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A comparative evaluation of floor slip resistance test methods

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HIGHLIGHTS

- Three test methods for floor slip resistance were compared with user perceptions.
- A scale of user perception of floor surface slipperiness was constructed.
- The JIS A 1454 test method best represents footwear and floor surface conditions.
- JIS A 1454 results match user perceptions better than EN 13893 and ASTM D 2047.

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ABSTRACT

Floor slipperiness is among the most influential parameters affecting the life safety of users. However, slip resistance coefficients determined using some methods do not correspond well to the perception of slipperiness by real users. From a life safety standpoint, a suitable test method for the slip resistance of a floor surface reflects slipperiness as sensed by users. We compared the results of three slip resistance test methods and their correspondence with sensed slipperiness as reported by users. The JIS A 1454 test method was found to be a better test of slip resistance than EN 13893 and ASTM D 2047.

1. Introduction

Floor slipperiness is one of the most influential parameters affecting the life safety of users, and therefore, many researchers worldwide have sought to establish test methods for floor slipperiness [1–4]. To date, more than 100 different types of test methods and apparatus have been proposed [5–8], some of which are used in setting national standards. However, the slip resistance coefficients determined using some of these methods do not correspond well to the perception of slipperiness by real users [9–12]. From a life safety standpoint, a suitable test method for the slip resistance of a floor surface reflects slipperiness as sensed by users [13].

In this study, we compared the results of three slip resistance test methods that are used in setting typical standards with users' perceptions of floor slipperiness. We selected the following three test methods for comparison:

- European standard BS EN 13893:2002, Resilient, laminate and textile floor coverings—measurement of the dynamic coefficient of friction on dry floor surfaces.

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- US standard ASTM D 2047-93, standard test method for static coefficient of friction of polish-coated floor surfaces as measured by the James machine; and
- Japanese standard JIS A 1454:2010, Test methods—Resilient floor coverings.

Our evaluation procedure in this study was as follows:

(1) Select various flooring materials with various degrees of slipperiness as sample floors.
(2) With a panel of testers, conduct a sensory evaluation of the slipperiness while they perform a predetermined movement on the sample floors. Construct a psychological scale of slipperiness based on scaling theory using the responses of the panel of testers [14].
(3) Perform slip resistance tests on the sample floors in accordance with the methods prescribed in EN 13893, ASTM D 2047, and JIS A 1454.
(4) Evaluate and compare the suitability of the three testing methods by assessing the relationship between the values on the psychological scale and the results of the slip resistance tests.

2. Sensory evaluation of floor slipperiness and construction of a psychological scale

2.1. Summary of the sensory evaluations

The sensory evaluations are summarized in Table 1 and described in the following subsections.

2.1.1. Scale constructed and method of construction

The scale constructed is termed the "Sensed Slipperiness Scale" and expresses the slipperiness felt by a person while performing a predetermined movement.

The successive category method was used for scaling [14], with the seven levels shown in Table 1 as decision categories. Because the objective was to construct a scale that accurately classifies the relative degree of slipperiness of floor materials, a standard floor was set as the control. We asked the panel members to compare the slipperiness of the selected sample floors with that of the standard floor. A seven-point grading scale was adopted for our evaluation after preliminary experiments, which we found to be the most workable system. The seven-point grading scale was judged to be a statistically significant and highly accurate psychological scale for evaluating slipperiness.

Table 1
Summary of the sensory test.

Scale to construct	Sensed Slipperiness Scale
Scaling method	Comparison with a standard sample by the method of successive categories
Question to panel	How slippery did the sample floor feel compared to the standard floor while walking on it? Select an answer from the following seven options
Judgment range	(1) Very much more slippery (2) Much more slippery (3) Moderately more slippery (4) About the same (5) Moderately less slippery (6) Much less slippery (7) Very much less slippery
Footwear and floor surface condition	Four combinations: Hard-soled shoes on cleaned floor Hard-soled shoes on floor sprinkled with muddy water Socks on cleaned floor Slippers on cleaned floor
Panel members	12 male and female adults (see Table 3)
Movement	Walking

Table 2
Summary of the sample floors.

Sample floor No.	Floor material and surface texture
1	PVC sheet A, smooth surface
2	PVC sheet B, smooth surface
3	PVC sheet C, rough surface
4	PVC tiles A, smooth surface
5	PVC sheet D, rough surface
6	Tile carpet, smooth surface
7	PVC tiles B, smooth surface
8	PVC sheet E, rough surface
9	PVC sheet F, rough surface
10	PVC sheet G, smooth surface
11	Fluorocarbon polymer sheet, smooth surface
12	Wooden material flooring, smooth surface
Standard floor	PVC[a] tiles C, smooth surface

[a] PVC = polyvinyl chloride.

2.1.2. Sample floors

The 12 floor materials listed in Table 2 were selected for the sample floors, namely, seven different polyvinyl chloride (PVC) sheets, two different vinyl chloride tile materials, one type of tile carpet, a fluororesin sheet, and a wooden flooring. The size of each sample floor was set to 600 × 1800 mm to provide the panel members a large enough surface area to perform the predetermined movement.

The sample floor materials were selected to meet the following conditions:

- Provide a wide range of slipperiness, from "very slippery" to "not slippery at all".
- Use materials that remained consistent in slipperiness throughout the testing period; and
- Limit the number of materials to limit panel fatigue.

The standard floor used as the control was made of PVC tiles with moderate slipperiness.

