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PROPER SELECTION OF INDOOR FLOOR BASED ON FRICTION COEFFICIENT AND ELECTROSTATIC CHARGE

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ABSTRACT

The present study investigates the coefficient of friction and generated electro-static charge during sliding of foot socks against indoor flooring tiles. The static coefficient of friction of different textile materials rubbing on different flooring materials under dry sliding was investigated.Floor tiles of ceramics, flagstone, parquet, parquet ceramics, marble, porcelain and rubber were tested as flooring materials. The experimental results showed that, there is an increasing demand to establish codes for the generated electro-static charge during the sliding friction on floor surface. Rubber floor showed the highest friction, while marble produced the lowest values. Porcelain generated the highest electrostatic charge followed by ceramic, rubber, flagstone, parquet, parquet ceramic and marble. When mixing polyamide textiles of positive charge with Lycra textiles of relatively negative charge, the generated electro-static charge during rubbing decreased. It recommends further experiments to set the flooring materials on the triboelectric series chart aiming at setting proper selection guidelines to avoid generation of excessive electro-static charges on the rubbing flooring systems.

Keywords: friction coefficient, electro-static charge, flooring materials.

INTRODUCTION

There is an increasing demand to avoid slip accidents indoor through paying attention to a proper selection of foot wear and flooring materials. The effect of the percentage cotton content in fabrics on the frictional behavior of foot was investigated during walking, [1-3]. The friction coefficient increased with percentage increase of the cotton content. Polyamide showed the lowest friction while cotton produced the highest.

One of the major environmental factors affecting walking and materials handling is the resistance of flooring materials to slip and fall. It is quantified by using the static or the dynamic coefficient of friction, [4]. Recommendations for a specific friction values are reported for unloaded, normal walking conditions within the Slip-resistant standards, for, [5, 6]. Safe walking during handling loads requires higher friction. The subjective ranking of floor slip ability was compared with the static friction coefficient (μ) and found that the two measures are consistent, [7, 8]. Many state laws and building codes have established that a static $\mu \geq 0.50$ represents the minimum slip resistance threshold for safe floor surfaces. Furthermore, the Americans Act Accessibility Guidelines for Disabled, [9, 10], contain recommendations for static friction of $\mu \geq 0.60$ on accessible routes such aswalkways and elevators and increasing up to $\mu \geq 0.80$ on ramps.

Excessive relative motion can create a feeling of safeless situations and generate pressure and rubbing between the foot and the shoe, [11, 12]. Accordingly, rubbing includes friction between the foot and the inner surface lining, and also between the outer surface of lining and shoe. Low friction at both interfaces leads to excessive relative movements and causes discomfort and insecurity. It is reported that the values of friction at the two interfaces through the light on slip interface, [13]. Accordingly, it was predicted that slip would be expected at the lower friction interface rather than the other one of higher friction coefficient. Furthermore, it was recommended to allow low friction on one interface to permit foot sliding, and high friction on the other side to ensure reasonable degree resistance limiting excessive movement.

In the present work, coefficient of friction and generated electro-static charge during sliding of foot wear against indoor flooring tiles are investigated. Different textile materials and floor tiles of ceramic, flagstone, parquet, parquet ceramics, marble, porcelain and rubber are tested under dry sliding condition.

EXPERIMENTAL

The experimental work was conducted using a specially designed and manufactured test rig measuring the friction and normal forces during dry sliding conditions.

METHODOLOGY

The tested flooring materials are loaded in a base supported by two load cells, the first measures the horizontal force (friction force) and the second measures the vertical force (normal force). The ratio between the friction and normal forces defines the Friction coefficient. The test set up arrangement is reported in earlier work [10]. The flooring tiles were thoroughly cleaned with soap to eliminate dirt and dust and then carefully dried before the testing. Table-1 shows different textile materials, rubbed against the selected flooring tiles. Quadratic sheet of 0.4 m × 0.4 m and 5 mm thickness of each flooring tile was used for testing. The tests were carried out at different normal loads.

The generated electro-static charge during the sliding was measured. The experiments simulate the

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indoors walking. An electrostatic fields (voltage) measuring device (Ultra Stable Surface DC Voltmeter) was used to measure the electrostatic charge (electrostatic field) for test specimens. The measuring scale ranged from 1/10 volt up to 20 000 volts (20 kV). Measurements were done with a sensor set at 25 mm from the tested surface.

Table-1. Textile materials of the tested mating surface.

Code	Material
A	50 wt. % Polyester, 50 wt. % Cotton
B	80 wt. % Cotton, 20 wt. % Lycra
C	100 wt. % Polyester
D	50 wt. % Polyester, 50 wt. % Polyacrylonitrile
E	100 wt. % Cotton
F	100 wt. % Polyester-Polyurethane Copolymer
G	80 wt. % Polyamide, 20 wt. % Polyester-Polyurethane Copolymer (Lycra)
H	100 wt. % Polyamide

RESULTS AND DISCUSSIONS

Table-2 and Figure-1 show the European recommendation of slippery material classifications, [4].

Table-2. Slippery material classification.

Flooring material status	Coefficient of friction (μ)
Very Slip Resistant	$\geq$ 0.3
Slip Resistant	0.2 – 0.29
Unsure	0.15 – 0.19
Slippery	< 0.15
Very Slippery	< 0.05

Rubber tends to provide higher effective contact area and more pronounced microscopic deformations when mechanically interacting with the material of hard and rigid surface asperities. Therefore higher friction coefficients are expected for rubber as compared with plastics. Such characteristic frictional behavior of rubber is usually greatly affected in presence of fluid film separating the two mating surfaces.

