Procedures for Evaluating Bathing Facility Slip and Fall Accidents

by
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Bathing facility slip and fall injuries are a significant part of the great number of slip and fall accidents that occur each year in the United States. As a consequence, they are an important factor in personal injury allegations in both litigation and insurance claims. One of the key problems faced both by attorneys and insurance adjustors, however, is sufficient proof that the facility at which the accident took place was inherently dangerous and not caused by any inappropriate action on the part of the injured. And the key suspect in the search of this proof is the slip resistance of the surface of the bathtub or shower.

The American Society for Testing and Materials (ASTM) standards for evaluating the slip resistance of walkway and bathing facility surfaces are accepted, almost universally, by experienced and reliable slip and fall experts in the United States. The protocol for testing bathing facility surfaces is contained in ASTM Designation F 462 that is entitled "Standard Consumer Safety Specification for Slip-Resistant Bathing Facilities" [1].

This standard was published in 1976 by ASTM Task Group 15.03 and was developed specifically for wet, soapy bathing surfaces consisting of either combined bathtub/shower or shower stalls alone and for a test material that resembles the texture of the bottom of the human foot as closely as possible. The standard is based on test results from 50 different bathtub and shower surfaces with such surface materials as porcelain enamel, acrylic, terrazzo, ceramic tile, synthetic castable marble, sheet molding compound, pressed steel, cast iron, and fiber glass reinforced plastic.

2.0 DEFINITION OF COEFFICIENT OF FRICTION AND SLIP RESISTANCE

A number called the *coefficient of friction* (COF) identifies the slipperiness of a surface and, hence, the safety of that surface for walking.. The COF is equal to the frictional force [along the walking surface] divided by the vertical force (generated by the walker) that acts perpendicular to the surface contacted by the bottom of the foot. It is a measure of the relative difficulty with which the surface of one material (the shoe bottom or bare foot) will slide over the adjoining walking surface. The *static* COF is determined by the force requiring initiation of movement of one surface (the foot) COF relative to the walking surface. The force maintaining this movement determines the *dynamic COF*. The dynamic COF

For both static and dynamic conditions, the COF is measured by test instruments that are designed to simulate, as closely as the possible, the motion of the foot at either the inception of slip (static) or during slip (dynamic).

For the purposes of this paper, it is important to recognize the difference in the definition of coefficient of friction and *slip resistance* (SR). The COF and SR are measured in an identical manner. The intention of the measurement, however, is different. The COF is a scientific number that determines the ratio of the horizontal and vertical force acting to initiate or maintain motion of an object sliding on a surface. Slip resistance, for the purposes of ASTM F 462 is the property of a bathing surface that acts in opposition to the forces and movements exerted by the bather under all conditions of bathing and showering that can result in uncontrolled sliding and falling.

Slip resistance must incorporate a measured COF that encompasses both the anticipated physical movement and psychological mood of the bathing facility user. As an example, some very slippery surfaces can be safely traversed if the walker is aware of the hazard and assumes the appropriate stride and caution. It is possible that one can safely rise in soapy water in a bathtub without grab bars or other supports if it is done carefully. Similarly, it is possible that one can step into a smooth soapy surfaced shower stall if extreme caution is used. In the previous examples, the user must have prior knowledge of the hazard and the physical dexterity to overcome the hazard. It is, furthermore, highly probable that the measured COF in these instances would be below the acceptable threshold. The point is that the normal bather does not use extreme caution in entering a bathing facility; hence, accommodations must be made by the manufacturer and installer of the facility to provide a surface that will allow safe use without unreasonable caution. In ASTM Standard F 462, the desired slip resistance is equal to the value of the COF that will allow safe movement across the surface of a bathing facility without undue caution on the part of the user. This value has been determined to be equal to a static COF of **0.04** or above.

It is generally agreed by most slip and fall experts in the United States that a walkway should be considered safe for normal pedestrian travel if the static COF is equal to a minimum value of 0.50.
Walkway safety increases with increasing values of the COF above the minimum of 0.50 and decreases, as the values get lower. The longer the length of the stride the greater the numerical value of slip resistance or COF of a walkway required to avoid a slip and fall accident. The shorter the stride, the lower the numerical value of required slip resistance. As an example, women wearing high heel shoes usually take shorter steps than with flat soles and heels and, hence, require a walkway slip resistance value or COF of approximately 0.4 to avoid slipping. Values of slip resistance below 0.3 however, are indicative of hazardous surfaces regardless of stride.

