Literature Search 620: Pavement Marking/Colored Pavement Friction Differential and Product Durability

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Search Terms: Pavement friction differential, differential friction, differential pavement friction, pavement friction, pavement markings, colored pavement, pedestrian, cyclist, disabled

Resources searched: TRID, Transport, Internet, Google Scholar, ASCE database, pooledfund.org

Summary: I interpreted the product durability of this statement to relate to whatever I could find on pavement markings and/or colored pavement and its friction differential to the pavement it was applied to or within. I did not search on product durability of pavement markings and/or colored pavement. I was able to find very little published or current research related to this topic; I did include a few sources that are outside of your requested date range because they seemed important for you to know about. I also reviewed various Pedestrian and Bicycle streetscape guides, design guidelines, toolboxes, etc. and was able to find no instances where this research topic was mentioned or implemented. I used all of the search terms listed above in various permutations. A broader aspect of this topic seems to have been popular in the early 2000s and prior.

Most Relevant Results
Title: Cycling on the edge: the effects of edge lines, slanted kerbstones, shoulder, and edge strips on cycling behaviour of cyclists older than 50 years
Author: Westerhuis, Frank, Fuermaier, Anselm B M, Brookhuis, Karel A, de Waard, Dick
Publisher: Ergonomics, Volume: 63, Issue Number: 6, pp 769-786. 2020. ISSN: 0014-0139

Abstract: To prevent single-bicycle crashes, this study is the first to evaluate effects of slanted kerbstones, edge lines, shoulder strips, and edge strips on cycling behaviour of cyclists ≥50 years. In Experiment 1, 32 participants cycled on a control path and paths with edge lines, slanted kerbstones, and three types of 0.5 m wide shoulder strips (with grey artificial grass, green artificial grass, or concrete street-print). In Experiment 2, 30 participants cycled a different route including a control path and paths with edge lines or 0.3 m white edge strips. Cyclists rode closer to the main cycle path’s edge in the shoulder strips conditions, although the presence of these strips resulted in a larger total distance to the verge compared to the control condition. Furthermore, cyclists cycled further from the verge in the edge strip condition than the control condition. Safety implications of the shoulder and edge strips are considered to be positive. Practitioner Summary: Older cyclists have a high risk for
single-bicycle crashes (e.g. riding into the verge). In two experiments, cyclists ≥50 years cycled a route
where different treatments were applied on a cycle path. Shoulder and edge strip treatments were
related to more efficient path use and safer distances from the verge. Abbreviations: AGS: artificial
grass strip; CL: control location; CSS: concrete street-print strip; ELC: edge line continuous; ELI: edge
line intermittent; LP: lateral position; SDLP: standard deviation of the lateral position; SK: slanted
kerbstones; WCES: white chippings edge strip
Full Text: Request from the Library

Title: Friction and Surface Texture Evaluation of Green-Colored Bike Lanes
Authors: Offei, Edward, Wang, Guangming, Holzschuher, Charles, Choubane, Bouzid, Carver, DeWayne
Publisher: Transportation Research Board 96th Annual Meeting, 2017.
Abstract: Interest in colored treatment on bicycle lanes and crossings has been growing in the United
States in recent years. In comparison, this practice, has been prevalent in European cities for longer
time. It was not until 2011 that the green colored treatment received official interim approval from
the Federal Highway Administration (FHWA) for experimental use on bicycle facilities across the
country. This study focused primarily on evaluating the friction and texture characteristics of five
independent green colored bicycle lane projects consisting of either (1) Epoxy Modified, (2)
Thermoplastic, or (3) High Friction Surface Treatment materials in Florida. A total of three types
of existing pavement surfaces (concrete, open and dense graded asphalt pavements) were used as
substrate for the colored application. These chosen sites include both control test sections
representing the bike lanes with limited/no traffic interaction and keyhole sections that represent
traffic conflict areas (areas where bicycles and vehicles come into conflict). The friction and texture
values were obtained using the Dynamic Friction Tester (DFT) and Circular Texture Meter (CTM),
respectively. Results indicated that all green bike lane projects met the initial friction number
requirements for Florida’s Patterned Textured Pavements. Minor friction loss was observed at the
keyhole sections when compared to the control sections indicative of traffic wear effects. Factorial
Analysis of Variance (ANOVA) showed that factors such as pavement surface type as well as type of
green bike lane material applied and the presence of traffic wear have significant influence on the
friction values. In addition, based on mean profile depth (MPD) measurements, only the interaction of
pavement surface type and the bike lane treatment type had significant impact on the texture. The
presence of traffic was not a significant factor. All these results ultimately lead to new design criteria
in 2016 permitting a more wide-spread application of green colored bike lanes on the Florida State
Highway System.
Full text: Request from the Library

