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Slip Resistance (Friction) and Safe Walk Characteristics of Selected Shoe Soles on Floor Tiles in Nigeria

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Abstract: *Slip-related accidents represent a significant public safety concern, particularly in environments where flooring may be exposed to various contaminants. This research investigates the slip resistance characteristics of selected shoe soles on different types of local floor tiles, employing the British Pendulum Tester (BPT) under diverse conditions, including: dry, sandy, wet, soapy, and oily surfaces. The study aims to provide quantitative data on friction coefficients to comprehensively assess the performance of different shoe sole and tile combinations. The results indicate varying levels of slip resistance across the tested combinations, with some shoe soles demonstrating superior performance under specific conditions. For instance, Poly-Urethane soles consistently showed higher friction coefficients in both dry and contaminated conditions, suggesting their suitability for environments prone to slip hazards. Conversely, certain tiles exhibited lower slip resistance when exposed to water and oily substances, highlighting the need for careful selection of both footwear and flooring materials in safety-critical applications. The findings underscore the importance of considering environmental factors in evaluating footwear performance, providing practical implications for improving safety standards in public and private spaces. The data generated from this research can inform recommendations for better footwear design, floor tile selection, and maintenance practices to mitigate slip hazards effectively. This study emphasizes the significance of evidence-based approaches in enhancing slip resistance standards, advocating for ongoing research and industry collaboration to ensure continuous improvement in safety protocols.*
Keywords: slip resistance, floor tiles, walk safety, footwear, British pendulum tester.

INTRODUCTION

Slip and fall incidents arise when there is a loss of traction between surfaces in contact, leading to the fall of an ungrounded body, such as a human being. For individuals walking on floor surfaces, slip and fall accidents commonly occur when floors are wet or contaminated and when footwear soles fail to provide sufficient traction. A slip, therefore, represents the loss of balance caused by too little friction between the sole of a shoe and the walking surface [1].

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Slippery floors frequently cause unintended slips and falls, resulting in traumatic injuries. According to studies by Hanson et al. (2014) [2] and Chang et al. (2016) [3], adequate traction between shoe soles and floor surfaces is crucial to reducing slipping risks. Viscous slippery contaminants like water or oil further decrease a floor's traction performance, increasing slipping hazards [1]. Non-fatal accidents resulting from slips and falls are a significant concern for public health and safety, accounting for over 37% of total falls, slips and trips, as reported by the U.S. Bureau of Labour Statistics in 2022 [4]. The National Safety Council (NSC) estimates that there are more than 25,000 falls in the US each day, with associated medical costs and compensation reaching $70 billion yearly [5]. The consequences of non-fatal slips and falls include joint dislocations, muscle or ligament tears, and fractures, which can lead to prolonged employee absences from workplaces [6]. Unintentional slips occur due to various factors, such as the type of footwear, flooring, presence of floor contaminants, and shoe outsole wear. Studies by Guptat et al. (2022) [7] and Chanda (2018) [8] highlight that these factors lead to variations in the traction performance of footwear. Friction at the shoe-floor contact is quantified by dividing the forces that oppose slipping (shear forces) by the vertical force (body weight) and is typically stated as the available coefficient of friction. Slip-related accidents on different types of floor tiles have been a concern for public safety. Available literature indicates that there is limited research addressing the slip resistance characteristics of shoe soles on local floor tiles, leaving a gap in our understanding of their performance. The specific performance disparities between slip-resistant local shoe soles fabricated using locally available materials and imported counterparts remain unexplored. Despite available statistics and growing consumer concerns, comprehensive research on the slip resistance of shoe soles on local floor tiles is lacking. This study aims to address this gap by investigating the performance of different shoe sole and tile combinations under various conditions. By quantifying slip resistance discrepancies and providing data-backed insights, this research seeks to contribute to the development of safer footwear options and subsequently reduce slip-related accidents.