The requirement for a number as low as 0.04 as a minimum safety criteria for bathing facilities confuses not only some experienced experts but authors of well known slip and fall textbooks as well. It is believed their confusion stems from the fact that they have not studied the development of the standard or assume they are reading a misprint; i.e., that the slip resistance minimum should be 0.40 instead of 0.04. As a consequence, it is deemed prudent to discuss the prominent details in the development of ASTM F 462 so as to give a clearer understanding of the development of this standard to personal injury attorneys and experts as well.

Despite the fact that bathers take shorter steps in a bathing facility, the slip resistance number of 0.04 is so low compared to the minimum safe value for normal walking that it is obviously based on factors in addition to the anticipated length of a stride in the tub or shower. This is discussed below.

3.0 SAFETY STANDARD DEVELOPMENT

3.1 Initial Conception-Safety standards for bathing facilities were initially conceived in the period between 1973 and 1976 under the guidance of ASTM Task Group 15.03. To initiate the work, the ASTM on December 6, 1973 wrote to approximately 250 organizations involved in the plumbing industry to advise them that, in response to the Consumer Product Safety Act, ASTM had created Committee F-15 on Consumer Product Safety. The objective of the committee would be the development of voluntary standards for specific consumer products that had been identified as hazardous. Since bathtubs and showers had been identified as hazardous products, representatives of the plumbing industry were invited to participate in the development of safe standards for the use of bathing facilities [3]. In 1973, the Consumer Product Safety Commission (CPSC) identified bathtub and shower structures as 14^{th} on the CPSC Product Hazard Index [2].

On the basis of available accident data, four task groups were formed which were to evaluate slipperiness or slip resistance, grab bars, burns and scalds, and information and education. The first ASTM standard for evaluating the slip resistance of bathing facilities (ASTM F 462) was written in 1976.

3.2 Research Initiation In the period between 1973 and 1975, the CPSC commissioned a research project by Abt Associates of Cambridge, Massachusetts to evaluate the National Electronic Injury Surveillance System (NEISS) regarding the safety of bathtubs and shower facilities [3]. The Abt study indicated that (1) bathtubs far exceeded shower stalls in accident potential as based on absolute frequency and severity of injuries (as established by over 110,000 bathtub and shower accidents each year in America) and (2) slips and falls were by far the most recurrent type of bathtub accidents and most frequently occurred while entering or leaving a tub or while changing from standing or sitting position.

As denoted in [4], it was in the spring of 1975 that the chairman of Task Force 15.03.01 contacted the Building Safety Section (BSS) of the then National Bureau of Standards.(NBS) to review NBS current work on slip resistance of walkway surfaces and to help define the necessary effort. At this point in time, the NBS Brungraber Slip Resistance Tester had been developed as a portable on-site alternate to the laboratory confined James Machine. Following a period of the orientation of the BSS staff as to the specific problems associated with measuring slip resistance in tubs and showers, the combined efforts of the NBS and Task Force 15.03.01 defined the following objectives and test procedures [4].

3.3 Task Group Objective-The objective of the Task Group was to develop a performance test for measuring the slip resistance of bathtub and shower base surfaces representative of typical worst case conditions of normal use, discriminated among various tub and shower surfaces, and was operator independent, easy to carry out under laboratory or field conditions, and relatively inexpensive. The target for the test procedure was as follows:

(1) Select an appropriate slip tester.

(2) Choose a foot bottom surrogate (*sensor*) material that most closely represented the skin on the bottom of the human foot.

(3) Develop a means for selection and control of the test environment in that the environment should represent bathing facility surfaces under wet and soapy conditions.

(4) Develop a test protocol in the test environment with the tester selected..

(5) Evaluate validation tests and pass/fail criteria.

3.3.1 Tester Selection-Three available testers were evaluated which were (1) the drag type tester as represented by the Horizontal Pull Slipmeter; (2) the pendulum type as represented by the Sigler Pendulum and the British Portable Skid Tester (BPST); and the articulated strut devices as represented by the James Machine.

