CERAMIC TILE INSTITUTE OF AMERICA, INC.

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Ceramic Tile Institute of America, Inc. Endorsement of Portable Test Methods and Slip Prevention Standards for Existing Flooring

Summary

The objective of this endorsement is to reduce the human and financial costs of slips and falls on all types of flooring materials. Such accidents cause some 1200 deaths, and in the workplace alone about $4 billion in lost productivity and compensation costs, in the United States each year.

The Slip Resistance Committee of the Ceramic Tile Institute of America (CTIOA) hereby endorses the following:

(1) The variable-angle ramp human traction test method as the primary standard for validation of portable slip-resistance test methods

(2) The Tortus dynamic slip resistance measuring instrument, with digital data acquisition, for wet testing, and the use of a trace of Triton X-100 wetting agent in distilled or deionized water (three drops per 250 milliliters) as the wetting liquid

The following minimum average dynamic coefficients of friction for safety based on Tortus measurements with a Four-S rubber slider on clean flooring, wet, with measurements in at least four directions, each measurement direction having a preferred total path length of 20 cm (8 inches):

(a) 0.50 for level floors (i.e., not ramps) that may get wet in use

(b) 0.70 for bathtubs, showers and swimming pool decks

(3) The pendulum dynamic slip resistance measuring

instrument for wet testing (without wetting agent), and the use of the pendulum test guidelines recommended by the United Kingdom Slip Resistance Group

A minimum British Pendulum number, BPN, on wet clean flooring, of

(a) 35, using a Four-S rubber slider, for level floors that may get wet in use

(b) 35, using a TRRL rubber slider, for showers and pool decks

Use 3M 261X Imperial pink lapping film on float glass (or a similarly smooth, flat surface) as a calibration check surface for both Tortus and pendulum.

Preference is for the pendulum in locations where some pedestrians (either adults or children) may reasonably be expected to be running rather than walking. On level flooring, in case of conflict between Tortus and pendulum findings, preference is for the pendulum. Higher slip resistance minimums may be appropriate in many situations, such as ramps, environments where lubricants other than water are present, etc.

The two portable instruments are recommended because they have achieved wide acceptance, and because data are now available to show that they correlate well with tests of human traction, and with well-simulated mechanical analogs of human traction.

The Tortus is less time-consuming per test than the pendulum. The Tortus is therefore more suitable for periodic testing of a floor (e.g. quarterly) and for checking uniformity of an area using repetitions covering various zones across the area. The slider speed of the pendulum is higher, making it possibly more conservative in evaluating hydroplaning potential.

We request that manufacturers of hard and resilient flooring offered for sale in the United States supply potential buyers with pendulum test data for the manufacturers' products by June 1, 2003. As a substitute for the pendulum test, manufacturers may use any alternative slip test method, or combination of tests and calculations, that is scientifically proven to predict the results of the pendulum test or to be as good as, or better than, the pendulum test or the variable-angle ramp test as an indicator of human traction potential on wet flooring. Any such test device or method must be commercially available so that field tests by other parties are feasible.

These portable tests are intended to replace the horizontal pull-meter test, American Society for Testing and Materials Method C 1028-96, that U.S. ceramic tile manufacturers currently use for field testing of their products.

These test methods and the safety standards that are based on the test results are useful in field testing of flooring in ceramic tile, vinyl and linoleum, natural stone, terrazzo, concrete, wood, and other

common types of flooring.

This endorsement does not preclude use of other existing or improved portable test methods as long as they demonstrate a correlation coefficient R of 0.90 or higher, with human traction measurements using the ramp method, on a population of at least 14 samples well-distributed over the ramp test categories R9 through R 13.

Buyers of *new* flooring should use the safety standards endorsed by the Committee on September 19, 2001. Those standards are based on laboratory tests using the variable-angle ramp method, which is not suitable for field tests.

Introduction

The Slip Resistance Committee of the Ceramic Tile Institute of America ("the Committee") is tasked to advance and disseminate scientific knowledge of slip and fall issues in order to improve safety of walkway surfaces in the built environment, including floors, stairs, and pedestrian ramps.