The samples selected for this study were not intended to cover all types of flooring materials that are currently available. Instead, we selected materials that offer a range of slipperiness so that we could assess the relationship between the results of the panel study and measurements of slipperiness obtained using various test methods. Thus, the objectives of this study were achieved, regardless of the types of materials selected as samples.

2.1.3. Movement, footwear, and condition of sample floor surface

Walking was selected as the predetermined movement because it is the movement most commonly performed in buildings. The speed was left to the discretion of each panel member. The sole requirement was that each panel member walk on each sample floor at the same speed. The repetition of the movement was also unrestricted.

The three types of footwear used by the panel members were as follows: shoes with flat and relatively hard soles, cotton socks, and PVC heelless slippers. These represent commonly worn footwear in countries in which it is customary to remove one's shoes in the house, such as Japan and Korea. The hard-soled shoes selected for use had relatively slippery soles.

For tests conducted with shoes on, two floor surface conditions, cleaned and sprinkled with muddy water, were prepared. For tests with socks or slippers on, to represent the normal condition of interior floor surfaces, only a cleaned surface was prepared. The

Table 3
Characteristics of the panel members.

Panel member No.	Gender	Age	Body weight (kg)
1	Male	22	62
2	Male	25	58
3	Male	32	77
4	Male	42	85
5	Male	48	74
6	Male	54	88
7	Female	23	48
8	Female	29	45
9	Female	37	51
10	Female	38	55
11	Female	45	56
12	Female	56	52

Table 4
Analysis of variance (ANOVA) table.

		Footwear and floor surface conditions			
		Hard-soled shoes on cleaned floor	Hard-soled shoes on sprinkled floor	Socks on cleaned floor	Slippers on cleaned floor
Variance ratio	Main effect	36.97*	15.00*	63.38*	44.03*
	Individual variation	1.62	1.07	2.61*	3.07*
Contribution	Main effect	76%	51%	81%	74%
	Individual variation	1%	0%	2%	3%

* Significant at $p < 0.01$.

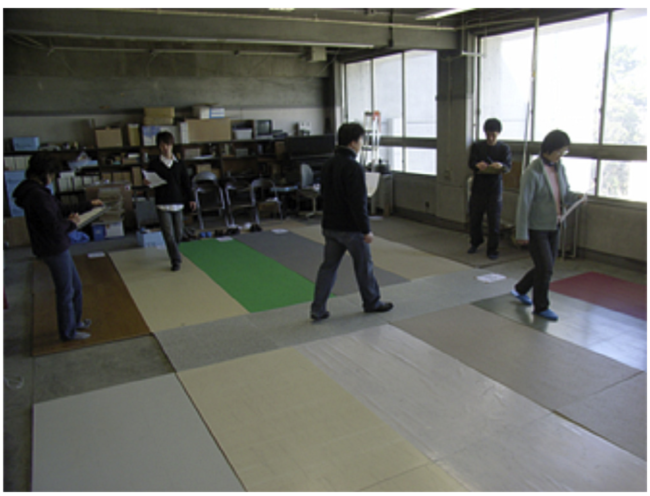

Fig. 1. Scene of the sensory test.

"sprinkled with muddy water" condition was produced by sprinkling a mixture of city water and JIS Z 8901 type 1-1 and 1-7 test powders at a ratio of 20:9:1 at 400 g/m^2 over the test floor surfaces. This condition was described by Ono et al. to be one of the most slippery conditions that may occur outdoors [15].

2.1.4. Test panel

The test panel was composed of 12 healthy adults ranging in age from 20 to 59 years. Table 3 summarizes the characteristics of the panel members. From a safety standpoint, assessing the perception of slipperiness by vulnerable persons, such as pre-school children and elderly or disabled persons is necessary. However, the objective of this study was to rank the sample floors according to their slipperiness and use the results in a comparative evaluation of slip resistance test methods, and a panel of healthy adults as defined above was deemed sufficient to accomplish this objective. Therefore, we did not include vulnerable persons, thereby avoiding exposing such persons to risk of harm.

2.2. Sensory evaluation, results, and the construction of the psychological scale

Under the conditions described in Section 2.1, the sensory evaluations were carried out, and responses were obtained from each member of the panel, with the following additional conditions. The sample floors were presented in a random order, the panel members were instructed not to take into account any aspects of the floors other than slipperiness, and the panel members were informed that they could take a break whenever they felt tired, provided that they reported this. Fig. 1 shows panel members in action performing the sensory evaluations.

The responses obtained from the panel members for each of the floor materials were analyzed using a two-way ANOVA, with the sample floor type and the panel members as factors. The results are shown in Table 4. The "main effect-to-individual variation variance ratio" expresses the ratio of the sample or panel variance to the error variance. The larger the variance ratio is, the greater the factor's effect is. The "main effect-to-individual variation contribution ratio" expresses the ratio of the net variation to the total variation. This ratio reflects the influence of each factor on the variation in the responses (the panel members' evaluations).

For every combination of shoes and floor surface types, the variance ratio of the main effect was highly significant, and the contribution was very high. These results indicate that the degrees of slipperiness of the various sample floors were significantly different and that there was a commonality in the judgments of the panel members, which demonstrates the validity of the experiment. The variance ratio of individual variation among panel members was found to have some significance, but its contribution was very low compared with that of the main effect. This indicates that although the constructed scale encompasses potential individual variation, it represents typical judgments concerning slipperiness appropriately.