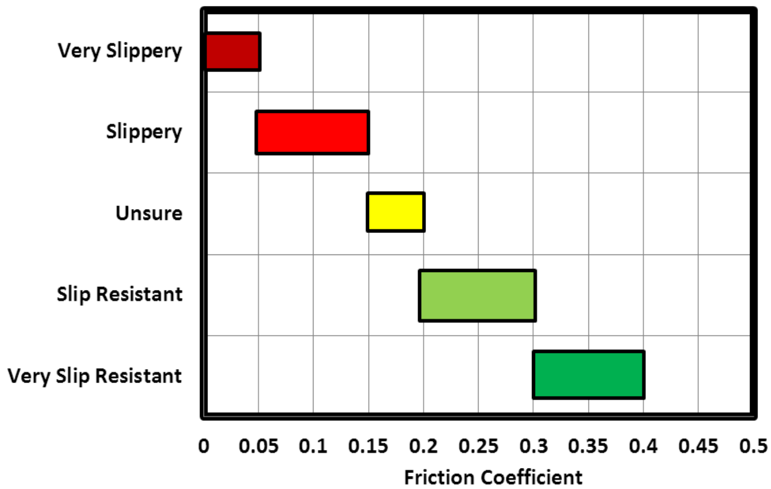

Figure-1. Dependency of the safety of walking on friction coefficient, [4].

Measured friction coefficient and electrostatic charge generated by the sliding of material (A) against the tested flooring materials are shown in Figures 2, 3. Rubber showed the highest friction values followed by ceramic, parquet ceramic, parquet, porcelain, flagstone, marble and parquet. The generated electrostatic charge for rubber was the lowest. Although ceramic was considered as very slip resistant it generated relatively higher values of electric static charge. Based on the results, it is clear that material (A) is well suited for use with rubber flooring.

Friction coefficient, displayed by the dry sliding of material (B) which contains 80 wt. % cotton and 20 wt. % polyesterpolyurethane copolymer rubbing against the tested mats, is shown in Figures 4, 5. Rubber floorings showed the highest friction coefficients which guarantee safe walking. Parquet ceramic tiles gave the lowest electrostatic charge at reasonable friction values. Porcelain generated the highest charge at lower friction coefficient.

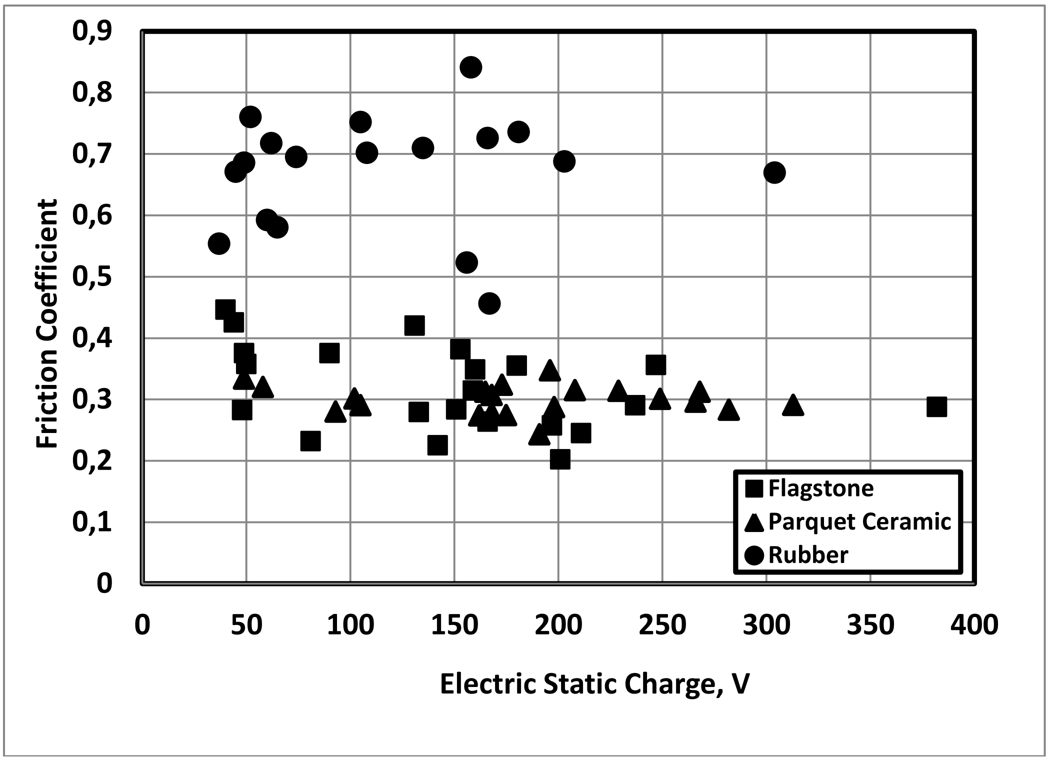

Figure-2. Friction coefficient of material (A) against different floor materials.