Pedestrian slips occur from an unfavorable combination of the person involved, the activity the person is involved in, the environment, the footwear (if any), and the flooring. Most slip accidents occur when the footwear or bare feet and/or the flooring are wet or otherwise lubricated. Some manufacturers of flooring and floor coatings presently offer as catalog information slip resistance test results, dry and/or wet, based on test methods standardized by the American Society for Testing and Materials (ASTM).

Experience with U.S. test methods and safety standards for prevention of slip and fall accidents shows that improved test methods and safety standards are necessary. National Safety Council statistics indicate that some 1200 Americans die each year — an average of one death every seven hours — as a result of slip-and-fall accidents on the same level (not on a ladder, stairs, etc.). In the workplace alone, in 1998 slips and falls caused 313,335 injuries (an average of one every two minutes) and over $4 billion (or $340,000 per hour) in workers' compensation and lost productivity (Ref. 1). Too many floors are potentially slippery under their normal conditions of use. The requests and recommendations here are in the interest of public safety.

On September 19, 2001 the Slip Resistance Committee approved "Endorsement of Improved Test Methods and Slip Prevention Standards for New Flooring," available from the Ceramic Tile Institute of America (telephone 1-310-574-7800). It endorsed a laboratory test method for rating slip resistance of new flooring. However, that test is not suitable for field testing of existing floors. The portable methods discussed here are suitable for field testing. We base the designation of portable test methods on their correlation with measurements of *human traction* as determined by the variable-angle ramp test. This test assesses human traction on wet or

otherwise lubricated surfaces through repetitions of controlled walking by two or more human subjects on a five-square-foot sample. The test determines the *critical angle,* for each flooring sample, at which it is not possible to walk on that sample without slipping. The larger the critical angle is, the greater is the potential for human traction on that sample.

To be acceptable, trends that a portable test method determines must give reasonable mathematical correlation with results from the variable-angle ramp method. It's not necessary that both methods give the same *numerical value* as output for a given sample. For instance, suppose that the critical ramp angle for Sample A is 5 degrees and for Sample B is 10 degrees, while the portable test output for Sample A is 0.40 and for Sample B is 0.80. As long as the portable test results can be used to predict, mathematically, the ramp test results to reasonable accuracy, the portable test is deemed acceptable.

Portable Test Methods

Portable test methods have several potential uses:

1. Periodic checks on existing flooring to confirm safe condition and maintenance (procedures and floor-care products) of the floor
2. Investigation of accidents and of complaints
3. Routine manufacturing quality control by flooring manufacturers

For slip resistance of all types of hard, resilient, and wood flooring we recommend the Tortus method and/or the pendulum method. Both, along with the variable-angle ramp method, are national standards or final draft national standards for wet tests in many nations (the pendulum in 21 nations, the Tortus in 19; Refs. 2, 3). They are also both included in the International Standards Organization (ISO) Draft International Standard 10545-17. The United States is a member of ISO.

The two methods have different advantages. Testing by Ceramics Research, Ltd. in Stoke-on-Trent, England, indicates that both of these methods show good correlation with test results from the variable-angle ramp test, which measures human traction potential as assessed by human subjects in walking tests. (Statistical correlation coefficients, R, of 0.90 or higher.) Both methods also show good correlation (R of 0.93 or higher) with the SATRA STM 603 tester, a computerized device which uses a complete shoe that moves with respect to the flooring. The SATRA test is a realistic simulation of human traction, but because it is done by machine it eliminates the element of human variability.

A very fine abrasive film, 261X Imperial pink lapping film sheets from 3M Company, should be used as a high-end calibration check for both instruments. This film, with a roughness of about three microns peak to valley, has good quality control and so yields

consistent results. For testing, the film should be placed on float glass or similar smooth, flat surface.

New ceramic tiles are sometimes shipped with a protective waxlike coating. Before testing, clean new tiles with Hillyard's Renovator (Hillyard Industries, St. Joseph, Missouri) at a dilution of one part Renovator to eight parts warm water. Scrub using this solution and a soft brush, then rinse thoroughly.