Four scales for sensed slipperiness were constructed according to scaling theory [14] from the panel responses: shoes on a cleaned floor, shoes on a sprinkled floor, socks on a cleaned floor, and slippers on a cleaned floor. Assuming that the responses of the panel members for each study sample (in our case, the floor material samples) follow a normal distribution, contiguous ranges were quantitatively obtained by fitting the study data to a normal distribution. Each of these ranges was located over a regression curve, normalized with respect to the standard deviation of the answers. A psychological scale was then obtained by plotting each floor sample with respect to the corresponding responses' mean value. Because a psychological scale is an interval (or distance) scale, the origin, or "0 point," can be set discretionally. In this study, the range (4) was set as the 0 point.

Fig. 2 shows the relationships between the four Sensed Slipperiness Scales. Dotted lines (1) to (7) show the decision score range used for the sensory test over the Sensed Slipperiness Scale. In all cases, the two parameters are far from a good match, and the ranking of sample floors in terms of their slipperiness obviously varies according to the footwear and floor condition. These findings suggest a necessity to include parameters such as footwear and floor condition in slip resistance test methods.

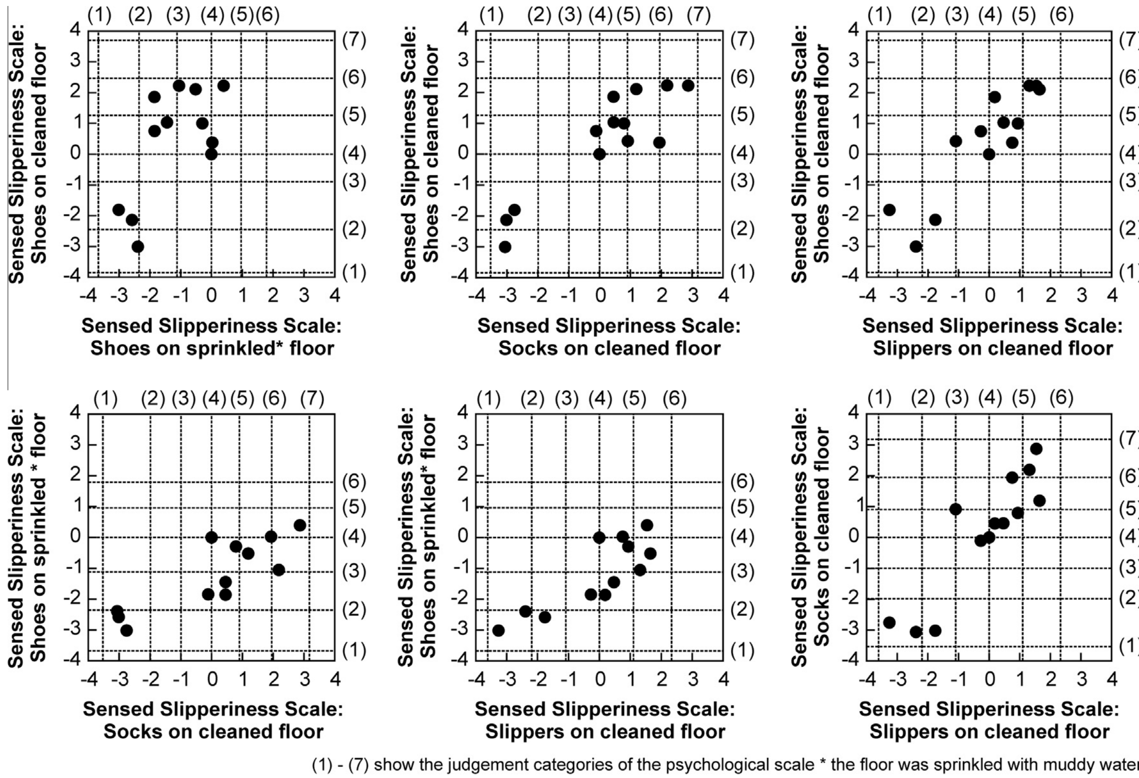

Fig. 2. Relationship between four Sensed Slipperiness Scales.

3. Sample floor slip resistance tests

3.1. Test prescribed in EN 13893

The test procedure, illustrated in Fig. 3, was as follows. A slider assembly was placed on the tested floor and pulled horizontally at a given speed while the tensile load was measured. The tensile load was divided by the slider assembly's vertical load to obtain the coefficient of friction μ. The total mass of the slider assembly was 10.0 ± 0.1 kg, and the pulling speed was 0.2–0.3 m/s. The tensile load was measured when the value was stable at a pulled distance of at least 0.3 m.

Three sliders, 2–6 mm in thickness, were placed on the bottom surface of the slider assembly, as shown in Fig. 3. The contact surface between the slider and the floor was 37.5 ± 2.5 mm in length and 10 ± 0.5 mm in width. The front edge of the slider was beveled at 35 ± 5°. Two of the three sliders, placed at the front, were leather sliders with a density of 1.0 ± 0.1 g/cm^3, constructed using Shore D hardness 60 ± 10 tanned leather. The back slider is a shoe-rubber slider constructed using Shore A hardness 95 styrene-butadiene rubber.

EN 13893 prescribes that the test be performed on a cleaned floor.