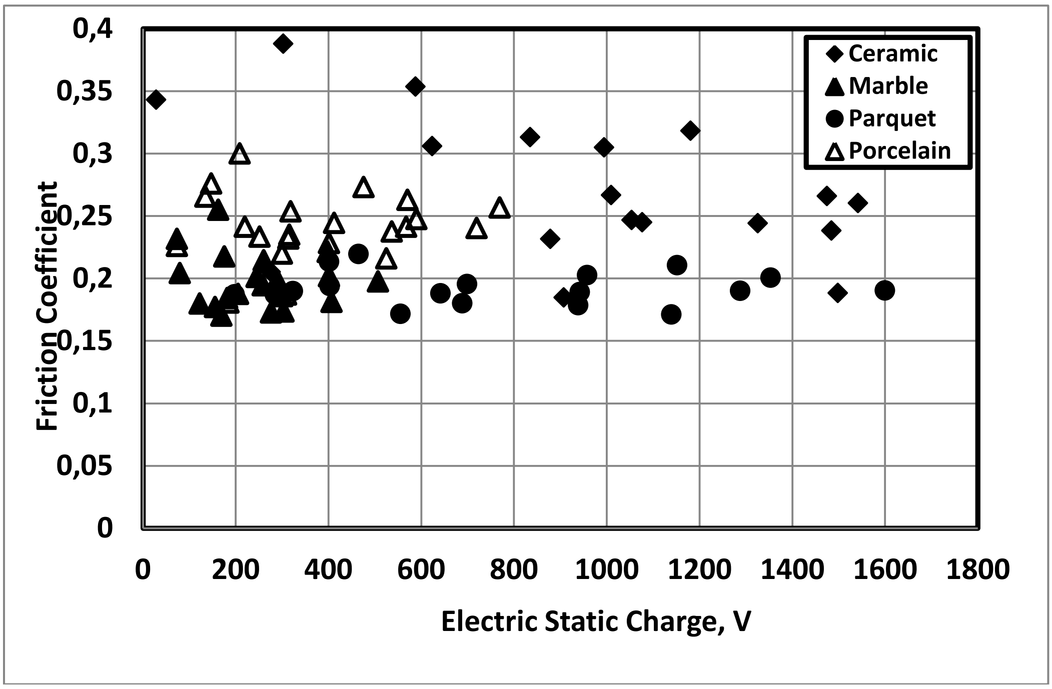

Figure-3. Friction coefficient of material (A) against different floor materials.

Polyester material (C) rubbed against the tested floor specimens, Figures 6, 7, showed higher friction values ranging between 0.84 and 0.41. The disadvantage of using polyester materials to rub against rubber is due to the generation of high electrostatic charge up to 2000 volts, while flagstone showed slip resistant sliding with 1500 volts electrostatic charge. Among the tested tiles, porcelain showed the lowest charge associated with slip resistant sliding.

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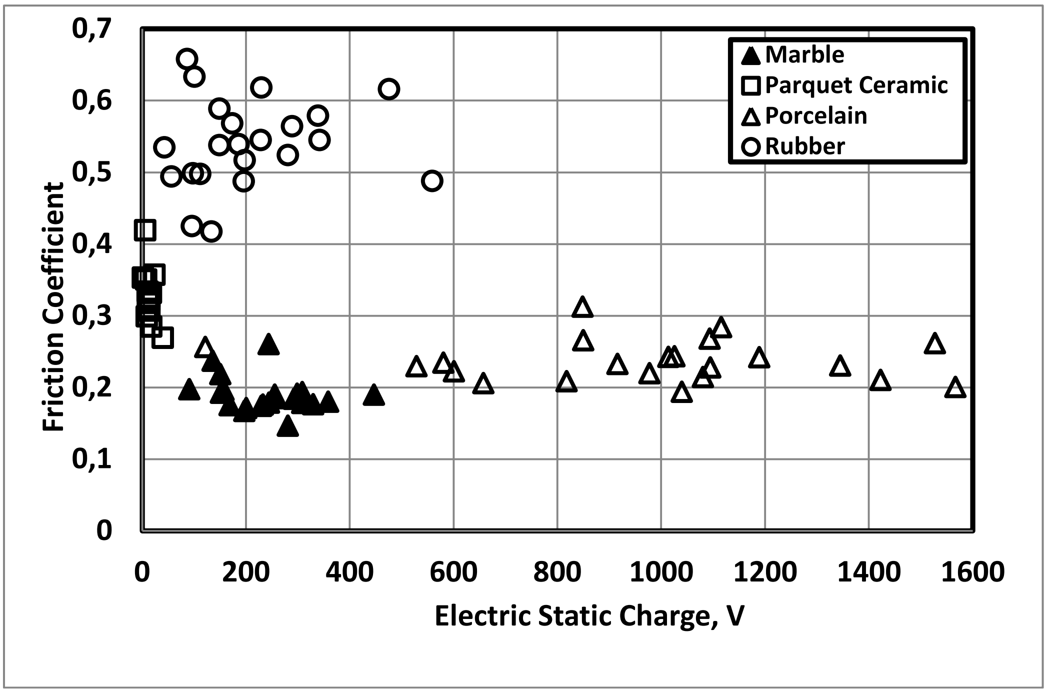

Figure-4. Friction coefficient of material (B) against different floor materials.

