic	0.000	0.000	0.000	0.000	0.000	0.555
Centerline Striping	0.000	0.354	0.000	0.001	0.000	0.002

## 4.2 Field Testing

A scale was developed for bicycle riders to qualitatively rate the pavement markings. The ranking system can be seen below:

- 1 – safe → no slipping, felt comfortable
- 2 – moderately safe → felt comfortable even if minor slipping occurred
- 3 – moderately unsafe → felt like control may be lost
- 4 – unsafe → slightly lost control or slid
- 5 – extremely unsafe → lost control and/or fell

On the basis of this scale, the riders evaluated the markings under dry and wet conditions. Each marking was tested while the cyclists rode straight and turned, with braking and without braking. Each riding scenario was repeated three times by the same rider to evaluate the repeatability and consistency of the rankings. Table 4.3 and Table 4.4 show the data from the straight riding and turning events, respectively. Because each value is an average of three rides, any average above 2.0 is highlighted in red for the tests that had at least one ride in the moderately unsafe rating. Most of the highlighted tests were those that occurred during braking or turning events in wet conditions. The mountain bike had lower ratings because it had thicker ribbed tires than the road bike (figure 4.2).



**Figure 0.2:** Snapshots of (left) mountain bike tire and (right) road bike tire.

**Table 0.3:** Field evaluations on a bike, riding in a straight line over a painted pavement marking.

Surface Condition	Bicycle Type	Test Site	Rider	Straight no braking	Straight braking	BPN
Dry	Mountain Bicycle	1	1	1.3	1.0	84
			2	1.0	1.0	
		2	1	1.0	1.3	88
			2	1.0	1.0	
Wet	Mountain Bicycle	1	1	1.0	1.2	48
			2	1.0	<u>3.7</u>	
		2	1	1.0	1.2	65
			2	1.0	1.0	
Wet	Road Bicycle	1	2	1.0	<u>3.3</u>	61
Wet	Road Bicycle	2	2	1.5	1.8	70

**Table 0.4:** Field evaluations on a bike, turning over a painted pavement marking.

Surface Condition	Bicycle Type	Test Site	Rider	Turning no braking	Turning braking	BPN
Dry	Mountain Bicycle	1	1	1.0	1.0	84
			2	1.2	1.3	
		2	1	1.0	1.0	88
			2	1.5	1.7	
Wet	Mountain Bicycle	1	1	1.2	1.7	48
			2	1.2	<u>3.3</u>	
		2	1	1.2	<u>2.3</u>	65
			2	2.0	<u>2.3</u>	
Wet	Road Bicycle	1	2	<u>3.0</u>	<u>3.7</u>	61
Wet	Road Bicycle	2	2	<u>2.8</u>	<u>3.3</u>	70