3.2. Test prescribed in ASTM D 2047

The ASTM D 2047 test uses a James Machine, shown in Fig. 4, to obtain the static coefficient of friction. A specimen is fixed to the test table, and a shoe, which has a load applied to it via a strut, is placed on the top of the sample. The test table is then moved

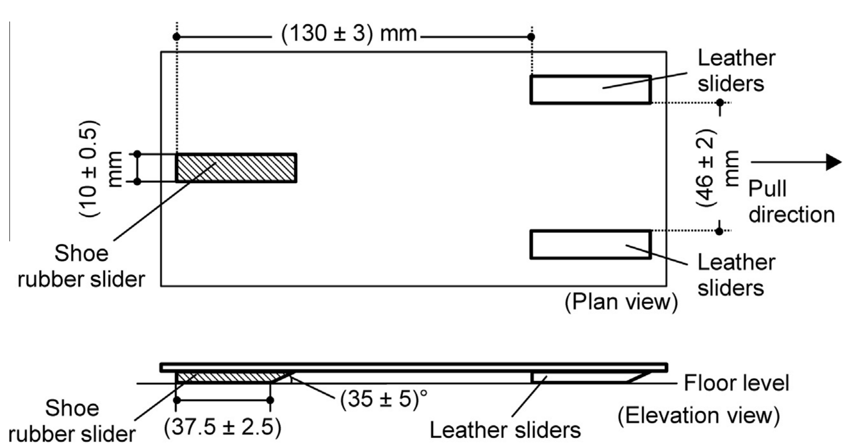

Fig. 3. Schematic drawing of the slider assembly prescribed in EN 13893.

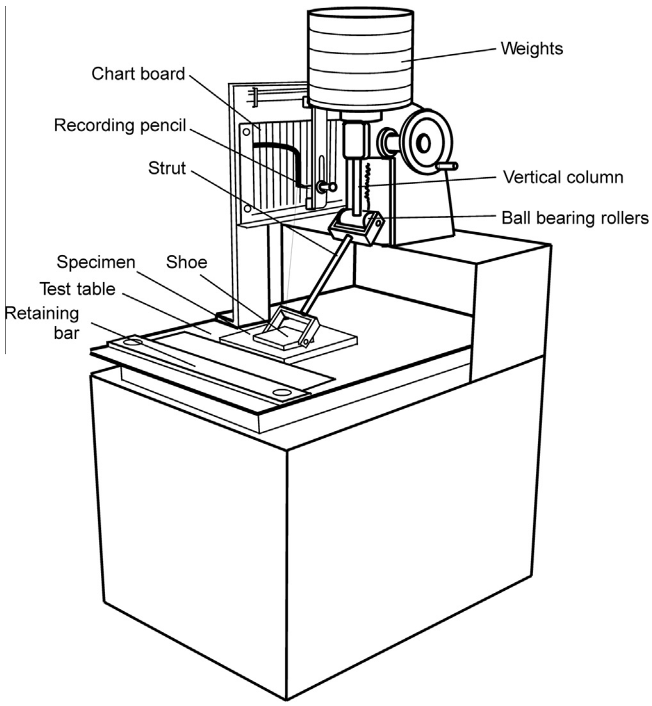

Fig. 4. Schematic drawing of the James Machine prescribed in ASTM D 2047.

horizontally at a constant speed while the shoe also moves, causing the angle of the strut to gradually increase. Hence, the vertical load on the shoe gradually decreases while the horizontal load increases. The test table is moved farther to obtain the shoe's traveling distance at the point in time at which the shoe slides and the vertical column drops. From the traveling distance, we obtain the ratio between the horizontal load and the vertical load, that is to say, the static coefficient of friction. In this study, the traveling speed of the test table was 25.4 mm/s, and the vertical pressure on the shoe was in the range of 6.9–90 kPa.

As specified by Federal Specification KK-L-165C, the shoe material used in ASTM D 2047 is a piece of cowhide 76.2 × 76.2 mm in size and 6.4 mm in thickness that should be uniformly ground with a #400 abrasive paper prior to use. ASTM D 2047 does not mention the Shore A hardness of the test specimen, but we employed a piece of cowhide with Shore A hardness of 80 in our study.

ASTM D 2047 prescribes that the test be performed on a cleaned floor.

3.3. Test prescribed in JIS A 1454

This test uses the O-Y·PSM (O-Y Pull Slip Meter) shown in Fig. 5 to obtain the slip resistance coefficient. Fig. 6 shows the O-Y·PSM, a device that reproduces the contact between the sole of the footwear and the floor and the load applied to the sole as the foot is being lifted. The lifting movement is mentioned here because it was verified that, in terms of slipperiness, there is no noticeable change in the ranking of sample floors between the landing and lifting phases of stepping.

As Fig. 7, the O-Y·PSM puts a "slip piece", a sample of a sole cut from a piece of footwear, in contact with the floor, loads the weight, and measures the load as the slip piece is pulled diagonally upward. The pulling angle approximates the lifting angle of a foot during stepping, i.e., 18°. The vertical load applied to the slip piece, the size of the contact area between the slip piece and the floor, the tension loading speed during the pulling of the slip piece, and the lead time between the placement of the slip piece on the floor and the pulling are described below. These parameter values were based on the results of analysis of a large amount of experimental data conducted to define an optimal match to the perceptual evaluation of slipperiness by building users.

- Vertical load applied to the slip piece: 784 N.
- Contact surface between the floor and the slip piece: 80 mm × 70 mm (length × width).
- Tension loading speed: 784 N/s.
- Lead time: 0 s.