Tests on existing floors should include both high- and low-pedestrian-traffic areas, and areas of visibly noticeable differences in wear, texture, or color. For high-traffic areas, entrances, exits, and zones where pedestrians make turns or accelerate are preferable.

Tortus method. The Tortus is a computerized, battery-driven cart about the size of a bathroom scale. It has a 3/8-inch-diameter slider of laboratory-grade Four-S rubber. The liquid for wet tests is demineralized water with a trace (three drops per 250 milliliters) of Triton X-100 wetting agent (available from chemical supply houses; the wetting agent is not used in pendulum testing).

The Tortus is manufactured by Severn Science (Instruments) Ltd. in Bristol, England. The Tortus crawls across the floor at 2/3 inch per second, continuously measuring dynamic coefficient of friction (DCOF). It prints a continuous trace of the DCOF together with a calculated average. The Tortus was invented by Ceramics Research Ltd. and has a history of over 20 years of use. In more recent years, digital data acquisition has greatly improved the accuracy of Tortus test results.

The Tortus is generally repeatable to 0.02 in coefficient of friction over the same path. This is four percent of the level-floor safety standard recommended here, and two percent of the safety standard for swimming pool surrounds.

The test method is given (except for use of the wetting liquid in wet tests) in Ref. 3. The Tortus should be calibrated at each location where it is used, immediately preceding the start of testing. At least once a week when in use, the Tortus reading should be checked on 3M Imperial lapping paper obtained from a reputable supplier. When testing flooring, take an average of readings in at least four different directions (e.g., north, south, east, west). Each of these four readings should be an average over a total path length of 8 inches (20 cm). This may be on the diagonals of 8-inch-square tiles, or may combine measurements on diagonals of smaller tiles.

Pendulum method. The United States National Bureau of Standards devised the pendulum method. British researchers developed it further (Ref. 4), and the American Society for Testing and Materials (ASTM) specifies the pendulum in its Method E 303-93 (1998). Australia and New Zealand have established the pendulum as the standard for wet testing and the Tortus for dry testing. The pendulum test procedure we endorse is that specified by the United Kingdom Slip Group (Ref. 5). The slider is three inches wide, one

inch wide in the direction of travel, and covers a path five inches long.

Pendulums are available from two companies in England: Wessex Engineering Ltd. (located in Weston Super-Mare) and Munro Group (Woodford Green, Essex).

Comparison of Tortus and pendulum. The pendulum's rubber slider strikes the floor at eight miles per hour, about 200 times faster than the movement of the Tortus slider. The pendulum's slider speed is close to that of a typical young adult's body when running at a sustainable pace. The Tortus' slider speed is typical of the speed of a person's heel when it first lightly touches down in normal walking. The Tortus' slower speed might to some extent be compensated for by the addition of a trace of wetting agent in the water for wet testing. In addition to aiding in uniform wetting, the wetting agent makes the water a better lubricant. This may make hydroplaning possible at lower speeds on a smooth surface. Tests by CERAM in the United Kingdom show good correlation ($R = 0.94$) between pendulum and Tortus test results for ceramic tile (17 samples).

The operating procedure for the Tortus makes it possible to conduct many more tests in a given amount of time. This is an advantage in testing of areas for nonuniformity that results from poor production quality control, wear, or inappropriate maintenance. Some owners (or their agents) of commercial or industrial property have their floors' slip resistance tested quarterly to confirm that the floors are safe despite possible changes in floor-care chemicals, personnel, or procedures. We recommend that periodic Tortus tests, with safe ratings or remedial action to restore the floor to safe ratings, be accepted as due diligence for commercial and industrial property owners with respect to documenting the safety of their floors. The Tortus is also more suitable for testing curved surfaces, such as the bottoms of some bathtubs.

The higher speed of the pendulum may make it more suitable for areas where pedestrians may reasonably be expected to run: airport concourses, subway, bus and railroad stations, lobby areas where doors stand open during rainfall, swimming pools used by children, etc.

