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STUDY TO DEVELOP GUIDELINES FOR PAVEMENT MARKING APPLICATIONS COMPLETED

The lack of systematic and standardized methodology to quantitatively evaluate pavement marking materials used on South Carolina's primary and secondary roads has made it difficult for the South Carolina Department of Transportation (SCDOT) to track the performance and lifecycle of pavement markings from installation to eventual restriping applications. Thus, an efficient and economical method for determining a regular replacement schedule based on the retroreflectivity values is not readily available. Another desirable capability would be a method for determining the maximum service life for different types of markings. The shortcomings that currently exist in the evaluation of pavement markings as well as the impending federal minimum retroreflectivity requirements for pavement markings makes it apparent that statewide pavement marking application guidelines are needed.

Clemson University recently completed research project SPR 669, "Guidelines for Pavement Marking Applications." Dr. Wayne Sarasua served as the Principal Investigator for the project and Mr. Jim Feda, SCDOT Director of Maintenance, chaired the Steering and Implementation Committee. The entire Steering and Implementation Committee included:

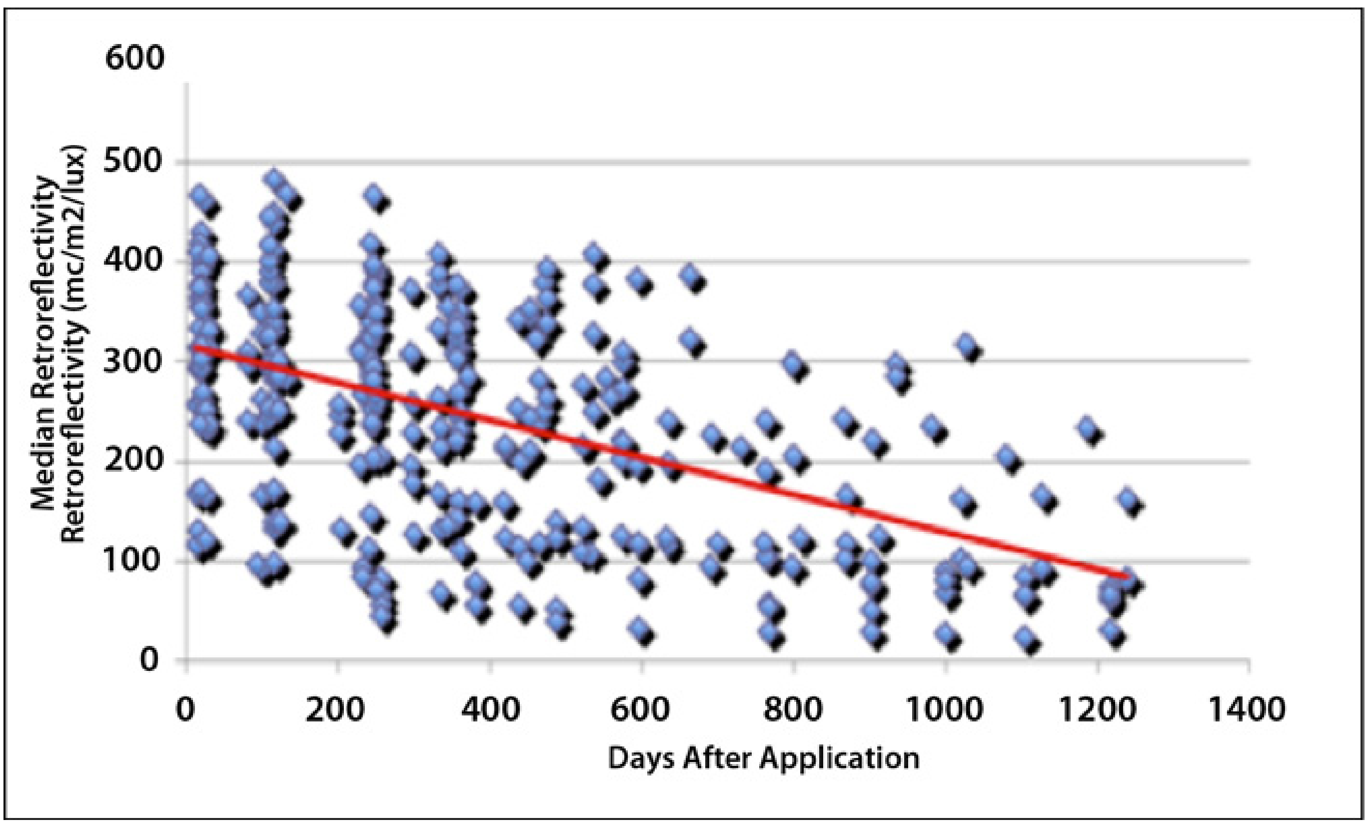
- **Mr. Jim Feda**, *Director of Maintenance (Chairman)*
- **Mr. Robert Dickinson**, *District Maintenance Engineer, District 1*
- **Mr. Nick Boozer**, *State Traffic Operations Engineer*
- **Mr. Efrem Dantzler**, *District Maintenance Engineer, District 7*
- **Mr. Terry Rawls**, *Traffic Services Manager*
- **Mr. Scott Bowles**, *Operations Engineer, FHWA*