The O-Y·PSM is operated by manipulating the hoist located on the left to lower the guide rail on which the weight and the slip piece are placed. The motor starts immediately after the slip piece is placed on the floor, pulling the slip piece by winding the wire. The tension load is then measured with the load converter installed on the wire.

Fig. 8 shows a typical curve of the tension load over time as measured by the O-Y·PSM. The maximum tension load P_{max} indicated in the figure is divided by the vertical load applied to the slip piece to obtain the coefficient of slip resistance (*C.S.R.*). The initial tension load of 29.4 N indicated in the figure is applied to prevent sagging of the wire until the motor starts.

$$C.S.R. = P_{max}/784\ \text{N}$$

JIS A 1454 prescribes the use of a piece of sole cut from commonly used footwear and prescribes that the surface of the floor meet actual usage conditions.

3.4. Slip resistance tests

A total of 13 different floor models, i.e., the 12 sample floors made of the selected materials described in Section 2.1.2 and the standard floor, were subjected to the slip resistance tests as described in Sections 3.1 to 3.3. The conditions prescribed for each test method are compared in Table 5.

The tests prescribed by EN 13893 and ASTM D 2047 were performed using either the slider assembly or the shoe on a cleaned surface, depending on the test. JIS A 1454 does not specify the use of a particular material, and thus, the normal procedure is to use a piece cut out of the sole of the footwear as a slip-piece. Hence, in our study, we cut out the soles of three different types of footwear for the sensory test and used them as slip pieces. These consisted of: a 3 mm-thick, Shore A hardness 80 polychloroprene shoe sole for hard sole shoes; a 10 mm-thick, Shore A hardness 10 polyurethane foam rubber sole covered with a cotton sock; and a Shore A hardness 50 double-layer slippers sole consisting of 8 mm-thick polyurethane foam rubber laminated with a 0.6 mm-thick vinyl chloride sheet. The hard-soled shoe slip pieces were also used in tests on the floor surfaces sprinkled with muddy water. In summary, *C.S.R.* values were determined for four conditions: shoes on a cleaned floor, shoes on a sprinkled floor, socks on a cleaned floor, and slippers on a cleaned floor. Table 6 lists the test results.

4. Assessment of the relationship between the psychological scale and the slip resistance tests

Fig. 9 summarizes the relationship between the Sensed Slipperiness Scale, constructed as described in Section 2, and the results of the respective slip resistance tests described in Section 3. The vertical axis represents the Sensed Slipperiness Scale. On the horizontal axes, the top row shows the dynamic

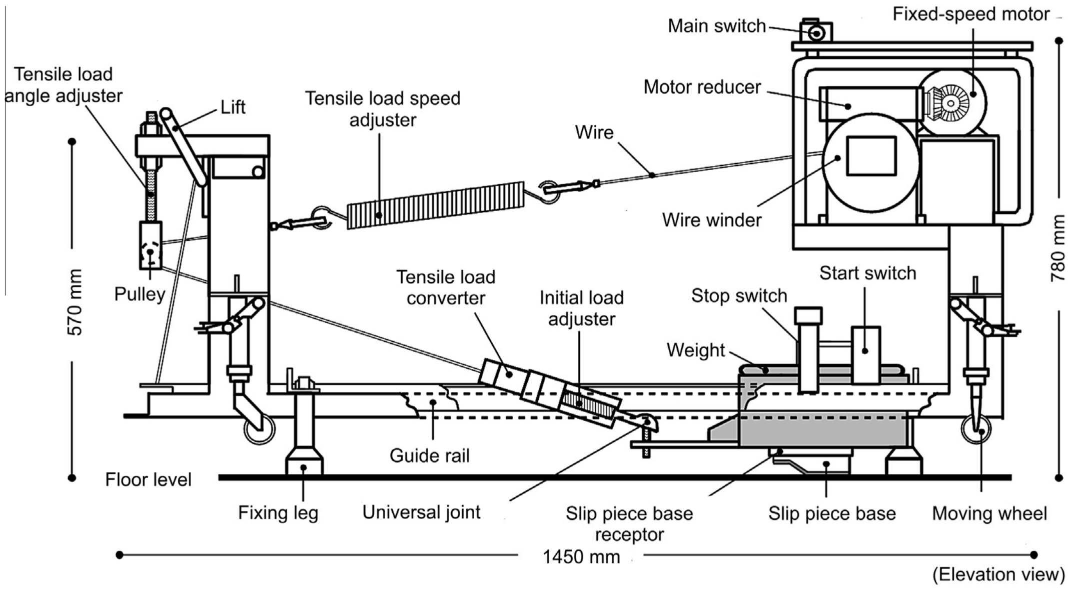

Fig. 5. Schematic drawing O-Y·PSM prescribed in JIS A 1454.