Title: Definition and validation of a new methodical approach for friction evaluations of dropped-on
products for road markings
Authors: Pasetto, M, Barbati, S D
Publisher: 3rd International Road Surface Friction Conference, Gold Coast, Queensland, 15-18 May
2011
Abstract: Road safety is well known to rely on a combination of the components of man, vehicle and the environment. The latter plays an important role through the geometric design of the infrastructure, but the road markings and signs are also highly strategic in reducing accidents, especially in the more unfavourable driving conditions, such as with low night-time visibility, or when it is raining or foggy. As part of a study on the contribution to road safety of high-visibility road markings with dropped-on materials, a new test protocol has been defined for verifying the surface friction requirements, at the same time studying which parameter might be most effective and representative of the in situ performances of the products, depending on the maintenance state of the pavement. This has led to the identification of more effective criteria of judgement than those reported in the current European standards (EN 1436:2008).

Full Text: Request from the Library

Title: High Friction Surface Treatment Curve Selection and Installation Guide
Author: None listed
Publisher: FHWA May 2016
Abstract: Not available

Title: Novel approach to pavement friction analysis with advanced statistical methods using structural equation modelling.
Authors: Goulias Dimitrios G; Awoke Girum S
Publisher: International Journal of Pavement Engineering. 2020/1. 21(2) pp 236-245(Refs.)
Abstract: Pavement skid resistance has a significant role in traffic accidents, especially in wet conditions. Pavement surface characteristics are affected by both materials and mixture properties. This study explored a 'novel' approach to pavement friction analysis in modelling and relating pavement friction to materials and mixture properties. Structural equation modelling (SEM) takes advantage of the correlation/collinearity among one or more predictor variables in generating predictive models for a response variable. While SEM has been used in a variety of fields, in pavement friction the use of such statistic approach has not been explored, and thus it is a 'novel approach' to pavement friction modelling in relation to the past modelling efforts. Thus, in this study the selection of SEM modelling is advantageous so as to, (i) capture the interdependency of mixture and material variables in hot mix asphalts; and (ii) address the high number of predictor variables in relation to the number of observations (small sample size of observations). While data from Maryland were used in this analysis the methodology can be used elsewhere reflecting similar materials and pavement conditions.
Full Text: Request from the Library
Least Relevant Results

**Pooled Fund Study Title:** Pavement Surface Properties Consortium – Managing the Pavement Properties for Improved Safety  
**Pooled Fund Number:** TPF-5(345)  
**Link to the Study Record:** [https://pooledfund.org/Details/Study/594](https://pooledfund.org/Details/Study/594)

**Background:**  
Functional pavement considerations are fundamental to the performance and management of pavements. In addition to structural and durability requirements, an optimum pavement wearing surface should provide a combination of a good riding quality, adequate friction and macrotexture, and a low noise level. All these properties are highly influenced by the various components of the pavement surface texture. Phase I of the program demonstrated that a collaborative research program can provide an accessible and efficient way for highway agencies and other organizations to conduct research on pavement surface properties. The collaboration helped the participating agencies explore new technologies, as well as verify the operation and accuracy of the equipment currently used for evaluating pavement function.

**Objectives:**  
The main objective of the pooled-fund program of research has been to conduct applied research focused on enhancing the level of service provided by the roadway transportation system by optimizing pavement surface characteristics.  
Phase I of the study included regular verification and validation of the participant’s equipment, opportunities for technology transfer, and the accumulation of a significant body of knowledge on the measurement of pavement surface properties. Practical and tangible results were documented and disseminated though a large number of publications listed in the Phase 1 Outcomes (see study Documents).  
Examples of technologies that were evaluated as part of this program include high-friction surfaces (HFS) and Continuous Friction Measuring Equipment (CFME). HFS treatments have been adopted as a low-cost countermeasure as part of the Every-day-Counts FHWA program. CFME’s are currently being used to support the development of a new generation of friction management programs.

