THE AFFECTS OF FLOOR WEAR ON SLIP RESISTANCE MESAUREMENTS (A PILOT STUDY)

William A. Mecham, University of Utah
Richard F. Sesek, University of Utah

billmecham@msn.com

ABSTRACT

An examination of how the normal surface wear on vinyl tiles affects slip resistance measurements. Statistical comparisons are made between slip resistance measurements made with normal pedestrian traffic flow, across normal pedestrian traffic flow, and between high and low wear areas. The results found significant differences between direction of slip resistant measurement and differences in slip resistance with the amount of wear.

INTRODUCTION

Slip resistance is defined as *"the relative force that resists the tendency of the shoe or foot to slid along the walkway surface. Slip resistance is related to a combination of factors including the walkway surface, the footwear bottom, and the presence of foreign materials between them."* ASTM Designation: F 1637-96 Standard Practice for Safe Walking Surfaces .

There is considerable controversy over how on site measurements of slip resistance of floor surfaces should be made. These are measurements that may be made for preventative safety measures or as part of a accident investigation. Surprisingly, there has been little analysis of how the wear of vinyl tile affects slip resistance.

Many tribologists (a tribologist is a person who measures floor slip resistance) feel that the wear as little affect slip resistance of a floor. They feel that only a few measurements under dry and wet conditions are all that is needed to quantify the slip resistance of a floor surface.

Other tribologists believe that slip resistance should be measure in four directions on a vinyl tile. These four measurement are: two measurements opposite to each other in the direction of people normally walk across the tile and two measurements opposite to each other in the across direction of people normally walk across the tile. Then an average of the four directions is made and that is reported as the slip resistance of the floor surface.

Still others believe that the slip resistance measurements should be made in the direction that people would normally walk across the area. If the slip resistance measurements are being made

in an investigation of an accident then the measurements should focus on the area where the accident happened. An average with the ranges of slip resistance will be reported.
The underlying question is, are investigators biasing floor's slip resistance by the measurement method they are using? Does the measurement method they are using giving a true representation of the slip resistance that a pedestrian would actually encounter?

The purpose of this pilot study is to determine if there is significant difference in the measured slip resistance of a floor surface of consistent material (vinyl tile) that has under done differences in wear. The wear on the vinyl tile is mainly from pedestrian traffic and maintenance of the floor (i.e. mopping and buffing). A principal cause of wear on the vinyl comes from small particle such as sand that becomes imbedded in the sole of shoes. The particles cause small scratches on the surface of the vinyl tile that can easily be seen. Several method were tried to quantify the wear on the vinyl tiles. These were unsuccessful because of the amount of small and large abraded areas on the tiles that did not allow for distinctive markings to be made.

Experimental Definitions

In order to make the study easier to understand and write about, some definitions were developed. This definitions are author derived and many not occur else were.

Cross travel -- movement across the direction that people normal walk down the hall being measured. When a surface is measured, the cross travel is 90 degrees from the main direction people move along the floor surface. Two measurements will be taken in opposite direction (180 degree).

Group -- the combination of sample point and slip direction combined with whether it was wet or dry. In this study there were six groups.

Middle of Hall -- The location name for the two measurement points one foot on either side of the center of the hallway on the sampling line. Assumed to be a area of high wear from observations of the tiles and traffic flow in the hallways.

Near wall -- The location name for the two measurement points one foot from the wall on the sampling line. Assumed to be a area of low wear from observations of the tiles and traffic flow in the hallways.

Sample line -- The line of tiles located midway between room doors (to reduce variation of wear) running the width used to group sample locations. The sample line consists four sample points: North-near wall, North-near center, South-near center, and South--near wall.

Sample points -- Names of the four tile locations used for the measurement. These points are: North-near wall (one foot from the wall), North-near center (one foot from center), South-near center (one foot from center), and South--near wall (one foot from the wall). Slip resistance measurements were made at or near the center on a individual tile avoiding any pronounced gouges or damage.

With travel -- movement in the same direction that people normal walk in the hall being measured.

Slip direction -- direction the tribometer's test foot will slide when the static coefficient of friction is exceeded. In this case the slip directions were: North-cross travel, East-with travel, South-cross travel and West-with travel.

Experimental Details

The site of the data collection was the Merrill Engineering Building at the University of Utah. The vinyl tiles are approximately 30 years old and are generally in good repair. The vinyl tiles are the type commonly found in school and retail buildings. The measurements were taken on the second floor, in the southern most hallways that runs East to West in two locations, between rooms 2266 and 2268, and rooms 2270 and 2278). The main directions that people move down the hall are East or West (this is noted as "with travel"). As people walk down the hallway they will turn North or South side to go into the rooms.