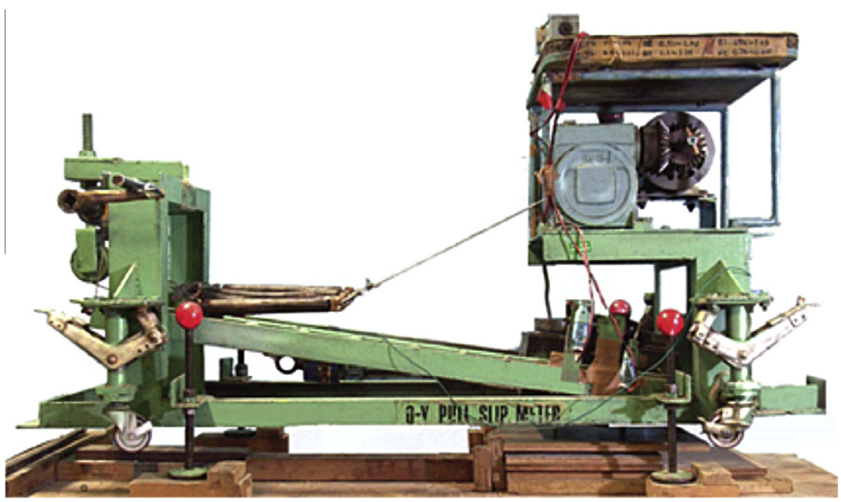

Fig. 6. O-Y·PSM [3].

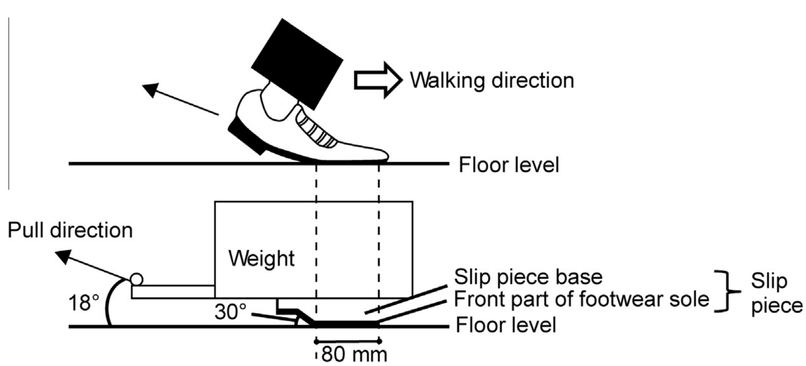

Fig. 7. Outline of the O-Y·PSM test method.

coefficient of friction μ according to EN 13893, the middle row shows the static coefficient of friction according to ASTM D 2047, and the lower row shows the *C.S.R.* according to JIS A 1454. The columns show, from left to right, the results for shoes on the cleaned floor, shoes on the sprinkled floor, socks on the cleaned floor, and slippers on the cleaned floor. The dotted lines (1) to (7)

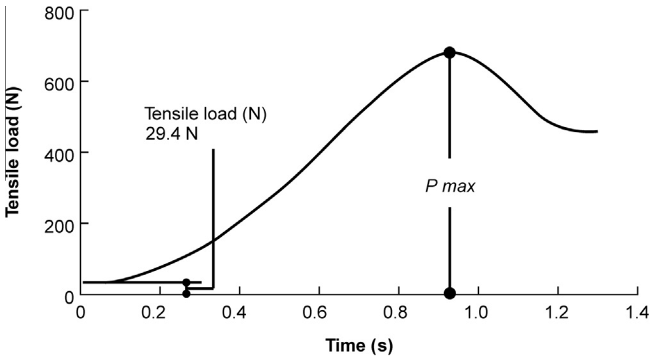

Fig. 8. An example of curve of O-Y·PSM tensile load over time.

show, as in Fig. 2, the decision score range of the Sensed Slipperiness Scale. The standard floor slipperiness sensory score was set so that 0 corresponded to the midrange value of (4).

The scattergrams on the top row indicate that the scale score and the test results do not match well, which means that measurement of the dynamic coefficient of friction μ as prescribed by EN 13893 fails to be representative of the slipperiness sensed by the users, regardless of the combination of footwear and floor material. The results in the middle row show a similarly weak correspondence between the parameters, indicating that, for every combination of footwear and floor material, the static coefficient of friction measured in accordance with ASTM D 2047 does not match the slipperiness sensed by the users. The scattergrams in the lower row indicate a satisfactory correspondence that results in a well-fitted regression curve, demonstrating that the *C.S.R.* obtained

Table 5
Comparison of test conditions specified by each standard.

		EN 13893	ASTM D 2047	JIS A 1454
Material in contact with the floor (“contact piece”)	Name	Slider assembly	Shoe	Slip piece
	Material	Leather slider: Shore D hardness 60 ± 10 leather piece Shoe rubber slider: Shore A hardness 95 Styrene-butadiene rubber	Cowhide ground uniformly with a #400 abrasive paper as specified by Federal Specification KK-L-165C	Piece of sole cut out from common-usage footwear
	Size	L = 37.5 ± 2.5 mm, W = 10 ± 0.5 mm, Thickness = 2–6 mm	L = 76.2 mm, W = 76.2 mm, Thickness = 6.4 mm	L = 80 mm, W = 70 mm
	No. of pieces	2 × leather sliders 1 × Shoe rubber slider	1	1
Measurement method		The slider assembly is placed on the floor and pulled horizontally at a constant speed, during which the tensile load is measured	The specimen is fixed to the test table, the shoe is placed on the specimen, and a vertical load is applied. Then, the test table is slid horizontally while the load is gradually shifted to the horizontal direction. The ratio of the horizontal load to the vertical load when the shoe starts sliding is calculated	The slip piece is put in contact with the floor, a predefined vertical load is applied, and the load is measured while the piece is pulled obliquely upward
Measured value		Dynamic coefficient of friction μ (tensile load divided by the vertical load applied to the slider assembly)	Static coefficient of friction (the horizontal load when the shoe starts sliding divided by the vertical load)	Coefficient of Slip Resistance (*C.S.R.*) (maximum tensile load divided by the vertical load applied to the slip piece)
Direction of load on the contact piece		Horizontal pull	Pressed from the upper oblique direction	Pulled upward obliquely at an 18° angle
Contact piece loading condition during testing		Total mass of slider assembly: 10.0 ± 0.1 kg Pulling speed of slider assembly: 0.2–0.3 m/s	Vertical pressure applied to the shoe: 6.9–90 kPa Traveling speed of test table: 25.4 mm/s	Vertical load applied to the slip piece: 784 N Tension loading speed: 784 N/s
Condition of floor surface during testing		Cleaned	Cleaned	Condition reflecting the actual use

Table 6
Results of slip resistance tests.