The Subcommittee F 15.03 rejected the foregoing devices in August 1976 for the following reasons;

(1) The Horizontal Pull Slipmeter (HPS) and similar devices were rejected because it was believed that the extremely small sensors used with this type of tester (1/2" diameter) would not yield realistic results on textured or appliquéd surfaces; (2) the extended time delay that is a feature of these type of testers would introduce adhesion between the bathing surface and the bottom of the sensors (which was not apt to develop in actual bathing circumstances) and would yield a higher than actual COF reading; and (3) The use of an electric motor on the HPS was an undesirable feature of a tester that had to be partially immersed in a liquid soap solution.

(2) The Sigler Pendulum and BPST are similar in that the BPST is a refinement of the earlier Sigler tester. These testers were rejected because there are dynamic mechanical devices that are supposed to simulate the skidding of a vehicle on a roadway. This type of action was considered inappropriate in simulating the accidental motion of the foot on the surface of a bathing facility. The basic purpose of these testers is to measure the energy loss of a pendulum after it strikes a surface and relate this to a single value of the dynamic COF. Slow motion photography also showed that the normal pressure resulting from the operation displayed a significant variation across the tested surface. This resulted in a corresponding variation in the dynamic COF wherein the actual average of these variations could not be determined by any reasonable analysis.

The James Machine is not applicable to surfaces of actual bathtubs or shower bases. It can only be used on small specimens of fairly limited thickness range and was designed for and limited to a laboratory environment. The Brungraber Mark I Slip Tester (then called the NBS-Brungraber Portable Slip Resistance Tester) is based on the same principle as the James Machine and, for normal purposes, can be called a portable James Machine. Its portability and size, however, allow it to fit within a relatively small area in bathtub or shower so that it can be used to make measurements over a number of adjacent areas as required by ASTM F 462.

On the basis of the tester evaluation, only two machines were found acceptable to the Task Group. These were the Brungraber Mark I and a machine called the "Kollsman Tester Mark I". The latter tester was developed by Paul Kollsman as part of his effort to produce an appliqué that would improve the slip resistance of bathtubs and showers. The task group then asked the BSS to conduct a series of tests to select one of these two testers.

The conclusion of BSS on the basis of the tests was that, while both testers were sufficiently sensitive in discriminating between different bathing surfaces on the basis of slip resistance, the Brungraber Mark I was preferable because (1) it was more convenient to use and maintain; (2) it was suitable for use in actual bathtub or shower stalls as well as on specimens of shower or tub surfaces; and (3) it could be calibrated against a reliable standard over the entire anticipated range of slip resistance values estimated for the particular facility being tested.

3.3.2 Sensor Material In the evaluation of a suitable sensor material, it was required that the sensor have the following attributes:

(1) Random specimens of the same material should yield consistent slip resistance values within an acceptable range over an extended period of usage.

(2) It should provide acceptable discrimination between the slip resistances of different surfaces in that the slip resistance between the least and most resistant materials should be relatively large.

(3) It should be readily attachable to any Brungraber Mark I tester to be used and require a minimum of preparation prior to use and minimum care between use.

(4) It should be reasonably inexpensive and easily obtainable.

(5) It should represent, as closely as possible, the skin on the bottom of the human foot.

Within the time available and, on the basis of test comparisons of several materials, the sensor selected was a medical grade elastomer identified as Dow Corning Silastic No. 382. Because it was of medical grade, it was manufactured under very rigid constraints and, consequently, was accepted to meet the requirements of consistency in slip resistance values and to display the desired slip resistant discrimination between different surfaces. Furthermore, since it was used as a simulated skin covering in artificial limbs, it also met the requirement to emulate the bottom of the human foot.

3.3.3 Test Environment The decision for the selection of the test environment was that it should realistically represent a safe environment for bathtub and shower surfaces under wet, soapy conditions where a person was washing one foot at a time or someone was stepping into a shower immediately after another person had used the shower.

After a significant amount of testing including the use of two well known soap chemists as consultants, the soap solution finally selected met Federal Specification P-S-24g or ASTM Specification for Liquid Soap [D799-74]. This liquid was to be mixed as one part soap to four parts of distilled or ionized water [1]. This resulted in a very soapy and stable mixture that lasted over a period of time sufficient to prevent curd from developing during the test period.