Phase II of the program continues to support the member’s effort to produce high-quality surface properties measurements but focuses on supporting the enhancing and adoption of emerging friction and macrotexture measurement technologies and the integration of these measurements into the next generation of pavement asset management systems. The focus will be on developing and deploying asset management approaches and tools that help improve the safety of our road networks.
by reducing the number of crashes and related fatalities. It will also seek participation of industry through the pooled-fund or an industrial affiliate program.

**Scope of Work:**

Within this new focus the consortium will continue to host annual equipment rodeos with more focus on the frictional properties of the pavement surface. These events provide a valuable opportunity for the verification and calibration of the equipment. Just as importantly, the annual gatherings provide a forum for discussion of common challenges, a unique opportunity to seek solutions for these challenges, learn from each other, and be exposed to emerging practices and technologies.

In addition, the consortium researchers will support the members with the evaluation, and enhancing if necessary, of emerging technologies for measuring the frictional properties. These evaluations will be complemented with demonstrations of the technologies (e.g., CFME) through pilot programs, equipment loans, and development of specifications for the acquisition of equipment or services, and/or support for the establishment of measurement programs. The consortium will also provide support for developing and deploying pilot pavement friction management programs (PFMP), which can be integrated into the agencies asset and performance management process. This will support the implementation of the MAP-21 requirements.

**Title:** Guide for Pavement Friction  
**Author:** J. W. Hall et al.  
**Publisher:** NCHRP Web-only Document 108, 2009.  
**Abstract:** This report documents the research performed under NCHRP Project 1-43. It describes the work activities undertaken in the study and presents the results of those activities toward the development of the Guide for Pavement Friction. The information provided in this report serves as the basis for many of the guidelines and recommendations contained in the Guide. The information will be of interest to highway materials, construction, pavement management, safety, design, and research engineers, as well as others concerned with the friction and related surface characteristics of highway pavements. Using information collected through detailed literature reviews and surveys/interviews with state highway agencies, this report discusses a variety of aspects regarding pavement friction. It describes and illustrates the importance of friction in highway safety, as well as the principles of friction, as defined by micro-texture and macro-texture. It identifies the factors affecting friction and examines the ways that friction can be measured (equipment and procedures) and expressed (reporting indices). Most importantly, it presents valuable information on (a) the management of friction on existing highway pavements and (b) the design of new highway surfaces with adequate friction. This information focuses on techniques for monitoring friction and crashes and determining the need for remedial action, as well as identifying combinations of aggregate (micro-texture) and mix types/surface texturing methods (macro-texture) that satisfy friction design.
requirements. The report includes various conclusions and recommendations based on the results of
the study, and it features five appendixes containing supplemental information on friction.


Pooled Fund Study Title: Fostering Innovation in Pedestrian and Bicycle Transportation Pooled Fund Study
Pooled Fund Number: TPF-5(370)
Link to the Study Record: https://pooledfund.org/Details/Study/622

Background:
Transportation agencies across the country are seeking ways to improve pedestrian and bicyclist
safety and mobility. We have seen a rapid rise in the demand for research on a wide variety of
pedestrian and bicycle issues in many different settings and situations. However, existing research
programs that advance innovation, such as the National Cooperative Highway Research Program,
cannot meet the growing needs for pedestrian and bicyclist research.

This TPF study will supplement existing research venues and fill an important missing gap by
emphasizing short turnaround practical research on issues immediately relevant to practitioners. It
will address national goals and priorities identified through input from local, State, and national
partners in FHWA’s Strategic Agenda for Pedestrian and Bicycle Transportation.

It will focus on bicycle and pedestrian network planning, safety, design issues (e.g. design flexibility,
developing crash modification factors, network connectivity), traffic control devices (e.g.,
experimenting on innovative markings, signals, and signs), and other relevant issues as designed by
TPF participants (e.g., equity, trip data).

This TPF study is a collaborative effort from numerous FHWA offices, including the Office of Planning,
Environment, and Realty; Office of Operations, Office of Operations Research and Development;
Office of Safety, Office of Safety Research and Development (HRDS); Office of Infrastructure, Office of
Highway Policy Information; and Office of Transportation Policy Studies. FHWA offices are
coordinating to ensure that the TPF addresses cross cutting issues, recognizes research underway and
planned, and does not duplicate other efforts.