Sample floor No.	Dynamic coefficient of friction μ (EN 13893)	Static coefficient of friction (ASTM D 2047)	*C.S.R.* (JIS A 1454)			
			Hard-soled shoes on cleaned floor	Hard-soled shoes on sprinkled floor	Socks on cleaned floor	Slippers on cleaned floor
1	0.70	0.70	0.89	0.49	0.57	0.71
2	0.74	0.62	0.93	0.49	0.48	0.72
3	0.68	0.74	0.88	0.63	0.56	0.94
4	0.74	0.58	0.88	0.52	0.47	0.77
5	0.57	0.59	0.90	0.75	0.67	0.83
6	0.41	0.56	0.86	0.00	0.47	0.55
7	0.51	0.41	0.65	0.44	0.36	0.39
8	0.56	0.68	0.84	0.73	0.58	0.79
9	0.57	0.67	0.83	0.55	0.56	0.79
10	0.55	0.61	0.83	0.50	0.40	0.60
11	0.24	0.28	0.64	0.50	0.29	0.37
12	0.43	0.53	0.69	0.46	0.31	0.47
Standard floor	0.43	0.44	0.82	0.63	0.42	0.70

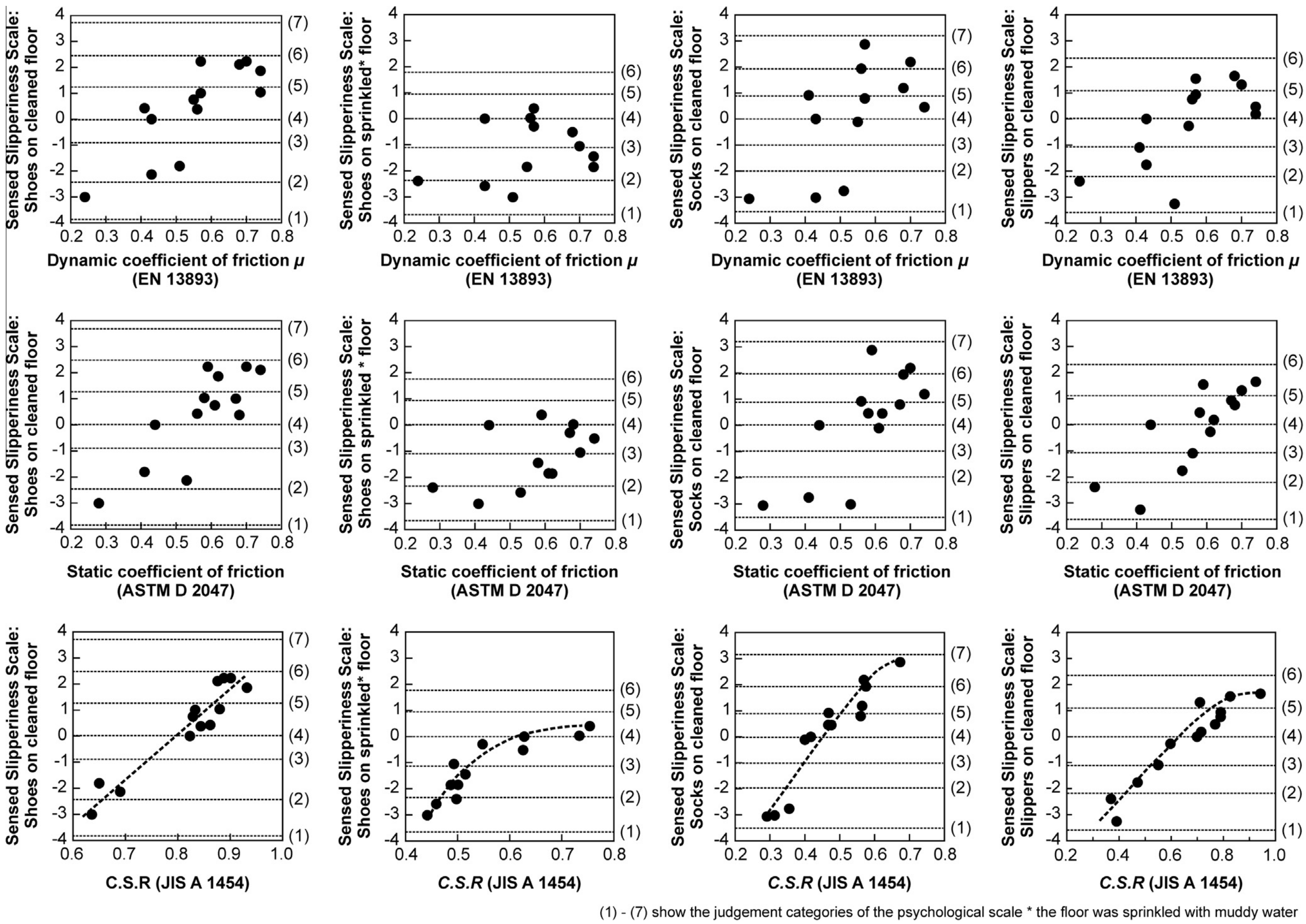

Fig. 9. Relationship between the Sensed Slipperiness Scale and the slip test results.

by the test method prescribed in JIS A 1454 may be considered to match the slipperiness sensed by users well.