The hallway is approximately ten foot wide. Four series of slip resistance measurements were taken across the across the width of the hallway. Slip resistance measurement on a tile was taken in four slip directions (North-cross travel, East-with travel, South-cross travel and West-with travel in this case) and formed the groups.

The slip resistance measurements were made with and English XL tribometer (a.k.a. as Variable Incidence Tribometer, VIT) following manufacture's and ASTM F1679-00 instructions. Slip resistance measurements were made under dry and wet conditions. The surface was wiped first, with a dry paper towel to remove any foreign particles. While this would not be a normal accident investigation procedure which would use the preferred an "As is, were is" methodology looking for possible accident causes such as third body particles. This does give a better representation of the interaction of the test foot to floor surface having remove possible modifier variables.

At each sample point, slip resistance measurements were made in the four slip direction and were made either wet or dry. The order of the slip directions was randomized to reduce possible biasing of the data collection. There were a total of 64 slip resistance measurements made.

Specific details of the maintenance of the floor were not obtained, but it is believed that it would be consistent in its application. This would be important factor to note if the comparisons were being made between the flooring of two or more buildings.

RESULTS

The data was analyzed using a "Paired Two Sample for Means t-Test" in Microsoft Excel. Excel performs a paired two-sample student's t-test to determine whether a sample's means are distinct. This t-test form does not assume that the variances of both populations are equal. While some of

the data did have natural pairings (measurements taken at the same location, but in different directions) which would allow for the use of an alternate t-test, the "Paired Two Sample for Means t-Test" fits the experimental needs well.

Table 1 lists the measured slip resistance by sample points and slip directions. Note that there is significant differences between the wet and dry slip resistances. While the dry measurements are considered slip resistant, the wet measurements slippery to very slippery. (6)

In comparison of all dry "with travel" to all dry "cross travel" there is not a significant difference in slip resistance (t Stat = 0.345732). In the comparison of wet slip resistances, "cross travel" slip resistance was significant higher than "with travel" slip resistance (t Stat = 1.79602).

Tables 2 and 3 makes comparisons (dry and wet, respectively) between different groups. The table notes if there are statistical differences and which of the groups has the higher slip resistance.

There are many significant differences between the comparison of the different groups in both the wet and dry measurements. What is most interesting is that in every group that had a significantly higher slip resistance when measured dry, had significantly lower slip resistance when measured wet. The difference appears to be do to the amount of wear. Groups that have lower floor wear have higher slip resistance when dry than do compared to groups that have high wear. However, groups that have higher wear have higher slip resistance when wet than do compared to groups that have low wear.

It is hypothesized that the difference is do to the interaction of the different types of surface and test foot asperities. If the surface is dry, the smaller asperities of the floor surface and the test foot are able to interact has an affect of larger surface area that the asperities would need to shear in order to cause the slip. In the worn areas, because the asperities are larger there is less effect are to resist the shear that results in a slip.

When the surface is wet, the smaller asperities are covered by a water film and are not able to make as complete of contact and there is effectively less surface area to shear.

Table 1: Results of Slip Resistance Measurements

With Travel Middle D	Cross Travel Middle D	With Travel Near D	Cross Travel Near D	With Travel Near W	Cross Travel Near W	With Travel Middle W	Cross Travel Middle W
0.55	0.60	0.57	0.65	0.40	0.40	0.43	0.44
0.58	0.60	0.68	0.70	0.37	0.37	0.45	0.45
0.63	0.58	0.60	0.60	0.35	0.45	0.45	0.45
0.60	0.57	0.60	0.58	0.33	0.35	0.50	0.50
0.55	0.57	0.65	0.65	0.35	0.37	0.40	0.43
0.60	0.58	0.67	0.67	0.40	0.35	0.43	0.45
0.62	0.67	0.65	0.63	0.40	0.41	0.40	0.41
0.60	0.57	0.63	0.60	0.40	0.42	0.43	0.45

D = Dry Floor Conditions, W = Wet Floor Conditions

Table 2:

		t-Test: Paired Two Sample for Means (Slip Resistance, Dry)			
		WITH TRAVEL		CROSS TRAVEL	
		Middle of Hall	Hall Near Wall	Middle of Hall	Hall Near Wall
WITH TRAVEL	Middle of Hall	XXXX	Mid W < Near W -2.28748	Mid W = Mid C 0.420084	Mid W = Near C -1.56864
	Hall Near Wall		XXXX	Mid C < Near W -3.19845	Near W = Near C 1.108832
CROSS TRAVEL	Middle of Hall			XXXX	Mid C < Near C -2.15754
	Hall Near Wall				XXXX