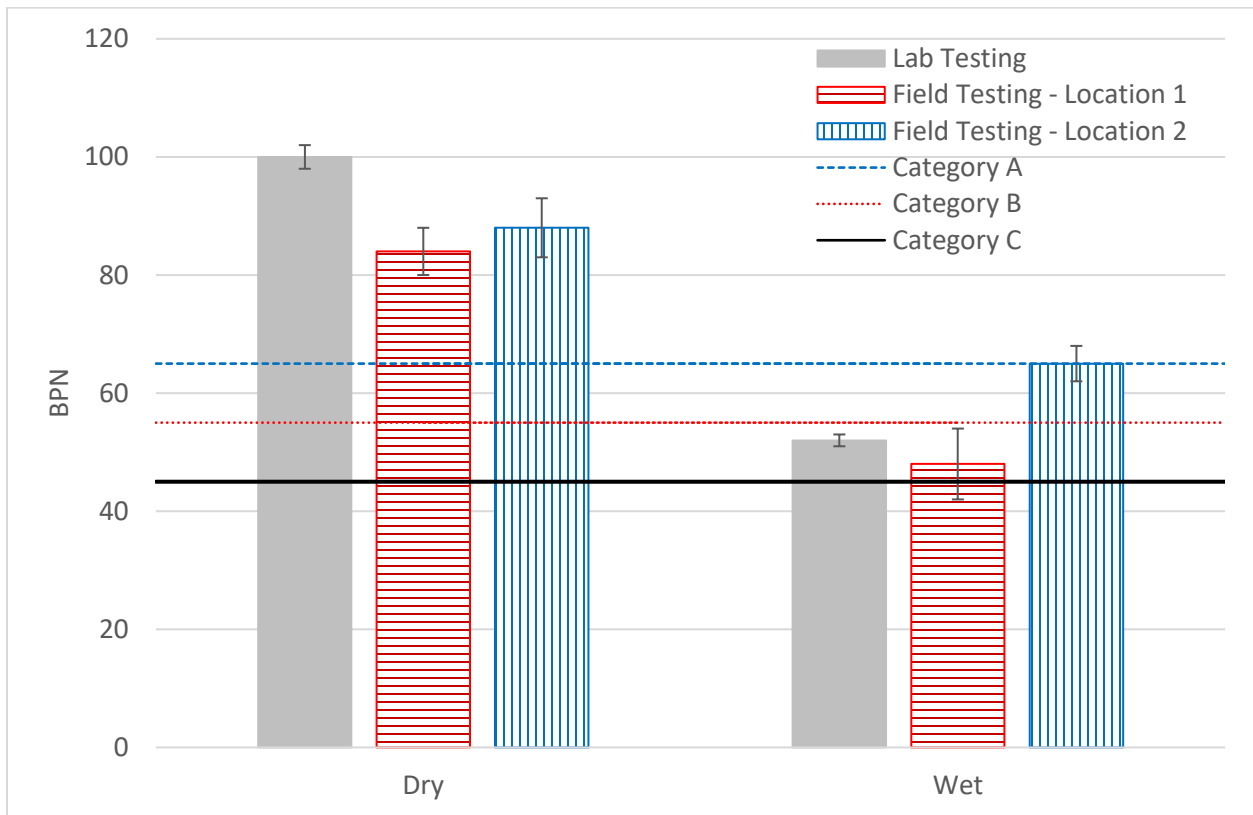
Note that even though the field BPN values were higher than some of the average BPN values obtained in the laboratory testing for paint, riders still felt unsafe on the markings in wet conditions. This is because BPT does not simulate braking or cornering events and is only an indication of the surface microtexture. However, overall, it can be concluded that the lower BPN values, especially under wet conditions, showed higher ratings on the field testing scale. As the BPN values dropped, the riders' feeling of safety also decreased.

There were more unsafe ratings during the turning event than riding straight, which is to be expected. The riders experienced more discomfort during turning as the bicycle tires were unable to remain steady on the pavement markings. In relation to crosswalk markings, bicycle

riders may frequently experience unsafe conditions while making turns from one street to the next during rain events.

#### 4.3 Comparison between Laboratory and Field BPN Values

The results were compared by using the data from the TSR testing in the laboratory and the respective field tests (figure 4.2). Under dry conditions, the laboratory tests showed higher BPN values. For wet testing conditions, Test Site 2 had higher BPN values than the laboratory testing and Test Site 1. The differences in BPN values for wet conditions may have been due to different levels of wetness, different paint film thicknesses, levels of degradation, and the amount of dust and debris in the field.



**Figure 0.2:** Comparison of laboratory and field testing on painted markings.

Statistical analysis showed significant differences between the laboratory and field tests (table 4.5). However, under wet conditions, the laboratory testing at Test Site 1 had comparable BPN values. The significant differences between the tests may have been due to the age and degradation (amount of remaining marking and beads) of the field markings in comparison to the laboratory tested markings.

**Table 0.5:** Statistical comparison of laboratory testing and field testing.

Field Location	P-value comparing BPN from laboratory testing to those obtained in the field for paint	
	Dry	Wet
Test Site 1	0.004	0.328
Test Site 2	0.015	0.004





## 5. Conclusions and Recommendations

### 5.1 Conclusions

In this study, three different pavement marking types were compared to neat portland cement concrete (PCC) slab surfaces to evaluate their frictional properties. On the basis of local practice and the availability of materials and application equipment, paint with beads, thermoplastic with beads, and cold-applied preformed tape were evaluated under dry, wet, and icy conditions.