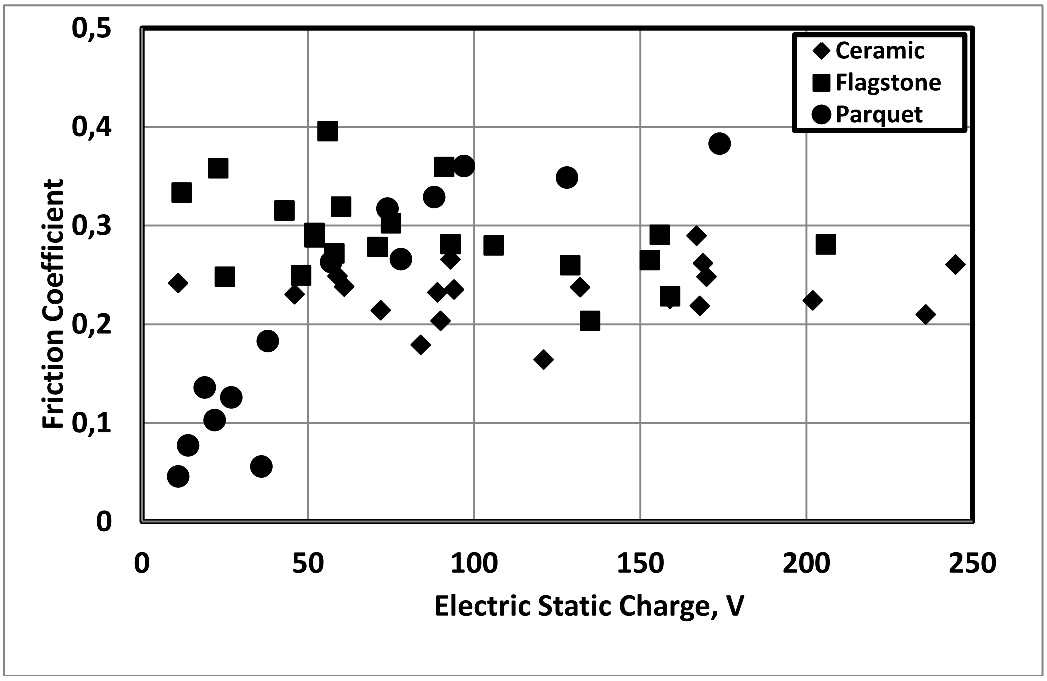

Figure-5. Friction coefficient of material (B) against different floor materials.

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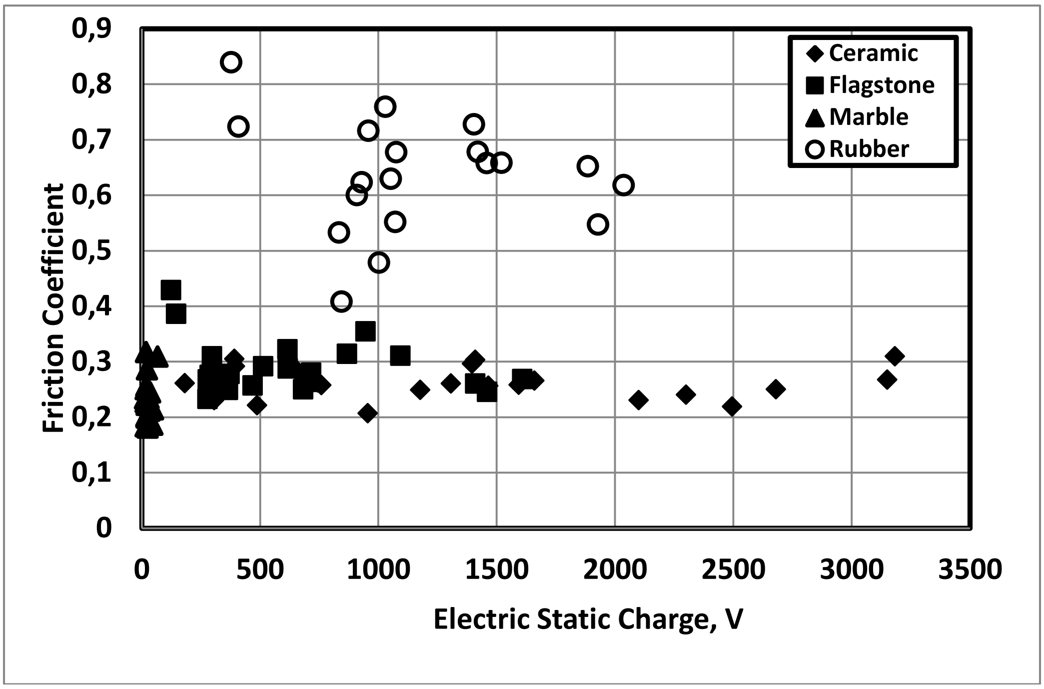

Figure-6. Friction coefficient of material (C) against different floor materials.

