

SAE Technical Paper Series

872286

The Effect of Open Area on the "Self- Cleaning" Characteristic of Vehicular Walking Surfaces

Mark E. Lichty and David J. Rosenkrantz

Bustin Industrial Products, Inc.

**Truck and Bus Meeting
and Exposition
Dearborn, Michigan
November 16-19, 1987**

The appearance of the code at the bottom of the first page of this paper indicates SAE's consent that copies of the paper may be made for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition, however, that the copier pay the stated per article copy fee through the Copyright Clearance Center, Inc., Operations Center, P.O. Box 765, Schenectady, N.Y. 12301, for copying beyond that permitted by Sections 107 or 108 of the U.S. Copyright Law. This consent does not extend to other kinds of copying such as copying for general distribution, for advertising or promotional purposes, for creating new collective works, or for resale.

Papers published prior to 1978 may also be copied at a per paper fee of \$2.50 under the above stated conditions.

SAE routinely stocks printed papers for a period of three years following date of publication. Direct your orders to SAE Order Department.

To obtain quantity reprint rates, permission to reprint a technical paper or permission to use copyrighted SAE publications in other works, contact the SAE Publications Division.



*All SAE papers are abstracted and indexed
in the SAE Global Mobility Database*

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

ISSN0148-7191

Copyright © 1987 Society of Automotive Engineers, Inc.

This paper is subject to revision. Statements and opinions advanced in papers or discussion are the author's and are his responsibility, not SAE's; however, the paper has been edited by SAE for uniform styling and format. Discussion will be printed with the paper if it is published in SAE Transactions. For permission to publish this paper in full or in part, contact the SAE Publications Division.

Persons wishing to submit papers to be considered for presentation or publication through SAE should send the manuscript or a 300 word abstract of a proposed manuscript to: Secretary, Engineering Activity Board, SAE.

Printed in U.S.A.

The Effect of Open Area on the "Self-Cleaning" Characteristic of Vehicular Walking Surfaces

Mark E. Lichty and David J. Rosenkrantz

Bustin Industrial Products, Inc.

ABSTRACT

A review of past and current codes, standards and specifications reveals that while "self-cleaning" is a desirable characteristic of vehicle access and walking surfaces, its importance and definition needs further study. A method is proposed to aid in determining if a step or walking surface can be said to be "self-cleaning". This method attempts to relate the percentage of open area to whether foreign substances can readily build up on the walking surface and degrade friction between the walking surface and the sole of a shoe.

FEDERAL HIGHWAY ADMINISTRATION regulations require that "steps and deck plates shall be of a slip resistant design which minimizes the accumulation of foreign material. Whenever practicable self-cleaning material should be used" (49 CFR subsection 399.207(b)(3)). It is not clear how the term "self-cleaning" modifies the requirement that steps and deck plates shall be of a design that minimizes the accumulation of foreign materials. Does self-cleaning suggest an absolute standard of total self-cleaning? While the standards for minimizing accumulation of foreign material and "self-cleaning" are not set out, intuitively these appear to be desirable characteristics of vehicle walking surfaces inasmuch as the accumulation of foreign materials such as snow or mud may cause slips and falls from vehicles. A review of past and current codes, standards and specifications reveal that the term self-cleaning is not defined adequately.

Many standards, codes and regulations use the term self-cleaning in reference to stairways, steps, walkways and general walking surfaces. Self-cleaning is often cited as an example of ways to make a surface safe for pedestrian and industrial foot traffic or to improve existing walking surfaces. Below are some examples of "self-cleaning" requirements and recommendations.

...Solutions for slippery metal steps include: improved housekeeping, the use of self-cleaning materials, and if possible, appropriate footwear with slip resistant properties... (1)*

...Tread surfaces of all walkways and platforms shall have high slip resistance as well as self-cleaning properties... (2)

...Step design should minimize the accumulation of debris and aid in the cleaning of mud and debris from the shoe sole... (3)

...The steps will be constructed of, or covered with, a self-cleaning safety material (ie., expanded or pierced metal, grating, etc.)... (4)

...In very few cases can shoe bottoms be designed to provide adequate slip resistance to foreign materials. Instead, walkway surfaces should be self-cleaning as they are used by pedestrians... (5)

The regulations that mention self-cleaning do not specify whether the self-cleaning property applies to the ability of a surface to automatically rid itself of foreign material or the action of the walking surface scraping foreign material off of the shoe bottom. In some cases, the inference is that the walking surface should do both! For the purposes of this paper, it was assumed that the "self-cleaning" property desired is that of the step being able to clean itself, ie. not allow the buildup of foreign material to the point of degrading or eliminating sole-to-surface friction.