Objectives of this research focused on determination of evidence-based guidelines and recommendations to support pavement marking best practices for consistent implementation across the state. Through the use of a data-driven research methodology and measured retroreflectivity values systematically collected at selected representative control sites, lifecycle models and degradation models were determined for waterborne, high-build and thermoplastic pavement marking applications for the State's primary and secondary road network. A comparison of marking lifecycles was performed and recommendations regarding material selection for typical applications were developed.

Key Findings

Pavement marking data showed a great deal of variability in initial readings as illustrated in the figure below. The models developed in this research require initial readings to be taken in order to predict a marking's lifespan. High-build markings were found to perform comparable to thermoplastic markings on roads with volumes less than 2000 ADT. High-build installations are roughly half the cost of thermoplastic making them a cost effective alternative. Conventional waterborne markings had the fastest deterioration rates. Pavement marking performance varied considerably for different brands. Yellow markings tend to have lower initial values and higher degradation rates than white markings.

Waterborne White Edge Line Marking Performance



Estimate of Pavement Marking Service Life

Pavement marking degradation models for high-build, waterborne, and thermoplastic markings developed to predict retroreflectivity and determine service life estimates, are summarized as follows:

Retroreflectivity Degradation Models

Material	Model	Avg. Initial Value	Estimated Marking Lives	
White Edge HB	DIFF = -57.8900 (C)	390	5.01 C (13.6 years @1000 ADT)	
	% DIFF = -15.6744 (C)		4.74 C (13 years @ 1000 ADT)	
White Edge WB	DIFF = -0.1317(D)	315	1632 Days	4.47 Years
	% DIFF = -0.0537(D)		1271 Days	3.48 Years
White Edge T	DIFF = 54.142 – 0.0403 (D)	426	6745 Days	18 Years
	% DIFF = 13.699 – 0.0079 (D)		9279 Days	25 Years
Yellow Solid WB	DIFF = -0.0721 (D)	141	569 Days	1.56 Years
	% DIFF = -0.0569 (D)		511 Days	1.40 Years
Yellow Skip WB	DIFF = -0.0594 (D)	150	879 Days	2.41 Years
	% DIFF = -0.0366 (D)		911 Days	2.50 Years
Yellow Solid T	DIFF = -0.0764 (D)	260	2094 Days	5.74 Years
	% DIFF = -0.0270 (D)		2279 Days	6.24 Years
Yellow Skip T	DIFF = -0.1123(D)	290	1691 Days	4.64 Years
	% DIFF = -0.0364(D)		1800 Days	4.93 Years
Legend HB high-build, T thermoplastic, WB waterborne, DIFF change from initial value, % DIFF percent change from initial value, C cumulative traffic passages in million vehicles, D days since initial reading,				

Selection of Pavement Marking Material

A variety of factors should be considered when selecting and specifying waterborne, high-build, or thermoplastic pavement marking materials. Primary factors for consideration in selecting optimal pavement marking materials include traffic volumes, roadway functional class, roadway surface type, expected remaining service life of pavement, and whether marking materials will be provided by in-house crews or by external pavement marking contractors. Based on models developed from the field-collected data, recommended criteria for selection of white edge pavement markings are summarized in the table below. For yellow markings, the average life span is roughly half of the white edge markings, dependent on the initial retroreflectivity of the markings.