MATERIALS AND METHODS

The British pendulum tester, shown in Figure 1, was used for the measurement of the slip resistance of the two mating surfaces, namely: the shoe sole surface and the floor tile surface. The measurements were carried out in accordance with ASTM E303-93 (Now ASTM E303-22) standard test method.

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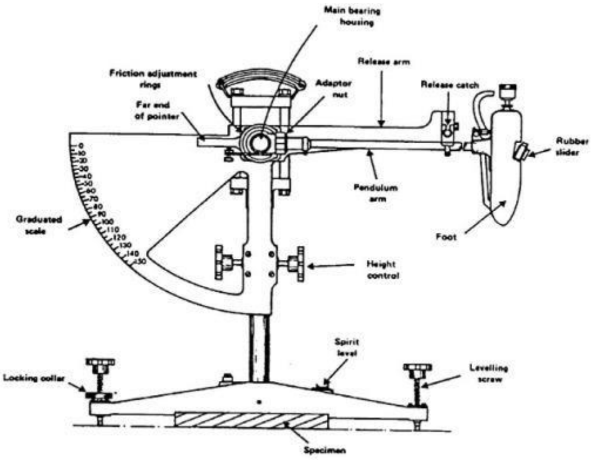

Figure 1. The British Pendulum Tester

This study utilized locally available ceramic, porcelain, and vinyl floor tiles, representing common residential and commercial flooring materials as shown in Figure 2. Various shoe soles, including rubber, leather, and synthetic materials, were selected to represent different types of footwear, such as work boots, casual shoes, and athletic footwear. Both locally manufactured and imported shoe soles were included. To simulate real-world conditions, contaminants such as water, oil, and detergent solutions were uniformly applied to the tile surfaces to evaluate their impact on slip resistance.

Figure 1: Sampled tiles (a) Bespoke Tile (b) Fantansy Brown tile (c) Marbonite tile (d) Porcelain tile (e) Sandstone tile

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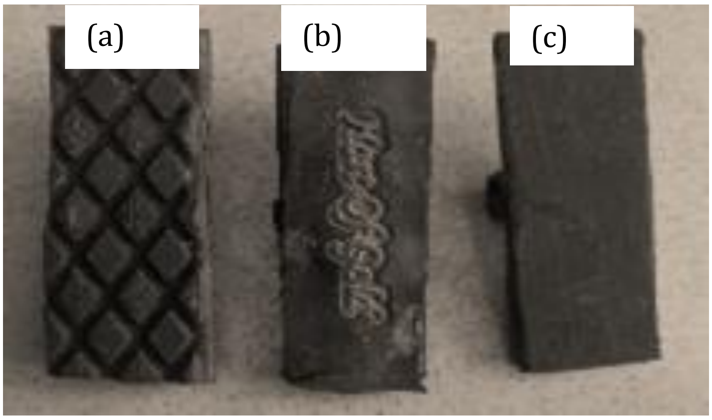

Figure 2: Rubber sliders used.

The British Pendulum Tester (BPT) was used to measure the slip resistance between the shoe soles and floor tiles surfaces. The BPT Standard Value is a set of values used to determine the slip potential of a material, presented as the Pendulum Test Value (PTV) as graded in Table 1. Initially, the test samples were cleaned and dried. The appropriate rubber slider was attached to the tester, which was placed on the test tile with the slider positioned to swing in the direction to level the base screws. The swinging arm was raised, clamped in the horizontal position, and released to ensure the pointer read zero.

