SOTTER ENGINEERING CORPORATION

Consultants

26705 Loma Verde, Mission Viejo, CA 92691-6055
Telephone/FAX: 949-582-0889

Licensed by the State of California Board for Professional Engineers and Land Surveyors

Approved by City of Los Angeles for testing slip resistance

November 6, 2014

Joe Zingale
CTS Cement

SUBJECT: Slip resistance test results for Primark project

Dear Mr. Zingale:

This report summarizes the findings to date of my review of polished concrete slip resistance data provided by you re retailer Primark's project in the USA.

I am an engineer and consultant specializing in slip/trip and fall safety. I earned a B.S. degree in a branch of Chemical Engineering from the Pennsylvania State University, and a Ph.D. degree in the same branch of Chemical Engineering from Sheffield University in England. I am a Professional Engineer registered by the State of California. I have worked as an engineering consultant for over 40 years and have authored dozens of technical publications, including articles on floor safety that I wrote at the request of the Ceramic Tile Institute of America and that were published by periodicals such as Tile Industry News, Tile and Decorative Surfaces, TileLetter, and Occupational Health and Safety. I published a paper at a U.S. CDC NIOSH symposium in 2010. I authored a book titled *STOP Slip and Fall Accidents!* that discusses both slips and trips and is sold by amazon.com. It is used on six continents. I have done fall-related consulting for tile manufacturers, tile retailers, floor treatment companies, municipalities, attorneys, building owners, builders, safety consultants, and architects. I am a member of several national committees, in two nations, the main focus of which is safety of floors and footwear. I'm in contact several times monthly with people in other nations who are leading authorities in safety of floors. I am not a full-time professional witness. I have testified in trials of fall cases

approximately nine times, in arbitrations twice, and have been deposed in such cases some 21 times since 1994. My curriculum vitae is at http://www.safetydirectamerica.com/SlipandFallExpert.html.

I have participated in a international-level panel discussion on slip resistance of polished concrete and authored a blog entry on the subject at http://blog.safetydirectamerica.com/variables-that-affect-slip-resistance-of-polished-concrete/.

The discussion below includes the German DIN variable-angle ramp test, the ANSI B101.3 test, and the relationship between the two.

Variable-angle ramp test method, DIN 51130
This test has been in use for many years and is based on walking by two human subjects individually on a ramp, the angle of which can be controlled by the subject to find the angle of slipping. The most shallow group of angles is defined as R9, and the steepest R13. Therefore R9 represents minimal traction, and R13 the greatest slip resistance.

The test is a direct measurement of the slipping tendency of humans. However, it has three weaknesses when applied to a shopping environment:

(1) The test is conducted using industrial-type work shoes having heavy treads. Most shoppers, particularly females, will not wear this type of footwear — the majority will have faint treads or no treads at all. For a wet floor, this is equivalent to driving on bald tires on a wet road.

(2) For the test the flooring is covered with motor oil. This is not typical of a wet shopping environment

(3) The combination of treaded footwear and oil favors flooring with a type of roughness that involves interlock between the flooring and the treads — interlock that is not available to the typical woman shopping.

I am informed by Dr. Stefan Bönig, who did some of the definitive floor traction work at the University of Wuppertal in Germany, that the variable-angle ramp has had some conspicuous failures in defining safe flooring for public spaces that get wet in use. An apparently acceptable R value can lead to slips and falls, e.g. in an airport concourse.

The BOT-3000 and ANSI B101.3
German research at the University of Wuppertal also led to the commercialization of a U.S.-manufactured digital tribometer for measuring dynamic friction — the BOT-3000E. This is used in American National Standards Institute (ANSI) test method B101.3. Published in 2012, this is a more modern method than the DIN ramp test. The ANSI test uses water with a trace of wetting agent added to prevent beading.

The ANSI standard states that for a level floor, a wet DCOF greater than 0.42 indicates "high slip resistance potential." The recommended action is just to "Monitor DCOF regularly and maintain cleanliness."

The manufacturer of the BOT-3000E has studied the German research and informs me that a DCOF of 0.42 or higher "should reduce the risk of slipping to no more than one near-slip every 10 years" for the average person.