3.3.4 Test Protocol The protocol for testing required (1) that the tub or shower base should be supported and spatially oriented as installed in a bath or shower room; (2) the area to be tested should be divided in nine sub-areas; (3) the test area should be thoroughly cleaned, the drain plugged and sufficient soap solution introduced to cover the test area; (4) two measurements should be taken in each region for a total of 18 measurements; and (5) finally, each region of the test surface should show a COF measurement of **0.04** or above. If the average of any of the two measurements in each of the nine test areas does not meet the minimum value of 0.04, the entire surface should be rejected as hazardous for safe bathing.

3.3.5 Validation and Selection of Pass/Fail Criteria In the development of the standards, the Task Group tested and rated 50 different bathtub surfaces from gel coated fiberglass to a porcelain enameled steel textured surface. Testing was conducted at the Owen-Corning Fiberglass Company in Granville, Ohio [5] during the period of May 17 to 21, 1976. The Brungraber Mark I Slip Resistance Tester was used for all testing using a Silastic 382 sensor as the surrogate human foot bottom for walking or standing under simulated bathing conditions and with the specified liquid soap and mixture denoted in 3.3.3 above. Despite the fact that the ASTM F 462 Standard currently requires two measurements each in nine different areas of the bathing surface, only six areas of two measurements each were used in the tests. Measured COF values ranged from 0.003 to 0.417. As a result of the testing, an acceptable standard for slip resistance was set at a minimum of 0.04 that the untextured surfaces that were tested could not meet.

3.3.6 Rationale for the Selection of a Standard of a Minimum COF of 0.04 The rationale for selection of the 0.04 minimum COF standard was that the overwhelming majority of bathing surface slip and fall accidents occur on untextured or untreated surfaces. Therefore, the Task Group decided that the standard should be set at a higher COF value than the highest COF value obtained on the untextured surfaces that were tested. The higher value was set at twice the static COF (rounded to the nearest hundredth unit) for the untextured surface on which the highest COF was obtained. In actuality, the highest untextured COF was 0.02. that was doubled to be 0.04. This was done to provide a high probability of not slipping on an untextured surface. This approach also compensated for the difficulties in measuring such low values of COF. The selection of this level of performance was acknowledged to be a conservative approach, erring, if all, on the side of safety.

3.3.7 Summary of Slip Resistance Tests A summary of the slip resistance testing is presented in Table 1. The first column gives the rank based on the minimum value that is the lowest of the average of the two readings taken in any of the six measurement areas. The lowest of these averages for any of the 50 surfaces is ranked as number 1 and the highest as number 50. The second column describes the type of surface tested. The third column shows the minimum COF as based on the lowest average of the two readings taken in any of the six measurement areas. The number shown under the code in the last column identifies the manufacturer of the specific item tested. Only the Material Bureau of Standards, the organization that was conducting the tests, knew the entire series of codes.

Each manufacturer providing test products was given their code at the time they received test data on their product. Thus, the manufacturers who provided products for testing, (1) knew their code number; (2) could determine the ranking of their products; and (3) could compare their product(s) with other products without knowing the identity of the manufacturer.

Table 1 indicates that only 27 of the 50 bathing surfaces passed the criteria of a COF equal or greater than 0.04. Nine of the 23 failed surfaces were textured surfaces indicating that a bathing surface may not be safe despite the fact that it is textured. Instead, ASTM F 462 should be used to test all new textured bathing surfaces prior to production.

TABLE 1

SLIP RESISTANCE TESTS OF 50 DIFFERENT BATHING FACILITY SURFACES

(Owen Corning Fiberglass Company, Granville, Ohio May 17 to May 21, 1976)