In litigation it may sometimes occur that there is a conflict between findings from the pendulum and the Tortus regarding whether flooring was safe when wet. In such cases we recommend that the pendulum take precedence. This is because of its acceptance by the United Kingdom Slip Group and Standards Australia/Standards New Zealand after extensive study. In the absence of pendulum results, we recommend acceptance of Tortus data.

Both pendulum and Tortus should be calibrated at least annually by an appropriate third party, preferably one with ISO certification for calibrations.

<u>This endorsement does not preclude use of other existing or</u>

improved portable test methods as long as they demonstrate a correlation coefficient R of 0.90 or higher, with human traction measurements made using the variable-angle ramp method, on a population of at least 14 samples, This allows for advances in the state of the art within the constraint that new measurements must be proven relevant to human traction. Any form of curvefit may be used to derive an equation from which to calculate R-squared; R is the square root of R-squared.

Values of R near 1 indicate that the curvefit is very useful for making predictions of the critical ramp-test angle for a sample using the results from the portable test method. Standard textbooks on elementary statistics describe the parameter R and how to calculate it. Widely-available software such as Microsoft Excel makes it easy to calculate curvefits and R.

Safety Standards

Different test methods yield different *numerical* results for the same sample, even if the test results are all converted to coefficients of friction. For instance, a sample that has a coefficient of friction of 0.60 (corresponding to a BPN of 55; see Ref. 4) on the high-speed pendulum using Four-S rubber gives a coefficient of friction of approximately 0.80 on the low-speed Tortus using the same rubber. This means that safety standards must depend on the test method that is used. Below are a few recommended minimum safety standards. For certain situations, higher minimums than these are appropriate; see Ref. 7.

Tortus. The traditional Tortus dynamic coefficient of friction safety standard of 0.40 minimum for most level floors is too low, and leads to passing grades for unsafe floors. We recommend a minimum average of 0.50 for any level floor that is likely to become wet. The average should include measurements in at least four directions, each measurement having a preferred path length of 20 centimeters (3 inches). No single 20-centimeter path at any one location on a floor should have an average of less than 0.38. This is based on the former safety criterion of 0.40, with allowance for a measurement variation of 0.02.

For bathtubs, showers and swimming pool decks we recommend a minimum average of 0.70 (Ref. 8). The high standard is desirable because of soapy water in baths and showers; and presence of suntan oil and body fats on swimming pool decks, as well as children running.

Pendulum. Following the lead of the United Kingdom Slip Group and Standards Australia/Standards New Zealand, we recommend a minimum British Pendulum Number (BPN) of 35 (when testing with a Four S rubber slider) for any level floor that is likely to become wet in use. For showers and swimming pool decks we recommend a minimum BPN of 45 (Ref. 9) when testing with Four-S rubber. However, for barefoot areas pendulum testing with TRRL rubber as

specified in Ref. 3 is preferable, and for showers and pool decks the BPN with TRRL rubber should be 35 or higher. Softer than Four-S rubber, TRRL rubber better simulates bare feet.

Catalog Data

We have previously requested that ceramic tile manufacturers supply catalog data for slip resistance categories based on the variable-angle ramp test or equivalent (Ref. 6). Pendulum data could be substituted for, or could supplement, the ramp data. Pendulum data can help manufacturers and building owners confirm that the tile delivered conforms to the manufacturer's specification. Such data can also serve as a benchmark for future periodic testing.

We request that manufacturers of hard and resilient flooring offered for sale in the United States supply potential buyers with pendulum test data for the manufacturers' products by June 1, 2003. (Tile manufacturers in leading tile-manufacturing countries China, Spain, Italy, and Germany already offer such data.) As a substitute for the pendulum test, manufacturers may use any alternative test, or combination of tests and calculations, that is scientifically proven to predict the results of the pendulum test or to be as good as, or better than, the pendulum test or the variable-angle ramp test as an indicator of human traction potential. Any such test device or method must be commercially available so that field tests by other parties are feasible.

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