The frictional properties were evaluated by using a British Pendulum Tester (BPT), and the values were recorded as a British Pendulum Number (BPN). Two different rubber sliders were used, pedestrian slippage rubber (PSR) and tire slippage rubber (TSR). Field tests were also performed by two bicycle riders to evaluate different riders' perceived level of safety while riding on the markings under different conditions. From this study the following conclusions can be drawn:

- BPT does not simulate cornering or braking events for motorcyclists and bikers. However, BPT is an informative tool to establish the baseline frictional properties of different pavement markings in comparison to a neat HMA or PCC pavement surface. Tests are recommended to be performed in both dry and wet conditions.
- The laboratory procedure followed in this study to evaluate the frictional properties of different pavement markings in dry, wet, and icy conditions are recommended at a minimum to establish baseline BPN values for different pavement marking products.
- Out of the three marking products tested with the BPT, only cold-applied preformed tape could be used in all roadway categories, including Category A, which includes approaches to traffic lights. Conversely, thermoplastic with beads did not satisfy the

minimum BPN threshold for Category A and B roadways in wet conditions. Paint with beads was found to be suitable for these categories in wet conditions.

- These results, even though limited, highlight the need for further tests of more products from a wide range of vendors, different material types, beads amount/type, film thickness, temperature, and other influential factors.
- Field testing showed that as the BPN decreased, the reported safety level for riders decreased. Both turning and wet conditions made riders uneasy while evaluating the pavement markings on a bicycle.

## 5.2 Recommendations for Future Research

Future testing is recommended to focus on the following areas:

- Identify key factors that influence the BPN of various pavement marking, such as temperature, film thickness etc., to develop a standardized friction testing procedure for pavement markings.
- Develop baseline required BPN values for different roadway classifications in wet conditions to be included in marking specifications.
- Use trailer type friction testers to establish baseline frictional properties for braking and cornering events under wet pavement conditions.


## 6. References

- 3M and Stamark, 2013. "3M™ Stamark™ Pavement Marking Tape Series 380." MN, US.
- 3M and Stamark, 2011. "Stamark™ Pavement Marking Tape Series 270 ES." Product Bulletin 270 ES, St. Paul, MN.
- Asdrubali, F., Buratti, C., Moretti, E., D'Alessandro, F., and Schiavoni, S. 2013. "Assessment of the Performance of Road Markings in Urban Areas: The Outcomes of the Civitas Renaissance Project." *The Open Transportation Journal*, 7: 7-19.
- Asi, I. M. 2005. "Evaluating skid resistance of different asphalt concrete mixes." *Building and Environment*, 42: 325-329.
- ASTM E303. 2013. "Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester." ASTM E303-2013, West Conshohocken, PA.
- Bagot, K. W. 1995. "Evaluation of Alternative Pavement Marking Materials." FAA Technical Center Atlantic City International Airport, DOT/FAA/CT-94/119.
- bostonbiker.com
- Carnaby, B. 2002. "The relationship between retroreflectivity, skid resistance and luminance." RIAA/NZRF Conference.
- Federal Highway Administration, 2010. "Manual on Uniform Traffic Control Devices: Part 3-Markings." Federal Highway Administration, Washington, DC, ISBN 9781560514732.
- Griffin, L., Reinhardt, R. N. 1995. "A Review of Two Innovative Pavement Marking Patterns that Have Been Developed to Reduce Traffic Speeds and Crashes." Prepared for the AAA Foundation for Traffic Safety Texas Transportation Institute.
- Harlow, A. 2005. "Skid Resistance and Pavement Marking Materials." International Surface Friction Conference: roads and runways: improving safety through assessment and design, The NZ Roadmarkers Federation Inc.
- Jun-Taek, L., Maleck, T., and Taylor, W. 1999. "Pavement Marking Material Evaluation Study in Michigan." *ITE Journal*, Vol. 69, No. 7.
- Lopez, C. A. 2004. "Pavement Marking Handbook- Manual Notice 2004-1." Texas Department of Transportation.
- Montebello, D. & Schroeder, J. 2000. "Cost of Pavement Marking Materials." Final Report, Minnesota Local Road Research Board, Minnesota.
- National Research Council. 1996. "Wet-Pavement Friction of Pavement-Marking Materials." Transportation research record: TRR. Washington, DC.