RANK	SURFACE DESCRIPTION	MINIMUM COF	CODE
1	Gel Coat Fiber Glass Reinforced Plastic Smooth	0.003	36
2/3	Gel Coat Fiber Glass Reinforced Plastic Smooth Tub/Shower	0.003	6
2/3	Acrylic Smooth	0.003	28
4	Fiber Glass Reinforced Plastic Smooth	0.004	24
5	Porcelain Enamel Pressed Steel Smooth	0.004	22
6	Gel Coat Fiber Glass Reinforced Plastic Smooth	0.006	48
7	Acrylic Smooth	0.009	31
8	Porcelain Enamel Pressed Steel Smooth	0.009	12
9	Gel Coat Smooth Tub/Shower	0.009	32
10	Porcelain Enamel Cast Iron Smooth	0.010	8
11	Gel Coat Fiber Glass Reinforced Plastic Smooth Tub/Shower	0.013	5
12	Gel Coat Fiber Glass Reinforced Plastic Smooth	0.014	18
13	Porcelain Enamel Pressed Steel Textured	0.015	9
14	Gel Coat Fiber Glass Reinforced Plastic Smooth	0.017	39
15	Gel Coat Fiber Glass Reinforced Plastic Textured Tub/Shower	0.019	52
16	Gel Coat Fiber Glass Reinforced Plastic Textured Shower	0.026	49
17	Porcelain Enamel Pressed Steel Textured	0.030	13
18	Gel Coat Fiber Glass Reinforced Plastic Textured Shower	0.030	4
19	Porcelain Enamel Cast Iron Textured	0.031	26
20	Acrylic Textured Tub/Shower	0.032	14
21	Porcelain Enamel Pressed Steel Textured	0.033	38
22	Gel Coat Textured	0.037	20
23	Gel Coat Fiber Glass Reinforced Plastic Textured Shower	0.039	51
24	Gel Coat Textured Shower	0.040	30
25	Sheet Molding Compound Textured	0.050	42
26	Porcelain Enamel Pressed Steel Textured	0.068	37
27	Sheet Molding Compound Textured	0.069	41
28	Ceramic Tile Shower	0.075	35
29	Gel Coat Fiber Glass Reinforced Plastic Textured Shower	0.077	50
30	Porcelain Enamel Cast Iron Textured	0.087	25
31	Porcelain Enamel Cast Iron Textured	0.094	7
32	Gel Coat Fiber Glass reinforced Plastic Textured Shower	0.097	17
33	Synthetic Castable Marble Textured Shower	0.106	46
34	Porcelain Enamel Pressed Steel Textured	0.118	10
35	Synthetic Castable Marble Textured Shower	0.136	47
36	Porcelain Enamel Pressed Steel Textured	0.142	21
37	Sheet Molding Compound Textured	0.154	40

38	Porcelain Enamel Pressed Steel Textured	0.164	29
39	Acrylic Textured Shower	0.202	16
40	Porcelain Enamel Pressed Steel Appliqué	0.203	44

TABLE 1 (C0NTINUED)

SLIP RESISTANCE TESTS OF 50 DIFFERENT BATHING FACILITY SURFACES

(Owens Corning Fiberglass Company, Granville, Ohio May 17 to May 21, 1976)

RANK	SURFACE DESCRIPTION	MINIMUM COF	CODE
41	Porcelain Enamel Cast Iron Appliqué	0.208	34
42	Porcelain Enamel Pressed Steel Textured	0.209	11
43	Porcelain Enamel Pressed Steel Textured	0.221	19
44	Terrazzo Shower	0.221	15
45	Porcelain Enamel Pressed Steel Appliqué	0.256	43
46	Gel Coat Fiber Glass reinforced Plastic Textured Shower	0.263	23
47	Porcelain Enamel Pressed Steel Textured	0.273	1
48	Porcelain Enamel Pressed Steel Textured	0.274	3
49	Porcelain Enamel Pressed Steel textured	0.411	33
50	Porcelain Enamel Pressed Steel Textured	0.417	2

REFERENCES

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2. ***F15.03 Safety Standards for Bathtubs and Shower Structures***, from the files of James H. Bower: Medina, Ohio (Member of ASTM Committee F 15.03).

3. Abt Associates: ***Executive Summary-A Systematic Program to Reduce the Incidence and Severity of Bathtub and Shower Area Injuries***, Cambridge, Massachusetts, 1975,

4. R. J Brungraber and S.C. Adler, ***Technical Support for a Slip Resistant Standard***, ASTM Special Publication 649, 1975.

5. Appendix A to Rationale for Consumer Product Safety Specifications for Slip Resistant Bathing Facilities, ***Summary of Slip Resistance Tests Conducted at Granville, Ohio (17-20 May, 1976)*** from the Files of James H. Bauer, Medina, Ohio, (Member of ASTM Committee F 15.03).