For this paper, self-cleaning was defined to be "the ability of a surface to purge itself of foreign material under the worst expected design conditions".

Design conditions and walking surface applications and needs vary widely, and at times may indicate that a non-self-cleaning surface is more desirable. To narrow the scope of this paper, a severe outdoor open exposure situation that emphasizes the need for a clean walking surface was chosen for examination. This application might be, for example, an unprotected step exposed to severe weather.

RATIONALE FOR TESTING SELF-CLEANING

From observations of truck access surfaces under various weather conditions, it was noted that the degree to which some surfaces were able to rid themselves of snow and ice was possibly related to the "openness" of the surface. The observations seemed to suggest that a surface with a high percentage of open area might outperform one with little or no open area under some adverse weather conditions.

In order to more fully understand the property of "self-cleaning" under these conditions, it was decided to independently test various walking surfaces to determine if a relationship exists between open area and the presence of friction surfaces. Those chosen represent a cross section of materials

*Numbers in parentheses designate References at the end of the paper.

0148-7191/87/1116-2286\$02.50

Copyright 1987 Society of Automotive Engineers, Inc.

currently used on over-the-road and off-road trucks as access and maintenance surfaces. Some samples were also chosen because they are commonly used as walking surfaces on trailers, fire trucks and in general industry.

The tests were of a pass or fail nature. Either the step presented a friction surface or it did not. If after depositing debris and the application of a weight representative of a weighted shoe the friction surfaces were visible and judged to be within reach to the shoe sole, the step "passed".

The design condition of "severe weather exposure" was arbitrarily approximated by the build up of two inches of mud or snow on top of the friction surface.

MEASUREMENT OF PERCENT OPEN AREA

The percent of open area was measured for each walking surface sample.

For each sample, the amount of open area of a horizontal projection of the surface was either measured or calculated.

Three methods of measuring the dimensions of the horizontal projection of open areas were used, depending on the complexity of the open area shapes. They were 1). Direct measurement 2). Direct tracing of the open area onto a sheet of paper 3). Indirect tracing of the open area onto a sheet of paper.

Method (1) involved accurate measurements of the straight segments and the radii of intersections of the open area profiles.

Method (2) consisted of placing the sample upside down on a white paper and accurately tracing the edges of the open areas.

Method (3) was as follows: The sample was placed under a $\frac{1}{8}$ " thick sheet of clear glass. A diffuse light was centered 24" below the sample. A piece of white paper was placed on top of the glass. As the light was shown through the walking surface sample, it cast a shadow onto the paper. The shadow, a mirror of the closed area of the sample, was traced onto the paper.

In all cases, the open area shapes were digitized into a CAD program which computed the areas of the shapes. The percent of open area of each sample was then calculated.

The open areas of the samples are summarized below in figure 1.

Sample	Walking Surface	% Open Area
1	Up and down punched hole step	51
2	Punched aluminum plank	28
3	Extruded aluminum	70
4	Up and down punched hole step	61
5	Up and down punched hole step	23
6	Up punched hole step	14
7	Serrated steel grating	81
8	Serrated steel grating	71
9	Plain aluminum grating	70
10	Serrated steel grating	72
11	Extruded aluminum plank	49
12	Formed cab step	0
13	Aluminum diamond plate	0
14	Serrated aluminum grating	76
15	Serrated aluminum grating	85

Fig. 1 — Percent Open Area of Tested Surfaces

TEST TO DETERMINE "SELF-CLEANING"

An acceptable test for "self-cleaning" is desirable for all manufacturers and users of walking surfaces to facilitate compliance with industry recommended practices and safety codes.

The tests performed used only two of many possible substances that can collect on truck access surfaces. Those were fine sand and granulated snow / ice.

The objective of these tests was to qualitatively evaluate the buildup of foreign material on a walking surface and its possible effect on friction between the walking surface and a shoe sole.

The testing reported herein for determining whether a walking surface is self-cleaning was intended to be qualitative, for reference and preliminary use only. The testing method was developed without the aid of a certified testing laboratory or testing engineer. It is desired that the test method be critically reviewed for applicability, replication and quality. The tests were repeated only enough to be able to show consistent results and should not be considered to be a significant sample size.