CTS Cement supplied me with some B101.3 test data for potential floor finishes for Primark. CTS polished using various grits from coarse (200 grit) to very fine (3000 grit). For the latter grit finish, they ran a second test point after sealing the surface.

Figure 1 below shows the results. Numbers on the vertical axis are wet dynamic coefficient of friction, and those on the horizontal axis are grit size, higher numbers representing finer grit. All the data are higher than the minimum safety standard of 0.42.

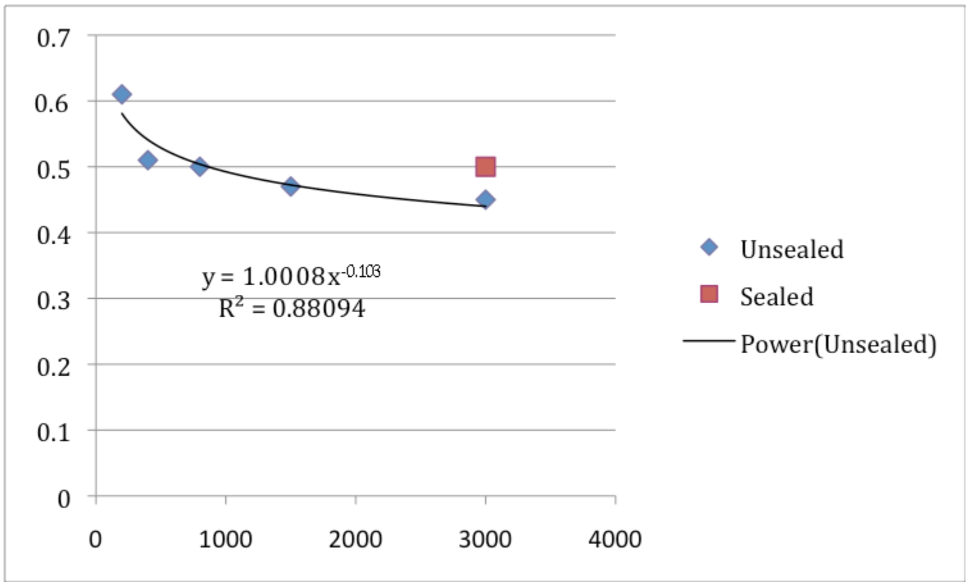


Figure 1. Wet dynamic coefficient of friction vs. grit size

The curve fitted on the unsealed data points indicates a correlation coefficient R of 94%, showing that the data are very orderly; that is, there are no surprises between data points. I did not witness the tests, but to me the data appear credible.

Relationship between the two test methods

The University of Wuppertal studied the correlation between BOT results and the variable-angle ramp. The results are in Fig. 2 on the next page. Since there is scatter, we can say that for a BOT wet DCOF of 0.45 — which is the lowest BOT test result in Fig 1 — the ramp friction coefficient is between roughly 0.35 and 0.60, as defined by the two "95% probability" dotted lines in Fig. 2.

Translating to R categories, a ramp friction coefficient of 0.35 corresponds to a ramp angle of of 19.3 degrees (the trigonometric tangent of 0.35), and a ramp COF of 0.60 corresponds to a ramp angle of 31 degrees. In DIN R categories, these correspond to R11 and R12 respectively. We can then conclude that 0.45 or higher on the BOT is equivalent to at R11 or higher on the variable-angle ramp. Thus, if the ramp method is taken as a measure of safety, all the CTS test points indicate greater safety than R9.

CONCLUSIONS

1. The CTS BOT test data appear orderly and credible.
2. All the BOT test data indicate a wet DCOF of 0.45 or higher, considered "high slip resistance potential" for level floors according to ANSI B101.3

3. The BOT data appear to indicate that any of the floor finishes tested by CTC "should reduce the risk of slipping to no more than one near-slip every 10 years" for the average person.
4. All of the CTS BOT-3000 test points indicate greater slip resistance than R9.