t Critical one-tail = 1.943181 t Critical two-tail = 2.446914

Table 3: **t-Test: Paired Two Sample for Means (Slip Resistance, Wet)**

		WITH TRAVEL		CROSS TRAVEL	
		Middle of Hall	Hall Near Wall	Middle of Hall	Hall Near Wall
WITH TRAVEL	Middle of Hall	XXXX	Mid W > Near W 3.059874	Mid W < Mid C -2.48868	Mid W > Near C 2.882307
	Hall Near Wall		XXXX	Mid C > Near W 4.062716	Near W = Near C -1.02523
CROSS TRAVEL	Middle of Hall			XXXX	Mid C > Near C 2.232209
	Hall Near Wall				XXXX

t Critical one-tail = 1.943181 t Critical two-tail = 2.446914

W = With Travel, C = Cross Travel, Mid = Middle of Hall, Near = Hall Near Wall

The worn areas have larger asperities that are allow interaction of the test foot asperities through the water film and give a larger surface area to shear.

Conclusions

- Surface wear does significantly affect slip resistance.
- There is a significant difference in the slip resistance of different locations.
- The measurement slip direction does affect slip resistance measurement.
- Averaging the slip resistance measurement of the four slip directions would give a higher slip resistance value than those pedestrians would normally encounter.

Recommendations

- Repeat the study will a larger, more diverse sample set.
- Find floors that have different floor treats (waxes, sealers, etc.) and maintenance (types of buffing, mopping, etc.) to determine if that affect slip resistance.

Examine different floor materials for the affects of wear. Example: marble, terrazzo, skid plate, cement, tile (fired, glazed, non-slip implants), etc.

REFERENCES

1. English, W., Pedestrian Slip Resistance: How to Measure I and How to Improve It., William English, Inc. Alva, Florida.

2. English, W., www.englishxl.com

3. Pilla, S.D. and Vidal, K., State of the Art in Slip Resistance Measurement, Profession Safety, June 2002 pages 37-42.

4. Jay W Preston, J.W., http://www.safetybiz.com/Sliptest.htm

5. Vidal, V., http://www.slipandfall.com/Interested_in_Wet_Testing.htm

6. Rosen, S. I., The Slip and Fall Handbook, James Publishing, Inc., Santa Ana, CA.

7. Turnbow, C.E., Slip and Fall Practice 2nd Ed.

8. Miller, J.M., Chaffin, D.B. and Andres,R., Work Surface Friction: Definitions, laboratory and Field Measurements and a Comprehensive Bibliography, University of Michigan Center for Ergonomics, Ann Arbor 1983.

9. **Americans with Disabilities Act** *(*ADA, U.S. Department of Justice*)* http://www.tracecenter.org/docs/compliance_with_the_ada_for_itm/comply_comp1.html

10. U.S. Department of Labor, Occupational Safety & Health Administration (OSHA), 1926 Subpart R - Steel Erection, http://www.osha.gov/pls/oshaweb

11. Fendley, A.E., What is Needed to Gain Valid Consensus for Slip Resistance Standards, Metrology of Pedestrian Locomotion and Slip Resistance, ASTM STP1424, ASTM International, West Conshohocken, PA, 2002.

12. National Center for Injury Prevention and Control (NCIPC), Center for Disease Control, http://www.cdc.gov/ncipc/factsheets/fallcost.htm

13. English, W. 1994, "The Validation of Slipmeters," Proceedings of the Annual Conference of Ergonomics Society, University of Warwick, Coventry, England, April 1994

14. Hunter, R. J., Jablonsky, R. D. and Merscher, J. H. 1985, "Development of Coefficient of Friction Measurement Methods by Consensus-Standards-Making Organizations," Ergonomics, 28, 1055-1063

15. Perkins, P. J. 1978, "Measurement of Slip Between the Shoe and Ground During Walking," In Anderson/Senne (ed.) ASTM STP 649 Walkway Surfaces: Measurement of Slip Resistance, American Society for Testing and Materials, West Conshohocken, PA, 71-87

16. Sherman, R. M. 1992, "Preventing Slips that Result in Falls," Professional Safety, March 1992, 23-25

17. Underwriters Laboratories, Inc. 1992, Slip Resistance of Floor Surface Materials, UL 410, First Edition

18. Vidal, Keith 1994, "The Americans with Disabilities Act and Slip/Falls," Proceedings of the National Conference of National Academy of Forensic Engineers, Kansas City, July, 1994

19. Winter, David A. 1990, Bio mechanics and Motor Control of Human Movement, Second Edition, Wiley-Interscience, 605 Third Avenue, New York, NY 10158-0012, 1990