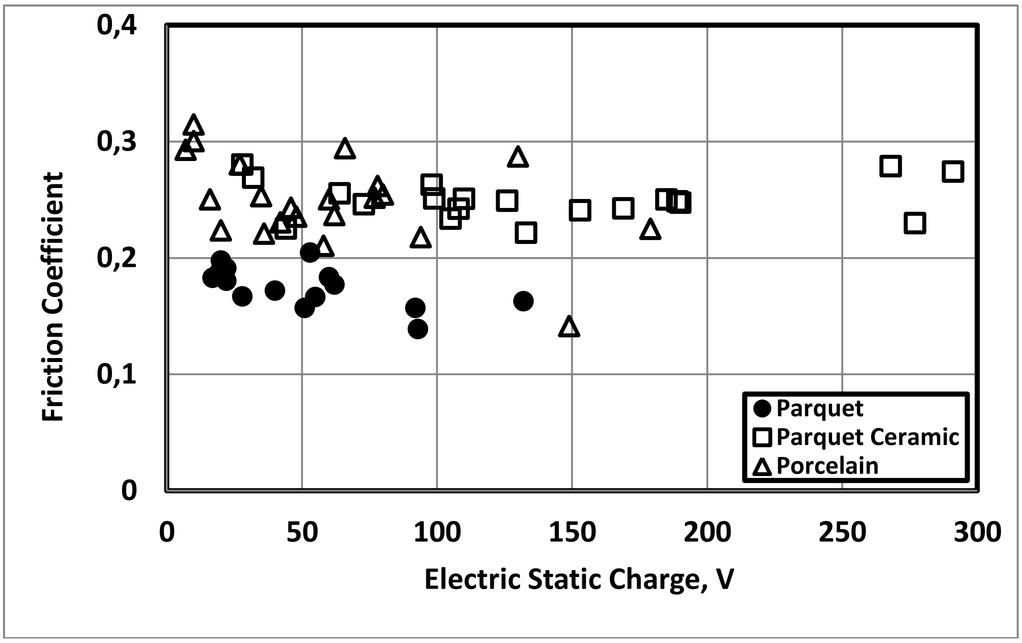

Figure-7. Friction coefficient of material (C) against different floor materials.

When material (D), having 50 wt. % polyester and 50 wt. % polyacrylonitrile, rubbed against the test tiles, rubber showed very high values of electrostatic charge up to 4000 volts, Figures 8, 9. The highest values of friction coefficient in this case were not high enough to ensure safe use. This behavior shows the importance of the proper selection of wearing materials.

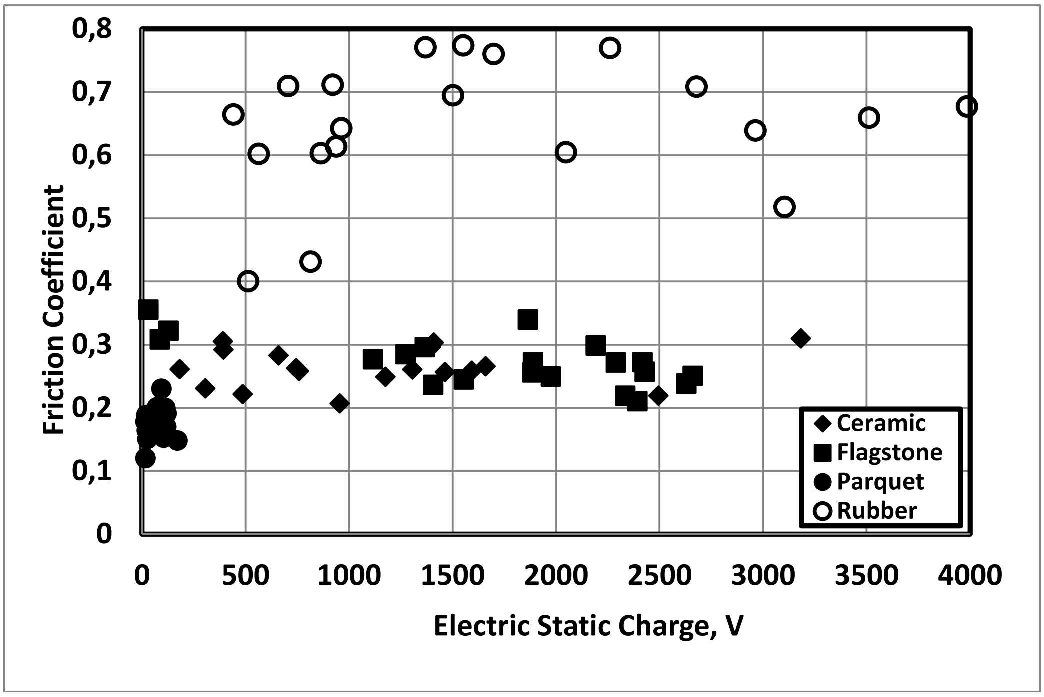

Figure-8. Friction coefficient of material (D) against different floor materials.

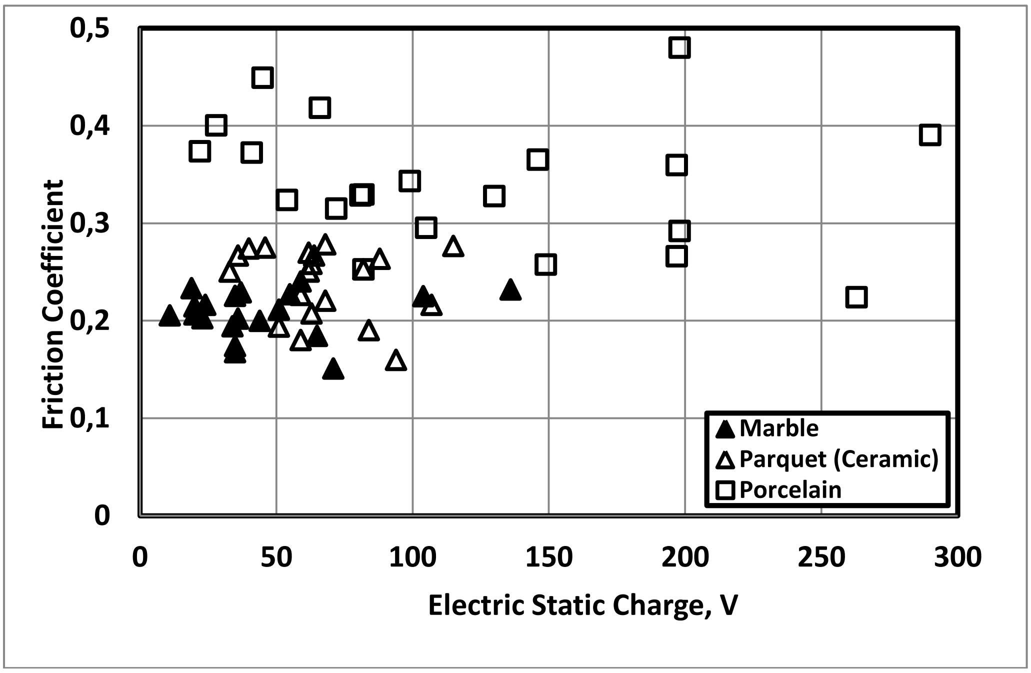

Figure-9. Friction coefficient of material (D) against different floor materials.