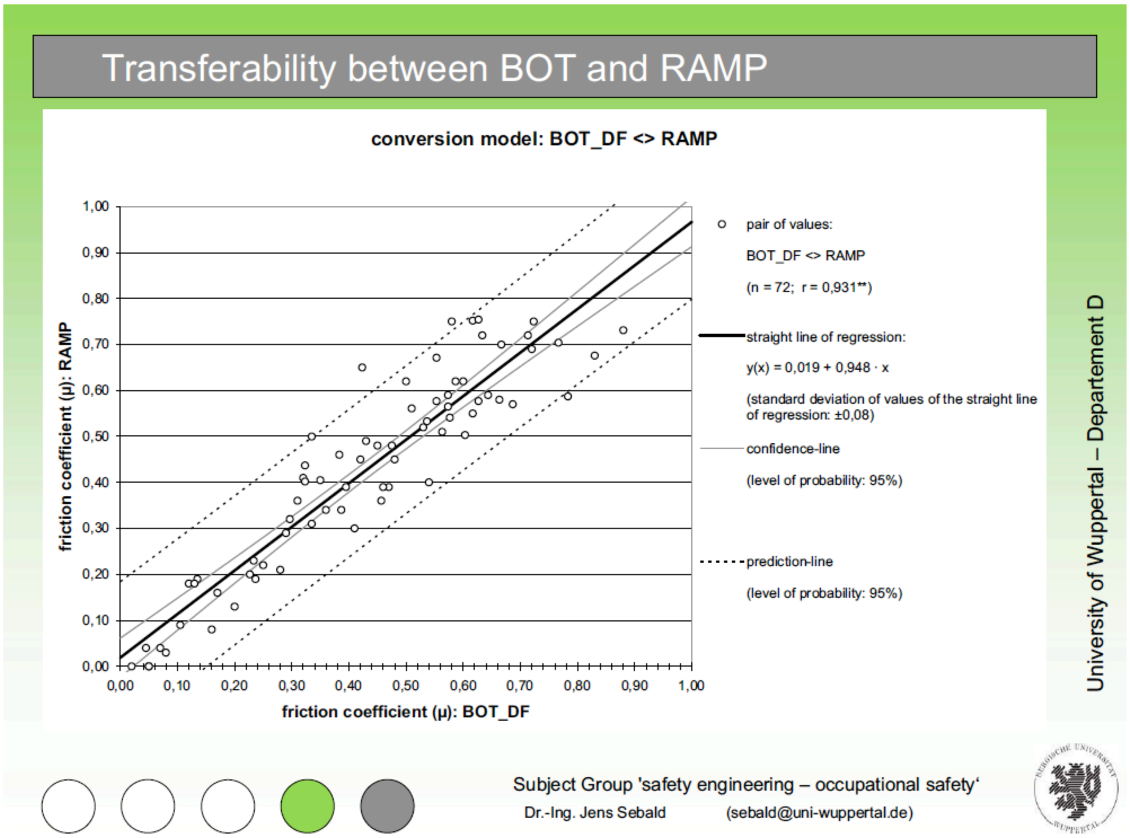


Figure 2. Correlation between BOT and variable-angle ramp test results

Closing

We have conducted the observations and analyses for this project with the degree of skill and care ordinarily exercised by engineers practicing in this and similar localities. No other warranty, express or implied, is given regarding the conclusions or professional opinions presented in this report.

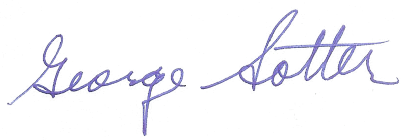
The scope of this report is limited to the matters expressly covered herein. This report is presented for the sole use of CTS Cement and may not be relied upon by any other party without written authorization from the undersigned.

In preparing this report, we have relied upon information derived from other sources. Except as set forth in this report, we have made no independent investigation as to the accuracy of the information we have been provided, and have assumed that such information is accurate and complete. More extensive studies may be performed to reduce any inherent uncertainties.

All recommendations, findings, and conclusions presented in this report are based upon facts and circumstances as they existed at the time this report was prepared. A change in any fact or circumstance upon which this report is based may necessitate reevaluation and/or modification of the recommendations, findings, and conclusions presented herein.

Should you require any further assistance, information or clarification, please contact our office. We appreciate the opportunity to provide this service.

Respectfully submitted,
SOTTER ENGINEERING CORPORATION



J. George Sotter, P.E., Ph.D.
President