- Pasetto, M., Barbati, S., D. 2011. "Definition and Validation of a New Methodological Approach for Friction Evaluations of Dropped-On Products for Road Markings." 3<sup>rd</sup> International Surface Friction Conference, Safer Road Surfaces, Australia.
- Pisano, P. A., Goodwin, L. C., Michael A. Rossetti, M. A. 2008. "U.S. HIGHWAY CRASHES IN ADVERSE ROAD WEATHER CONDITIONS." 88th American Meteorological Society Annual Meeting; FHWA, Noblis and RITA.
- Richards, D. 1997. "Improving the Skid Resistance of Pavement Markings." NZRF/RIAA Conference.
- Romero, P. & Brown, C. A. 2010. "Failure of Surface Courses Beneath Pavement Markings." Utah Department of Transportation.
- Siyahi, A., Kavussi, A., Boroujerdian, A. M. 2016. "Enhancing Skid Resistance of Two-Component Road Marking Paint using Mineral and Recycled Materials." *International Journal of Transportation Engineering*, 3 (3).
- Thew, C. and Dabic, T. 1999. "Alkyd, chlorinated rubber, waterbourne road-marking paints." NZRF/RIAA Conference.
- WSDOT 2013. "The Corridor Capacity Summary." The 12<sup>th</sup> Edition of the Congestion Report. Washington State Department of Transportation, Olympia, WA.
- WSDOT. 2016. "Standard Specifications for Road, Bridge, and Municipal Construction." M 41-10. Washington State Department of Transportation, Olympia, WA.



## Appendices



# PRO

## INDUSTRIAL™

# 113.80

**PRO-PARK™**  
WATERBORNE  
TRAFFIC MARKING PAINT  
B97 SERIES

As of 05/12/2016, Complies with:			
OTC	Yes	LEED® v9 NC CI	N/A
SCAQMD	Yes	LEED® v9 CS	N/A
CARB	Yes	LEED® v9 H	N/A
CARB SCM 2007	Yes	LEED® v4 Emitters	N/A
MPI	Yes	LEED® v4 VOC	Yes

### CHARACTERISTICS

**PRO-PARK TRAFFIC MARKING PAINT** is a premium quality waterborne acrylic alkyd traffic marking paint. It has excellent chemical and dirt pickup resistance. Pro-Park delivers the performance expected by the most discerning contractor, property manager or national retail chain.

- Apartments Communities
- Shopping Centers
- Schools and Universities
- Municipalities
- Property Managers
- Asphalt Seal Contractors
- Pavement Strippers

The coating may be made into reflective paint by dropping on glass beads while the paint is still wet.

Can be used with stencils (Available through Sherwin-Williams) for street and parking lot marking:

- Directional Arrows
- STOP
- YIELD
- Numbers
- Pedestrian Crossing
- Handicap Markings

White	B97WD2434
Yellow	B97YD2467
Firelane Red	B97RD2012
Blue	B97LD2022
Black	B97BD2021

### SPECIFICATIONS

**Finish:** Flat  
**Colors:** White, Yellow, Blue, Red, Black  
**Volume Solids:** 62 ± 2% (White)  
**Weight Solids:** 77 ± 2% (White)  
**Weight per Gallon:** 13.89 lb  
**VOC:** <50 g/L; <0.42 lb/gal  
As per 40 CFR 59.406 and 60R/2009-264, s.12

**Recommended Spreading Rate per coat:**  
 Approximately 330 lineal feet of standard 4" stripe per gallon  
**Wet mils (microns)** 15.0 / 375  
**Dry mils (microns)** 9.3 / 232  
**Coverage sq ft/gal (m<sup>2</sup>/L)** 108 / 2.7