On the other side, Porcelain generated very low electrostatic charge associated with considerably higher values of friction coefficient.

Friction and electrostatic charge values generated by cotton material (D) showed the highest values when rubbed against rubber tiles, Figures 10, 11. Parquet ceramic tiles gave the lowest electrostatic charge with friction coefficient ranging between 0.27 and 0.44.

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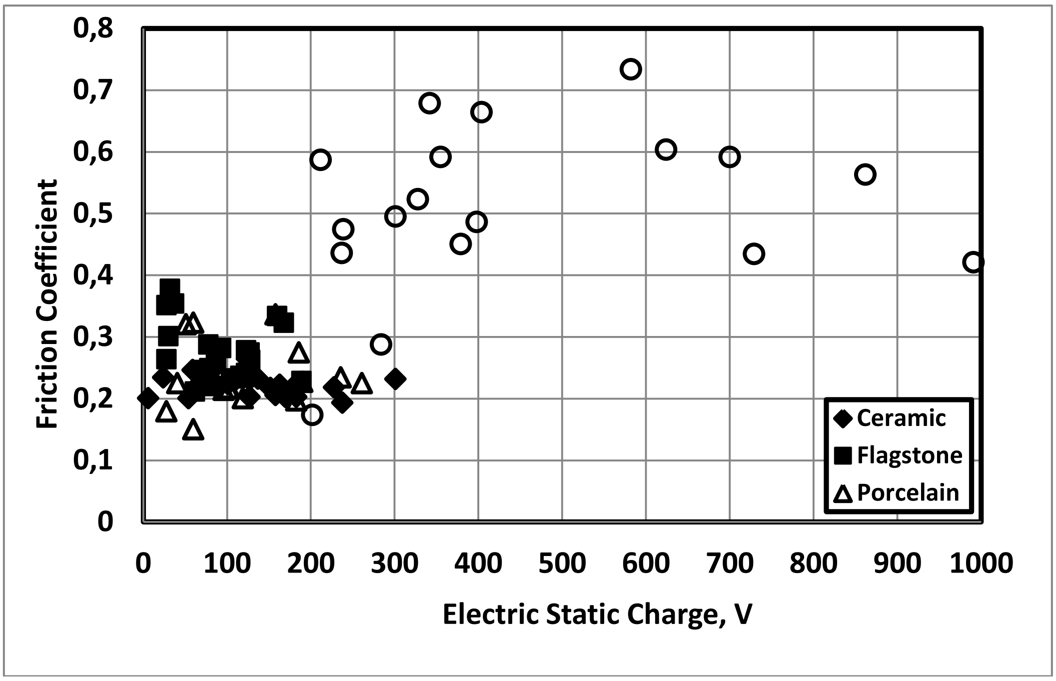

Figure-10. Friction coefficient of material (E) against different floor materials.

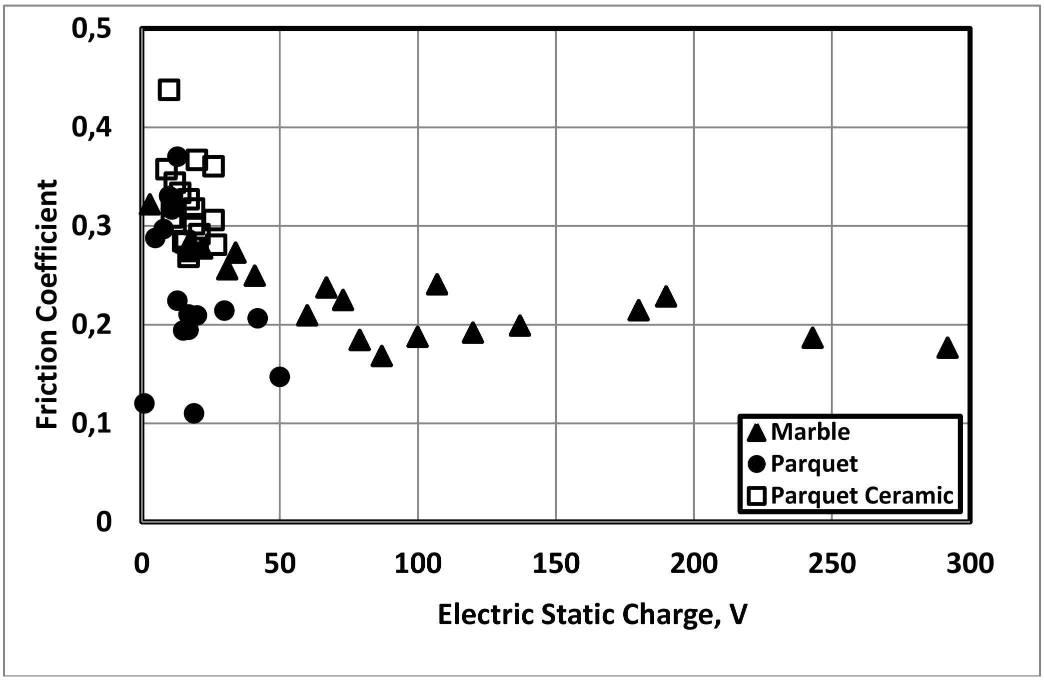

Figure-11. Friction coefficient of material (E) against different floor materials.