Table 1: British Pendulum Tester Standard Value

Slip Potential	Pendulum Test Value (PTV)
High Slip Potential	0 - 24
Moderate Slip Potential	25 - 35
Low Slip Potential	36+

In order to zero (or balance) the tester, a spacer was placed under the lifting handle setting screw to raise the slider, and the head of the tester was lowered until the slider just touched the tile surface. Slip resistance was measured by gently lowering the pendulum arm until the slider just touched the surface on either side of the vertical, recording the reading on the graduated scale. This test was repeated three times for each condition—dry, sandy, wet, soapy, and oily—wetting the surface between swings. The average slip resistance was calculated from these readings and recorded for each rubber slider (see Figure 3) on each of the floor tiles. For each test, the rubber slider was changed by unlocking the adapter, removing the old slider, attaching the new slider, and tightening the screw. To ensure accuracy, the slip resistance test was performed four times, recording the reading on the graduated scale after each swing, and the average of the four readings was calculated and recorded. Results were categorized according to standard values for the British pendulum tester scale. For example, the Marbonite tile was

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tested with a Maco sole rubber slider under dry conditions by preparing the test surface, selecting the rubber slider, setting up the British pendulum tester, zeroing the tester, measuring the slip resistance, repeating the test three times, calculating the average slip resistance, and recording the results. Data analysis involved calculating mean COF values for each combination, comparing COF values between different shoe sole materials and tile types, and assessing the impact of contaminants on slip resistance. All testing was conducted in a controlled laboratory environment to ensure safety and data integrity. No human subjects were involved, and all materials were handled following standard safety protocols.

RESULTS AND DISCUSSION

Figure 4 shows the average PTV value for the 3 shoe soles on the (a) Marbonite tiles (b) Sandstone tiles (c) Porcelain tiles (d) Bespoke tiles (e) Fantasy brown tiles under different surface conditions. The PTV values indicate the coefficient of friction between the surfaces and the rubber slider, with higher values suggesting better slip resistance.

The Marbonite tile shown in Figure 4 (a) exhibits strong slip resistance across all sole types. The Nora Sole had a particularly high average PTV of 117 under dry conditions and maintained good slip resistance under soapy conditions with a PTV of 57.5. The Maco Sole also performed well, with an average PTV of 103 in dry conditions and 57.75 in soapy conditions. The Poly-Urethane Sole showed consistent performance, averaging 111.25 in dry conditions and 52.5 in soapy conditions. These results indicate that Marbonite tiles paired with these soles provide robust slip resistance, making them suitable for various environments.

The Sandstone tile Figure 4 (b) showed excellent slip resistance, particularly with the Nora Sole, which had average PTVs of 105.25 in dry conditions and 56.25 in soapy conditions. Repeating tests with the Nora Sole confirmed these findings. The Poly-Urethane Sole also performed well on Sandstone, with an average PTV of 96.5 in dry conditions and 58.5 in soapy conditions. These results suggest that Sandstone tiles are highly effective in maintaining low slip potential, especially when used with these soles.

As observed in Figure 4 (c), Porcelain tile displayed more variability in slip resistance. The Nora Sole maintained low slip potential under most conditions, with an average PTV of 117.5 in dry conditions and 46.75 in soapy conditions. However, it showed moderate slip potential in wet conditions, with a PTV of 33.75. The Maco Sole performed robustly, with low slip potential across all conditions, averaging 99.25 in dry conditions and 50.5 in soapy conditions. The Poly-Urethane Sole had lower PTVs in wet and soapy conditions, averaging 37.5, indicating a need for caution when these conditions are present. These results highlight the importance of selecting appropriate shoe soles to mitigate slip hazards on Porcelain tiles.

The Bespoke Pattern tile in Figure 4 (d) exhibited good slip resistance with different soles. The Nora Sole displayed good slip resistance, with an average PTV of 98.75 in dry conditions and 53.5 in soapy conditions. The Maco Sole performed exceptionally well, with average PTVs of 106.25 in dry conditions and 67.75 in soapy conditions. The Poly-Urethane Sole showed

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consistent performance, with an average PTV of 89 in dry conditions and 45.25 in soapy conditions. These findings indicate that Bespoke Pattern tiles are effective in maintaining low slip potential across various conditions.