**Drying Schedule @ 15.0 mils / 375 microns wet, @ 77°F / 25°C, @ 50% RH:**  
**Dry-no-pickup:** 30 minutes  
**Dry to recoat:** 60 minutes  
**Open to heavy traffic:** 120 minutes  
**Drying time is temperature, humidity, and film thickness dependent.**

**Shelf Life:** 12 months, unopened  
**Store indoors at 40°F / 4.5°C to 100°F / 38°C**  
**Flash Point:** 150°F / 65°C, FMCC  
**Reducer:** Water

Spreading rates are calculated on volume solids and do not include an application loss factor due to surface profile, roughness or porosity of the surface, method of application, surface irregularities, over-thinning, climatic conditions, and excessive film build.

**Cured Asphalt, Concrete, and Brick:**  
 1 ct. Pro-Park Traffic Marking Paint  
 @ 330 lineal feet of standard 4" stripe per gallon

<b>Abrasion Resistance (falling sand)</b>	<b>Dry Opacity (Contrast Ratio)</b>
Method: ASTM D968	Method: Fed. Met. 141C at 5 mils (125 microns) wet
Result: 150 liters	Result: 0.95 (white)
<b>Bleed Resistance</b>	<b>Flexibility</b>
Method: ASTM D969	Method: ASTM D522, 1/2" mandrel
Result: >0.95 over seal coat	Result: Pass
<b>Color (yellow)</b>	<b>Reflectance (white)</b>
Method: Fed. Std. 595 #33538	Method: ASTM-E97
Result: Pass	Result: 85% minimum
<b>Dry-No-Pickup</b>	<b>Scrub Resistance</b>
Method: ASTM D711	Method: ASTM D2486
Result: <30 minutes @ 77°F/25°C	Result: 500 cycles minimum