Friction coefficients measured when material (F) polyester-polyurethane copolymer (Lycra) slid against floor materials are shown in Figures 12, 13. Rubber showed the highest values of both friction coefficient and electrostatic charge, Figure-12. Ceramic and marble gave the lowest electrostatic charge.

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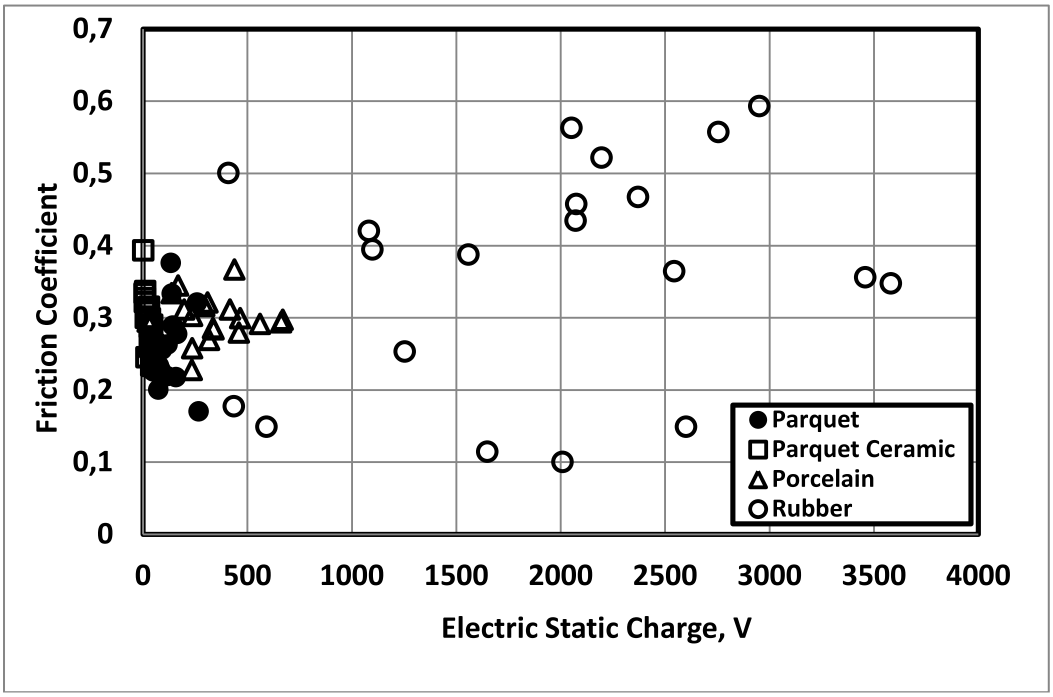

Figure-12. Friction coefficient of material (F) against different floor materials.

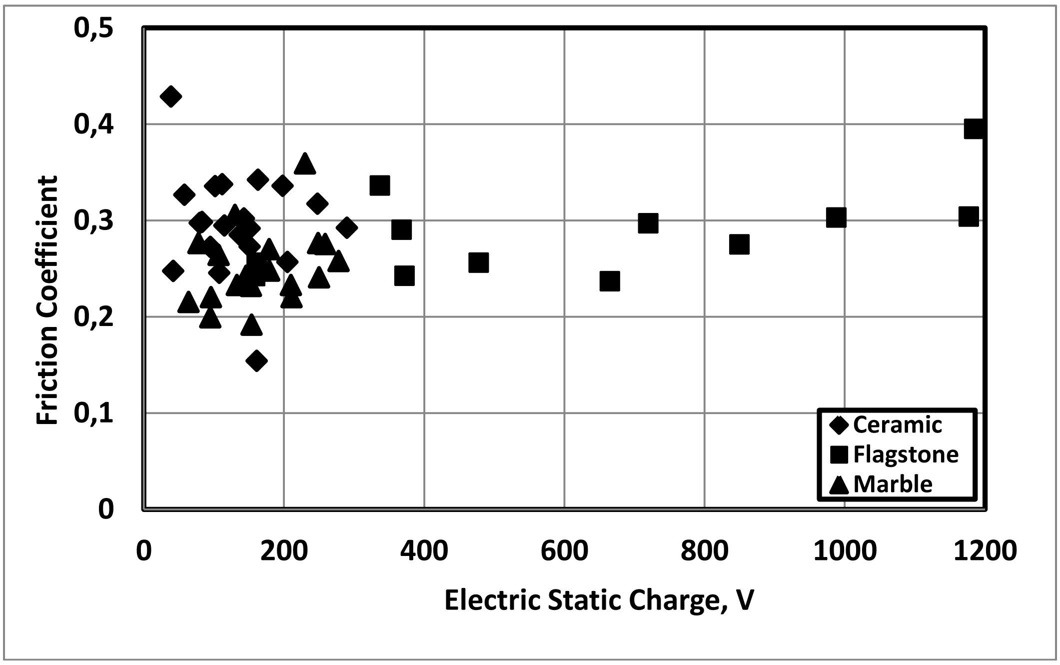

Figure-13. Friction coefficient of material (F) against different floor materials.