Each test sample was supported with one foot of clear space underneath the sample to allow the applied foreign material to freely disperse below the sample. The samples were simply supported on two by two inch steel angles placed one foot apart. No attempt was made to simulate the actual mounting configuration.

Two feet above the sample mounting angles was permanently mounted a coarse mesh of $\frac{1}{8}$ " by $\frac{3}{4}$ " steel bars. The open shape of the coarse mesh was approximately $2\frac{1}{2}$ " by $1\frac{1}{2}$ ".

To aid in the uniform dispersal of the sand deposited on the samples, two movable $\frac{1}{4}$ " mesh wire screens were placed on top of the coarse mesh. By overlapping the two screens, various size openings were created to control the dispersal of the sand.

The sand was poured onto the top of the fine mesh screens and allowed to fall down on top of the sample. No attempt was made to account for wind or vibratory effects that might affect the accumulation in actual use.

In the case of granulated snow / ice, due to weather conditions and limited supplies, the snow / ice was deposited on top of each sample by hand. Future testing using snow or ice could better be performed in a cold environment.

The foreign material was allowed to collect until the friction surfaces were covered by as much as two inches. The vertical depth of foreign material above the highest friction surface was measured.

A vertical load of approximately 150 pounds was applied over an area of approximately 30 square inches, and removed. The load was applied with a rubber pad backed with a steel bar sized to approximate a shoe sole.

After the load was removed, it was noted whether or not the friction surface was visible. The tests were repeated with different foreign materials and application rates.

All samples tested were in "as-fabricated", like new condition. None of the samples had rust or physical damage that might exacerbate the collection of debris.

A picture of the test apparatus is shown in figure 2.

The results of the "self-cleaning" tests are summarized in tables I and II.

DISCUSSION OF TEST RESULTS

The general tendencies were for surfaces with greater open area and lesser contact surface area to perform better.

With one exception, surfaces with less than fifty (50) percent open area failed even the least stringent test (dry sand).

With three exceptions, surfaces with seventy (70) or more percent open area passed all tests.

The three samples with seventy (70) or more percent open area that failed (samples 3, 9 and 14) are discussed below:

Surface number 9 had flat friction surfaces presenting plane contact to the shoe sole. Wet or dry sand and snow / ice showed a tendency to run or be pushed off of this surface by the shoe sole. Even after such self-cleaning action, some residual debris was often present on the friction surface which would degrade but not eliminate friction with the shoe sole.

Surface number 14 had three sixteenths of an inch ($13/16$ ") wide serrated friction surfaces that were wide enough to collect some ice. In addition, the vertical open area boundaries were one and one quarter inches ($1\frac{1}{4}$ ") deep which helped the snow / ice to pack in and eventually cover the friction surfaces.

Surface number 3 had longitudinally grooved top surfaces that trapped debris and exhibited slipperiness in at least the longitudinal direction under most test conditions.

It was evident that serrations, grooves, spikes and protrusions greatly improved the self-cleaning ability of a surface.

During the testing, it became clear that sufficient open area by itself does not guarantee a self-cleaning surface. The characteristics of size and quantity of the open areas and slope and depth of the open area boundaries each have an impact on the self-cleaning property of the surface.