**PRO-PARK™**  
**WATERBORNE TRAFFIC MARKING PAINT**



<u>SURFACE PREPARATION</u>	<u>APPLICATION</u>
<p><b>WARNING!</b> Removal of old paint by sanding, scraping or other means may generate dust or fumes that contain lead. Exposure to lead dust or fumes may cause brain damage or other adverse health effects, especially in children or pregnant women. Controlling exposure to lead or other hazardous substances requires the use of proper protective equipment, such as a properly fitted respirator (NIOSH approved) and proper containment and cleanup. For more information, call the National Lead Information Center at 1-800-424-LEAD (in US) or contact your local health authority.</p> <p>Surface must be clean, dry, and in sound condition. Remove all oil, dust, grease, dirt, loose rust, and other foreign material to ensure adequate adhesion. Surfaces should be clean and dry and free from loose or peeling paint. Do not apply when air or surface temperatures are below 40°F (4.5°C), or when the relative humidity exceeds 85%, or when the temperature falls below the dew point.</p> <p>The presence of concrete sealers or efflorescence on new concrete may interfere with adhesion and should be removed by extended weathering, etching, or abrasive blasting.</p> <p>Most previously painted lines may be repainted without additional surface preparation, provided the old paint is still tightly adhered to the surface. However, multiple layers of paint will eventually peel and require removal. Recognize that any surface preparation short of total removal of the old coating may compromise the service length of the system.</p> <p>New asphalt surfaces should ideally be allowed to age several months before striping. Exceeding the recommended film thickness will increase the tendency to cause asphalt lifting. Placing an inconspicuous test stripe to determine if a new asphalt surface has cured sufficiently to paint is recommended.</p> <p>If it is necessary to paint new asphalt surfaces, do not exceed an application rate of 8 mils (200 microns) wet (approximately 200 sq ft/gal / 4.9 ml/L). Special care should be given to laps and edges of stencils to prevent excessive film thickness.</p> <p>Asphalt surfaces generally require aging prior to painting. If the asphalt is insufficiently cured, applying a thin coat (approximately 1/2 the recommended df) generally reduces the extent of lifting and cracking.</p>	<p><b>Temperature:</b>                      minimum 40°F / 4.5°C                      maximum 110°F / 43°C                      air, surface, and material                      At least 5°F above dew point</p> <p><b>Relative humidity:</b> 85% maximum</p> <p>The following is a guide. Changes in pressures and tip sizes may be needed for proper spray characteristics. Always purge spray equipment before use with listed reducer. Any reduction must be compatible with the existing environmental and application conditions.</p> <p><b>Reducer</b> Water                      As needed up to 25% by volume</p> <p><b>Airless Spray Line Striper</b>                      Pressure.....1800-2700 psi                      Hose ..... 1/4" - 3/8" ID                      Tip......015" - .017"                      Filter......60 mesh</p> <p><b>Conventional Spray Line Striper</b>                      Gun ..... Binks 21 (Bleeder)                      Fluid Nozzle.....#68                      Air Nozzle..... Internal mix, #709                      Atomization Pressure.....45-80 psi                      Fluid Pressure.....40-70 psi</p> <p>NOTE: Fluid and atomization pressures are dependent on environmental conditions. Use the lowest pressures necessary to achieve a "flat line".</p> <p><b>Brush</b> Natural bristle  <b>Roller Cover</b> 3/8" woven                      with solvent resistant core</p> <p>If specific application equipment is listed above, equivalent equipment may be substituted.</p>
<b>APPLICATION PROCEDURES</b>	<b>CLEANUP INFORMATION</b>
<p>Apply paint at the recommended film thickness and spreading rate as indicated on front page. Application of coating below minimum recommended spreading rate will adversely affect coating performance.</p>	<p>Clean spills, spatters, hands and tools immediately after use with soap and warm water. After cleaning, flush spray equipment with compliant cleanup solvent to prevent rusting of the equipment. Follow manufacturer's safety recommendations when using solvents.</p>
<b>SAFETY PRECAUTIONS</b>	
<p>Refer to the Safety Data Sheets (SDSs) before use. <b>FOR PROFESSIONAL USE ONLY.</b> Published technical data and instructions are subject to change without notice. Contact your Sherwin-Williams representative for additional technical data and instructions.</p> <p>Painted surfaces can become slippery when wet. Zone Marking paints are not intended for use as floor paints, and should not be used to paint large areas subject to pedestrian traffic. For instance, painting an entire traffic stall is not recommended.</p> <p><b>Slip Resistance</b>-Some surfaces may require a slip resistant additive for safety. Add H&amp;C SharkGrip® Slip Resistant Additive to the final coat applied following label directions. Sand may also be broadcast onto the wet paint or incorporated in the final coat. These additives should not be used in place of a non-skid finish.</p>	
<b>PERFORMANCE TIPS</b>	
<p>No painting should be done immediately after a rain or during foggy weather.                      Do not paint on wet surfaces.                      Check adhesion by applying a test strip to determine the readiness for painting.</p>	
<p>The information and recommendations set forth in this Product Data Sheet are based upon tests conducted by or on behalf of The Sherwin-Williams Company. Such information and recommendations set forth herein are subject to change and pertain to the product offered at the time of publication. Consult your Sherwin-Williams representative or visit <a href="http://www.paintdocs.com">www.paintdocs.com</a> to obtain the most current version of the PDS and/or an SDS.</p>	

# Pavement Marking Field Evaluation Form

Name: \_\_\_\_\_

Date/Time: \_\_\_\_\_

Location: \_\_\_\_\_

Mark Type: \_\_\_\_\_

Rating:

- |                      |  |
|----------------------|--|
| 1- safe              | no slipping whatsoever, felt comfortable             |
| 2- moderately safe   | felt comfortable in situation even if minor slipping |
| 3- moderately unsafe | felt like you may possibly lose control              |
| 4- unsafe            | slightly lost control or slid                        |
| 5- extremely unsafe  | lost control and/or fell                             |

BPN Values:
#1:
#2:
#3:
#4:
Avg:

Condition:	dry, no brake	dry, brake	dry turn, no brake	dry turn, brake	Ride #
Rating:					1
Notes:					
Rating:					2
Notes:					
Rating:					3
Notes:					