The Fantasy Brown tile captured in Figure 4 (e) showed moderate slip potential in soapy conditions with the Nora Sole, averaging a PTV of 20.5, but maintained good resistance in other conditions, with an average PTV of 109.25 in dry conditions. The Maco Sole performed well across all conditions, averaging 87.25 in dry conditions and 53.5 in soapy conditions. The Poly-Urethane Sole exhibited moderate slip resistance in wet conditions, with an average PTV of 39.25, but generally maintained good performance, with an average PTV of 97 in dry conditions. These results suggest that while Fantasy Brown tiles can provide good slip resistance, careful selection of shoe soles is crucial to ensure safety, particularly in soapy and

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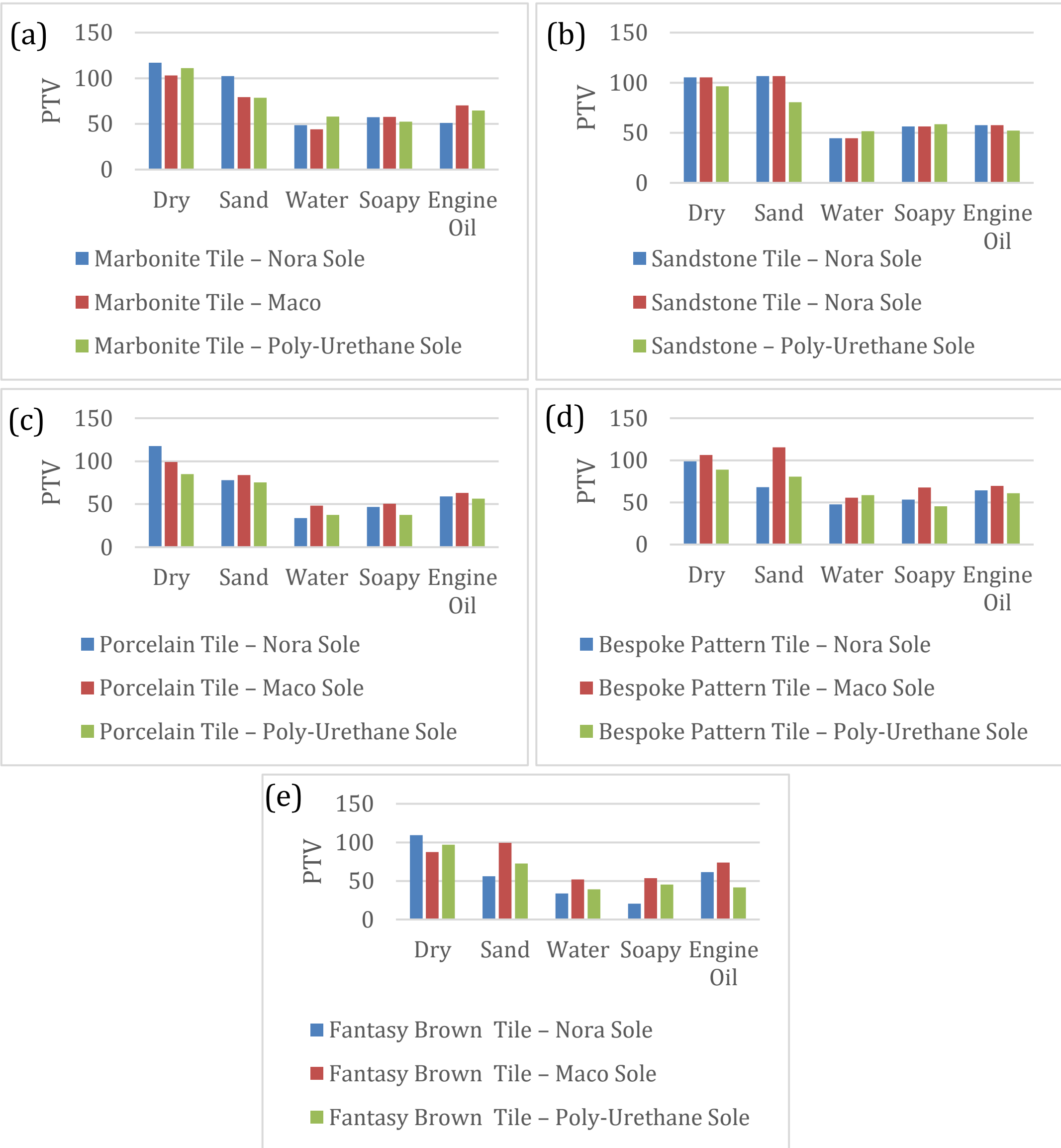