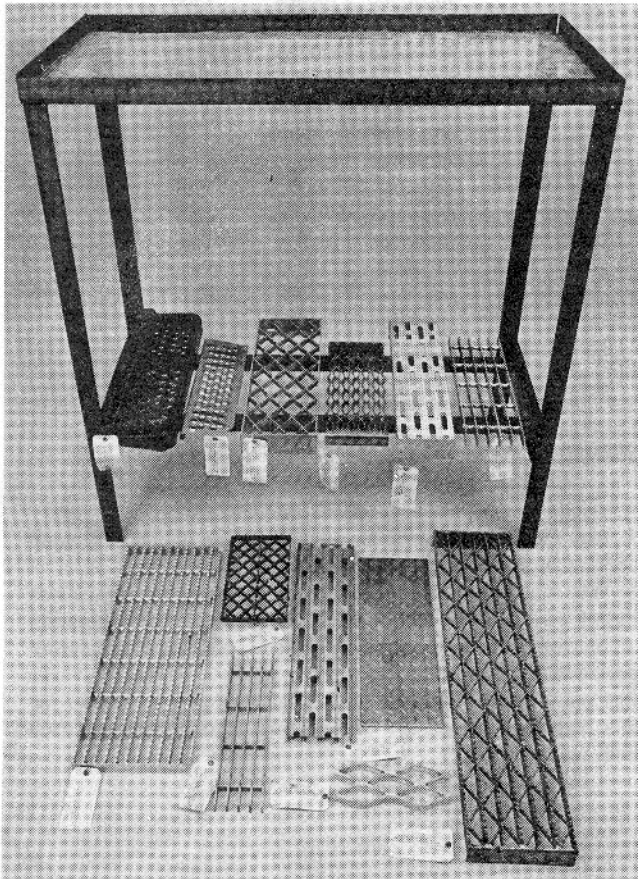


Fig. 2 — Self Cleaning Test Apparatus

CONCLUSIONS

From the observations of the testing and the test results, the following statements are advanced for the materials tested.

A surface with at least fifty (50) percent open area might be considered self-cleaning under some moderate conditions.

A surface with at least seventy (70) percent open area might be considered to be self-cleaning under some severe conditions.

To be effective, the open area ought to be comprised of as few open area segments as is possible.

The size of each open area segment should be proportioned according to the maximum size particle or clump that is expected to be deposited on the surface.

On punched hole products, open area boundaries that slope downwards may promote self-cleaning better than upwards sloping edges, and may enhance self-cleaning by being vertical or nearly vertical. However, deep open area boundaries may increase the likelihood of some debris filling the open area voids under extreme conditions.

Friction surfaces that were flat did not self-clean under these test conditions.

Friction surfaces that contain long continuous grooves did not self-clean under these test conditions.

Samples placed directly on solid surfaces did not self-clean as well as samples supported with ample room for debris to disperse.

SUMMARY

Safety on climbing and walking surfaces is a major concern to general industry, and the trucking world in particular. Truck access systems are particularly hazardous because of their exposure to various weather conditions. Governmental and industry codes and regulations such as Federal Specification RR-G-1602b (6) are requiring these surfaces to be "slip-resistant" and offer test methods to substantiate and qualify the slip-resistant characteristic. Slip-resistance by itself does not totally describe a "safe" step or walking surface. The surface must be able to maintain its slip-resistance when manmade or natural debris begins to accumulate on it. In order to do this, the surface must be "self-cleaning".

For this paper, self-cleaning was defined to be "the ability of a surface to purge itself of foreign material under the worst expected design conditions" and the design condition of "severe open outdoor exposure" was approximated by the application of up to two inches of debris.

The tests conducted here are not intended to be dispositive of this issue. The tests were performed only as the most basic initial step in addressing a definition of self-cleaning or the situations where self-cleaning is a prime design goal. Industry guidelines of self-cleaning will encourage the development of universally slip-resistant surfaces. This will help in reducing potentially serious but avoidable injuries.

Test results showed that to be self-cleaning under the test conditions, a step must have significant open area and be supported above any solid surface to allow debris to disperse. At fifty (50) percent open area most surfaces tested began to be self-cleaning, and might be suitable for some non-severe service applications.

For severe service, (outdoors, subject to snow, ice or mud build-up) tested surfaces with at least seventh (70) percent open area self-cleaned effectively when combined with vertical or nearly vertical open area boundaries and friction surfaces without entrapment grooves or long flat tops.

Open Sample	Foreign Area	Depth of Material	Pass / Application	Fail	Notes
12	0%	Dry sand	½ inches	Fail	
		Wet sand	½ inches	Fail	
		Snow/Ice	1 inch	Fail	
13	0%	Dry sand	½ inches	Fail	
		Wet sand	½ inches	Fail	
		Snow/Ice	1 inch	Fail	
6	14%	Dry sand	2 inches	Fail	
		Wet sand	¾ inches	Fail	
		Snow/Ice	1 inch	Fail	
5	23%	Dry sand	2 inches	Pass	
		Wet sand	½ inches	Fail	
		Snow/Ice	1 inch	Fail	
2	28%	Dry sand	¼ inches	Fail	
		Wet sand	¼ inches	Fail	
		Snow/Ice	1 inch	Fail	
11	49%	Dry sand	¼ inches	Fail	
		Wet sand	¼ inches	Fail	
		Snow/Ice	1 inch	Fail	
1	52%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	
		Snow/Ice	1½ inches	Fail	
4	61%	Dry sand	2 inches	Pass	
		Wet sand	1 inch	Fail	
		Snow/Ice	1 inch	Fail	
3	70%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Fail	1
		Snow/Ice	2 inches	Pass	2
9	70%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Fail	4
		Snow/Ice	2 inches	Pass	5
8	71%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	3
		Snow/Ice	2 inches	Pass	
10	72%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	
		Snow/Ice	2 inches	Pass	
14	76%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	6
		Snow/Ice	2 inches	Fail	7
7	81%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	
		Snow/Ice	2 inches	Pass	
15	85%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	
		Snow/Ice	2 inches	Pass	7