The lack of correspondence between the sensory score and the EN 13893 and ASTM D 2047 test method results can be attributed to both tests failing to take into account factors that reflect the surface conditions of the footwear and the floors. Moreover, the lack of correspondence for all combinations of footwear and floor materials indicates an intrinsic shortcoming of both of these two methods.

One of the causal factors for the mismatch might be due to these methods' attempts to express a user's sensory experience in terms of the coefficient of friction. The slipperiness felt by a user involves the sense of gripping or holding arising from the convexoconcavity, unevenness, and irregularity of the footwear sole and the floor surface. To take into account the convexoconcavity properly, evaluation tests must closely approximate the real-world situation when setting the contact surface between the slider, the shoe or slip piece, and the floor, as well as the magnitude of the load applied to the slider, shoe, or slip piece and the pulling speed. Because EN 13893 and ASTM D 2047 do not incorporate these elements, factors such as the sense of gripping and holding are not properly reflected in the results obtained. Therefore, the results fail to match the slipperiness actually sensed by users. In contrast, the JIS A 1454 test method properly takes into account the above elements, so that factors such as gripping and holding are reflected realistically, and a good match is obtained between the test results and the slipperiness sensed by users.

In summary, the JIS A 1454 test method can be considered the most appropriate of the three test methods compared because it yields results that correspond well to the slipperiness sensed by users.

5. Conclusions

This study compared the slip resistance test methods prescribed in EN 13893, ASTM D 2047 and JIS A 1454 and their correspondence to the floor slipperiness actually felt by users. The results can be summarized as follows:

(1) On 12 types of sample floors with different degrees of slipperiness, sensory tests were performed under four different conditions, namely hard-soled shoes on a cleaned floor, hard-soled shoes on a floor sprinkled with muddy water, socks on a cleaned floor, and slippers on a cleaned floor. The results obtained were used to construct a Sensed Slipperiness Scale expressing slipperiness during walking. A comparison of the scores obtained under each experimental condition showed that the slipperiness felt by the users is affected by the surface conditions of the footwear on the floor, suggesting the necessity of taking such parameters into account in slip resistance test methods.

(2) On 13 types of floors, i.e., 12 sample floors and one standard floor, slip resistance testing was conducted as prescribed in EN 13893, ASTM D 2047, and JIS A 1454, and the dynamic

coefficient of friction μ, the static coefficient of friction, and the coefficient of slip resistance *C.S.R.*, respectively, were determined.

(3) The results of the sensory tests expressed on the psychological scale (Sensed Slipperiness Scale) were compared with the dynamic coefficient of friction μ, static coefficient of friction, and *C.S.R.* values obtained from the testing. The results of the comparisons show that the dynamic coefficient of friction μ and the static coefficient of friction obtained in accordance with EN 13893 and ASTM D 2047, respectively, do not agree well the slipperiness perceived by the users, whereas the *C.S.R.* obtained in accordance with JIS A 1454 do agree well with the slipperiness perceived by the users.

(4) The lack of agreement noted above can be explained by the facts that EN 13893 and ASTM D 2047 do not take into account the footwear and the surface conditions of the floor and they also do not approximate the contact surface between the floor and the slider/shoe, the magnitude of loading on the slider/shoe, and the loading speed. Therefore, it is suggested that elements such as the gripping or holding of the footwear on the floor are not suitably reflected in these evaluation methods. In contrast, the footwear samples used in the JIS A 1454 test were cut from a sole of commonly used footwear and prepared as a "slip piece". Hence, the parameters relevant to the surface conditions of the footwear and the floor are taken into account and duly incorporated in this method. Furthermore, this method requires setting of parameters that approximate the contact surface, the magnitude of loading applied to the slip piece, and the pulling speed under real-world conditions (a walking movement). Therefore, elements such as gripping and holding are realistically reflected, and the results obtained match the slipperiness sensed by the users.

(5) Based on the agreement of its results with the floor slipperiness sensed by the users, JIS A 1454 is considered a more appropriate test of floor slipperiness than EN 13893 or ASTM D 2047.

EN 13893 and ASTM D 2047, which specify the use of specific sliders or shoes on a cleaned surface, are effective physical property evaluation methods, because they offer a simple test for floor manufacturers and building managers to use to control the slip coefficient. However, the results of this study clearly demonstrate that the slipperiness sensed by building users varies widely depending on the footwear worn and the status of the floor surface. Consideration of these factors is essential when developing a slipperiness test, without which a potentially dangerous floor might be considered to be safe. Therefore, JIS A 1454 is the most appropriate performance test for ensuring a building user's safety.

Elimination of dangerous flooring to ensure building users' safety requires further study focusing on the relationship between the evaluation of slipperiness from a safety standpoint and *C.S.R.*, so that a *C.S.R.* tolerance range for each requirement level can be proposed.

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