Figure 3: PTV for the 3 shoe soles on the (a) Marbonite tiles (b) Sandstone tiles (c) Porcelain tiles (d) Bespoke tiles (e) Fantasy brown tiles under different surface conditions.

oily conditions. Comparatively, the results indicate that Marbonite and Sandstone tiles generally provide strong slip resistance across various conditions, making them suitable for environments where safety is paramount. The Porcelain tile showed variability, especially under wet conditions, highlighting the importance of selecting appropriate shoe soles to mitigate slip hazards. The Bespoke Pattern and Fantasy Brown tiles performed well overall, though the Fantasy Brown tile required careful selection of shoe soles to ensure safety in soapy and oily conditions.

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CONCLUSION AND RECOMMENDATIONS

In conclusion, the research on slip resistance characteristics of various shoe soles on local floor tiles has provided valuable insights into the dynamic interactions between footwear and flooring materials. By employing the British Pendulum Tester under diverse conditions such as wet, dry, oily, soapy, and sandy surfaces, we obtained quantitative data on the friction coefficients, enabling a comprehensive assessment of slip resistance. The findings underscore the importance of considering environmental factors in evaluating footwear performance, particularly in real-world scenarios where slip hazards may occur. The outcomes have practical implications for enhancing safety standards in both public and private spaces. By understanding how different shoe soles respond to varying conditions, stakeholders in industries such as construction, hospitality, and healthcare can make informed decisions to create safer environments. This underscores the significance of evidence-based approaches in addressing safety concerns, emphasizing the need for research collaboration between industries and researchers to ensure continuous improvement in slip resistance standards.

Recommendations

Based on the finding, the following recommendations are provided to enhance safety standards and minimize slip hazards in various environments:

i. Footwear Design Improvement: Consider integrating the research findings into the design and manufacturing processes of footwear. Collaborate with shoe manufacturers to enhance the slip resistance features of shoe soles, especially under conditions such as wet, oily, and soapy surfaces. This can contribute to the development of safer footwear options for individuals in diverse environments.

ii. Flooring Material Selection: Share the research outcomes with architects, builders, and facility managers to inform decisions related to flooring material selection. The slip resistance characteristics of local floor tiles should be considered in spaces where slip hazards are a concern, such as public areas, workplaces, and homes. This recommendation aims to create environments with flooring that aligns with safety standards.

iii. Educational Initiatives: Develop educational programs to raise awareness among the general public, employers, and employees about the importance of slip resistance in footwear and flooring. Promote best practices for selecting appropriate footwear in different settings and highlight the significance of maintaining slip-resistant flooring in spaces with high foot traffic.

iv. Considerations: Advocate for or contribute to the development of industry standards and regulations related to slip resistance in footwear and flooring. Collaborate with relevant regulatory bodies to integrate research findings into guidelines that can influence building codes, safety standards, and occupational health and safety regulations.

v. Maintenance Protocols: Establish and promote effective maintenance protocols for flooring surfaces. Regular cleaning, removal of oily or soapy residues, and prompt addressing of spillages contribute to maintaining the slip resistance of floor tiles.

Disseminate guidelines to building managers and maintenance personnel on best practices for ensuring the ongoing safety of flooring surfaces.

vi. Continued Research and Development: Encourage continued research in the field of slip resistance, exploring advancements in footwear materials and innovative flooring solutions. Foster collaborations between researchers, manufacturers, and industry professionals to stay at the forefront of safety technologies and practices.

Conflicts of Interest

The authors declare no conflict of interest.

Data and code availability

There are no data or code repository for this work.

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