Table I. — Results of Self-Cleaning Test
(Organized by Open Area)

NOTES FOR TABLES I AND II

1. ¼" of debris was left on the friction surface, which was enough to limit contact.
2. Longitudinal motion would not have friction.
3. Any motion will clean the step except in the corners allowing a shoe to make contact.
4. Contact is degraded in the longitudinal due to sand particles on the smooth top surface.

Sample	Open Area	Foreign Material	Depth of Application	Pass / Fail	Notes
1	52%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	
		Snow/Ice	1½ inches	Fail	
2	28%	Dry sand	¼ inches	Fail	
		Wet sand	¼ inches	Fail	
		Snow/Ice	1 inch	Fail	
3	70%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Fail	1
		Snow/Ice	1 inch	Pass	2
4	61%	Dry sand	2 inches	Pass	
		Wet sand	1 inch	Fail	
		Snow/Ice	1 inch	Fail	
5	23%	Dry sand	2 inches	Pass	
		Wet sand	½ inches	Fail	
		Snow/Ice	1 inch	Fail	
6	14%	Dry sand	2 inches	Fail	
		Wet sand	¾ inches	Fail	
		Snow/Ice	1 inch	Fail	
7	81%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	
		Snow/Ice	2 inches	Pass	
8	71%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	3
		Snow/Ice	2 inches	Pass	
9	70%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Fail	4
		Snow/Ice	2 inches	Pass	5
10	72%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	
		Snow/Ice	2 inches	Pass	
11	49%	Dry sand	¼ inches	Fail	
		Wet sand	¼ inches	Fail	
		Snow/Ice	1 inch	Fail	
12	0%	Dry sand	½ inches	Fail	
		Wet sand	½ inches	Fail	
		Snow/Ice	1 inch	Fail	
13	0%	Dry sand	½ inches	Fail	
		Wet sand	½ inches	Fail	
		Snow/Ice	1 inch	Fail	
14	76%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	6
		Snow/Ice	2 inches	Fail	7
15	85%	Dry sand	2 inches	Pass	
		Wet sand	2 inches	Pass	
		Snow/Ice	2 inches	Pass	7

Table II. — Results of Self-Cleaning Test
(Organized by Sample Number)

5. Any motion will clean the step, but there would be limited contact in the longitudinal direction.
6. Wet sand filled the serrations, and the friction surface was lightly covered with wet sand. However the slightest vibration or motion cleaned the friction surface, and then the grating provided adequate contact.
7. Coarse snow / ice was from a second batch of snow / ice that had been screened a second time through one-half (½) inch mesh.

The testing also showed that to be self-cleaning, no matter how much open area exists, contact surfaces with long grooves, substantial flats, or deep open area boundaries might contain or trap debris.

It is recognized that self-cleaning is not always a major factor in the design of a walking surface and that some characteristics of walking surfaces that improve self-cleaning may degrade other desirable features. An integrated design methodology towards the goal of safe walking surfaces should include quality of self-cleaning when it is appropriate.

REFERENCES

1. Liberty Mutual Insurance Company "Loss Prevention Reference Notes"
2. Draft International Standard ISO/DIS 2867 "Earthmoving Machinery — Access Systems"
3. SAE Recommended Practice J185 June 1981 "Access systems for off-road machines"
4. The Maintenance Council Recommended Practice 404a-1 paragraph 5 "Cab Entry Steps"
5. ASTM F 802-83 section 2.1 "Standard Guide for Selection of Certain Walkway Surfaces When Considering Footwear Traction"
6. Federal Specification RR-G-1602B 21 March 1984 "Grating, metal, other than bar type (Floor, except for Naval vessels)"

ed in papers or discussion are the author's and are his
onsibility, not SAE's; however, the paper has been edited
SAE for uniform styling and format. Discussion will be
ted with the paper if it is published in SAE Transactions.
permission to publish this paper in full or in part, contact
SAE Publications Division.

lation or publication through SAE should send the manu-
pt or a 300 word abstract of a proposed manuscript to:
retary, Engineering Activity Board, SAE.

Printed in U.S.A.