Objectives:
The overall goals for this Transportation Pooled Fund (TPF) study are to:

1. Provide answers to emerging questions about innovative facility design, planning, and
implementation to improve safety and mobility for pedestrians and bicyclists.

2. Conduct effective and efficient research of innovative traffic control devices to accelerate their
incorporation into the Manual on Uniform Traffic Control Devices (MUTCD).
3. Facilitate the collection and reporting of robust transportation facility data that will allow for updating Federal, State, local, and other design guidelines, such as the American Association of State Highway and Transportation Officials (AASHTO) design guides.

4. Support research on addressing rural multimodal transportation needs, regulatory streamlining, opportunities to improve cost effectiveness and efficiencies in the transportation system, and multimodal investment analysis.

Scope of Work:
This TPF study will support research to test innovations on the ground and evaluate them for broader application. Topics to be addressed in the first 1-2 years of operation may include:

- Conducting research that will feed into the MUTCD experimentation process. For example tasks completed through the TPF could include research on bicyclist compliance and stopping placement in Two-Stage Turn Queue Boxes, bicycle symbols on signs (Turning Vehicles Yield to Pedestrians and Bikes), bicycle markings through intersections (chevrons), and green-back shared lane markings. Bicycle signal applications (protected vs. permitted phasing strategies) will also be considered.

- Evaluation of the pedestrian lane facility type identified in the Small Town and Rural Multimodal Networks report

- Evaluation of multimodal safety issues relating to clear zones on rural, suburban, and urban streets

- User testing of directional tiles/blocks to aid in wayfinding for people with visual disabilities (e.g. what surfaces are consistently detectable, proper placement so that consistent meaning is readily understood)

- Research on the economic benefits of pedestrian and bicycle investments

Additional topics may include:

- Developing crash modification factors and validating countermeasures for pedestrian and bicycle transportation facilities

- Incorporating multimodal network connectivity analysis and nonmotorized data in the metropolitan and statewide transportation planning processes, and evaluating equity and economic impacts of pedestrian and bicycle investments

- Supporting performance evaluation of infrastructure related applications of design flexibility

- Supporting efforts to document and maintain national data on pedestrian and bicycle activity and
infrastructure

- Operations and safety analysis of two-way separated bike lanes at intersections

- Research on strategies for addressing rural multimodal transportation needs, regulatory streamlining, and opportunities to improve cost effectiveness and efficiencies in the transportation system

**Comments:**
The pooled fund will provide a mechanism for Federal, State, regional, and local transportation agencies, academic institutions, foundations, private firms, and other stakeholders to collaboratively fund and implement pedestrian and bicycle research.

Individual tasks funded through the TPF will be contracted through existing FHWA Indefinite Delivery/Indefinite Quantity (ID/IQ) contracts (task topic will determine which ID/IQ to use. The Contracting Officer’s Representative (COR) for each project will be based on the issue area and the ID/IQ being used.

The status of commitments and research results and reports will be available on the Transportation Pooled Fund site and a page will be added to HEP’s Pedestrian and Bicycle Program page.

The TPF study will exist for the maximum allowed 5 years. The task Period of Performance for each individual task funded through the Pedestrian and Bicycle Transportation Pooled Fund Study is generally anticipated to take around 6-18 months; although some tasks may take longer.

**Title:** Differential Friction: A Potential Skid Hazard
**Author:** John C. Burns
**Publisher:** 1976?
**Full Text:** [http://onlinepubs.trb.org/Onlinepubs/state-of-the-art/1/1-005.pdf](http://onlinepubs.trb.org/Onlinepubs/state-of-the-art/1/1-005.pdf)
**Comment:** I realize this is a very old study, but it looked possibly relevant from a historical perspective.

**Title:** Friction Variations – Chapter 5 from an unidentified book
**Author:** John C. Burns, Wolfgang E. Meyer, Gordon F. Hayhoe, Don L. Ivey
**Publisher:** Possibly TRB
**Link to Full Text:** [http://onlinepubs.trb.org/Onlinepubs/state-of-the-art/1/1-005.pdf](http://onlinepubs.trb.org/Onlinepubs/state-of-the-art/1/1-005.pdf)
**Comment:** This is also a very old study but it looked possibly relevant from a historical perspective,