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A comparative evaluation of floor slip resistance test methods

Soo-Kyung Choi [a], Rumi Kudoh [b], Junko Koga [c], Takamasa Mikami [d], Yutaka Yokoyama [e,*], Hiroki Takahashi [f], Hidenori Ono [e]

[a] Department of Architecture, Hanseo University, 46 Hanseo 1-ro, Haemi, Seosan, Chungcheongnam-do 356-706, Republic of Korea
[b] Faculty of Human Life and Environment, Department of Residential Architecture and Environmental Science, Nara Women's University, Kitauoya Nishimachi, Nara-shi, Nara 630-8506, Japan
[c] Building Department, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, 1 Tachihara, Tsukuba-shi, Ibaraki 305-0802, Japan
[d] Department of Mechanical & Environmental Informatics, Tokyo Institute of Technology, 2-12-1 O-okayama, Meguro-ku, Tokyo 152-8552, Japan
[e] Department of Architecture and Building Engineering, Tokyo Institute of Technology, 2-12-1 O-okayama, Meguro-ku, Tokyo 152-8552, Japan
[f] Department of Building Technologists, Faculty of Technologists, Institute of Technologists, 333 Maeya, Gyoda-shi, Saitama 361-0038, Japan

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.

* Corresponding author.
E-mail addresses: skchoi@hanseo.ac.kr (S.-K. Choi), kudou@cc.nara-wu.ac.jp (R. Kudoh), koga-j2kn@nilim.go.jp (J. Koga), mikami@mei.titech.ac.jp (T. Mikami), yokoyama@arch.titech.ac.jp (Y. Yokoyama), takahashi@iot.ac.jp (H. Takahashi), hidenori236@gmail.com (H. Ono).

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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