Criteria for Selection of White Edge Pavement Markings

Traffic Volume (veh/day)	Recommended Marking	Avg. Estimated Lifespan (Years)	Cost/LF/year ($)
< 1000	Waterborne	3.5 - 4.5	0.026 - 0.020
500 – 2000 +	High-Build	5 +	< 0.036
> 2000	Thermoplastic	5 +	< 0.060

THE UNIVERSITY OF SOUTH CAROLINA RESEARCH LOOKS AT THE BEHAVIOR OF PILE-CAP CONNECTIONS SUBJECTED TO SEISMIC FORCES

South Carolina contains the highest level of seismicity along the east coast of the United States. Due to the potential of a large seismic event within the state of South Carolina, the development of connections that provide sufficient moment capacity and adequate ductility is necessary. Because the state of South Carolina relies heavily on its transportation system, maintaining the operational status of bridges following a large seismic event is critical. Currently the South Carolina Department of Transportation employs a detail of a plain pile embedment for the connection between precast prestressed piles and cast-in-place bent caps. This connection has proved beneficial in terms of time and cost associated with construction, and has been previously investigated albeit in a limited capacity. Research examining the behavior of the pile to pile-cap connections subjected to seismic induced forces was of immediate importance to SCDOT as the performance of the current design practice for such details under seismic conditions is largely unknown.

The University of South Carolina recently completed research project SPR 672, "Behavior of Pile-Cap Connections Subjected to Seismic Forces." The Citadel, The University of Nevada Reno, and LPA Group collaborated on the project. Dr. Paul Ziehl served as Principal Investigator for the project and Lucero Mesa, SCDOT Seismic Design Support Engineer, chaired the project's Steering and Implementation Committee. Other members of the Committee from the Department included Barry Bowers, Merrill Zwanka, HongFen Li, Charlie Matthews, and Bill Mattison. Ken Johnson represented the FHWA and Ted Geddis of HRI, Inc. also served on the Committee.

The research began with a focus on the evaluation and understanding of the current connection detail employed within South Carolina. This detail consists of plain pile embedded to a depth of a single pile diameter with a tolerance of + six inches. A review of available literature, discussions with members of local industry, and a parametric study of South Carolina bridges were conducted prior to initiating the laboratory investigations. Nine full-scale specimens were fabricated and tested. Eight of these specimens were created with a single pile and a representative portion of a typical cast-in-place bent cap. The eight single pile specimens, four exterior and four interior, were tested at the University of South Carolina. Based on the findings for the first eight specimens a three-pile specimen was designed, fabricated, and tested. The assembly and testing of the three-pile specimen was conducted at the University of Nevada-Reno. These specimens were evaluated according to their behavior with emphasis on moment and displacement capacity, ductility, development of a plastic hinge mechanism, and a cap performance. In addition to the physical specimens tested, finite element models were created and used to simulate the effects of varying pile sizes and embedment depths that could not be tested in the laboratory due to the constraints of the project.

Three-Pile Specimen Testing

Findings indicate that when constructed with an appropriate embedment length, the connections at the interior portions of the bent cap are able to achieve desirable response. Connections at exterior portions of the bent caps are also shown to respond desirably given sufficient pile embedment depth along with appropriate detailing of the bent cap. The following table details the difference between the current embedment depth and the recommended embedment depth. The table shows embedment depths of 18, 20, and 24 inch piles at the minimum and maximum depths based on current and proposed construction tolerances. It is further recommended that the cap depths be based on the current South Carolina Bridge Design Manual section 20.2.7.1. As such, a minimum cap depth of 30 inches should be used for 18 inch piles. The embedment depth of larger piles dictates the minimum depth needed.

Current versus Proposed Embedment Depths

18 inch pile		
	1.0*D	1.3*D
Maximum	24	26.4
Minimum	12	20.4
20 inch pile		
	1.0*D	1.3*D
Maximum	26	29
Minimum	14	23
24 inch pile		
	1.0*D	1.3*D
Maximum	30	34.2
Minimum	18	28.2

SCDOT CURRENT AND COMPLETED PROJECTS

For a complete list of current and/or completed research projects, please visit the Materials and Research web site located at **www.clemson.edu/t3s/scdot**. The current research projects page lists the project name, principal investigator, and the objective of the project. The completed research project page shows summaries of completed research projects and a number of them have pdf copies of final reports attached. The Research Problem Statement Form is also located on the website for your convenience.