Friction coefficient and electrostatic charge generated by material (G) of 80 wt. % nylon and 20 wt. % Lycra when sliding against the tested flooring materials are illustrated in Figures 14, 15. Rubber tiles again showed the highest friction values but with relatively low electrostatic charge.

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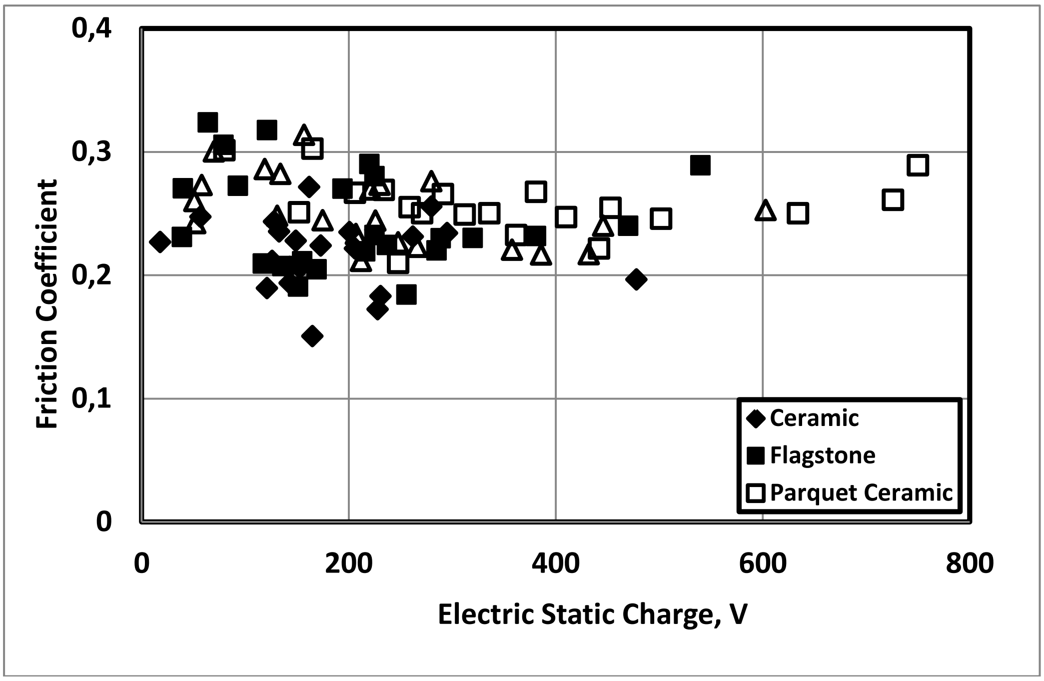

Figure-14. Friction coefficient of material (G) against different floor materials.

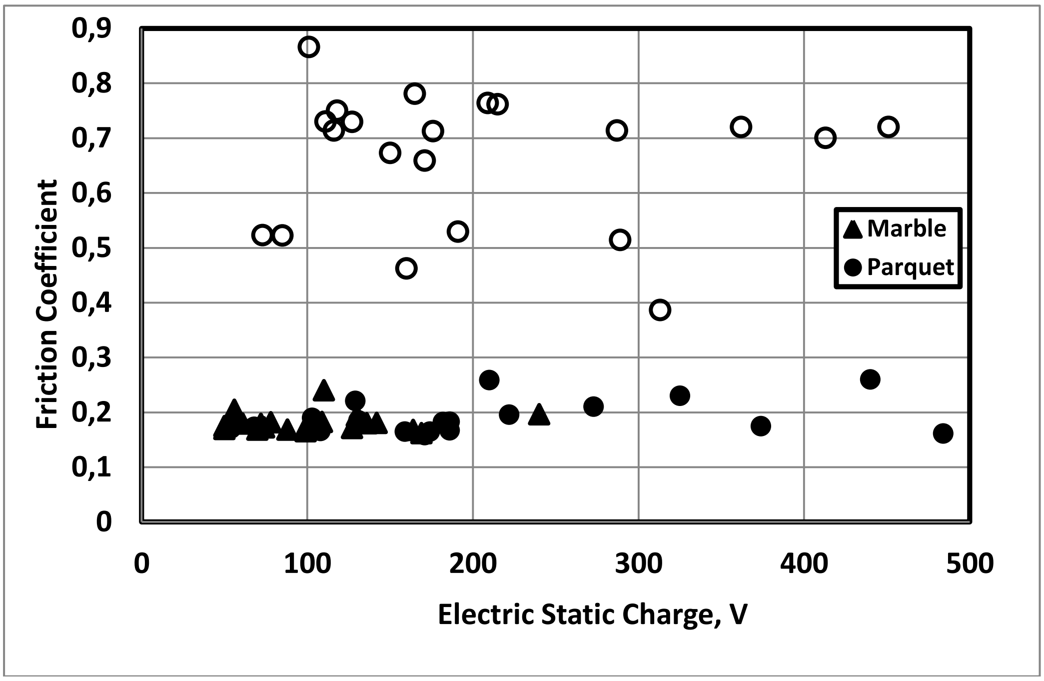

Figure-15. Friction coefficient of material (G) against different floor materials.

Polyamide material sliding against rubber flooring specimens showed significant decrease in both the friction coefficient and the electrostatic charge, Figures 16, and 17.These results are to be compared with those observed for materials made of 80 wt. % polyamide and 20 wt. % polyester-polyurethane copolymer (Lycra), Figures 14, and 15.

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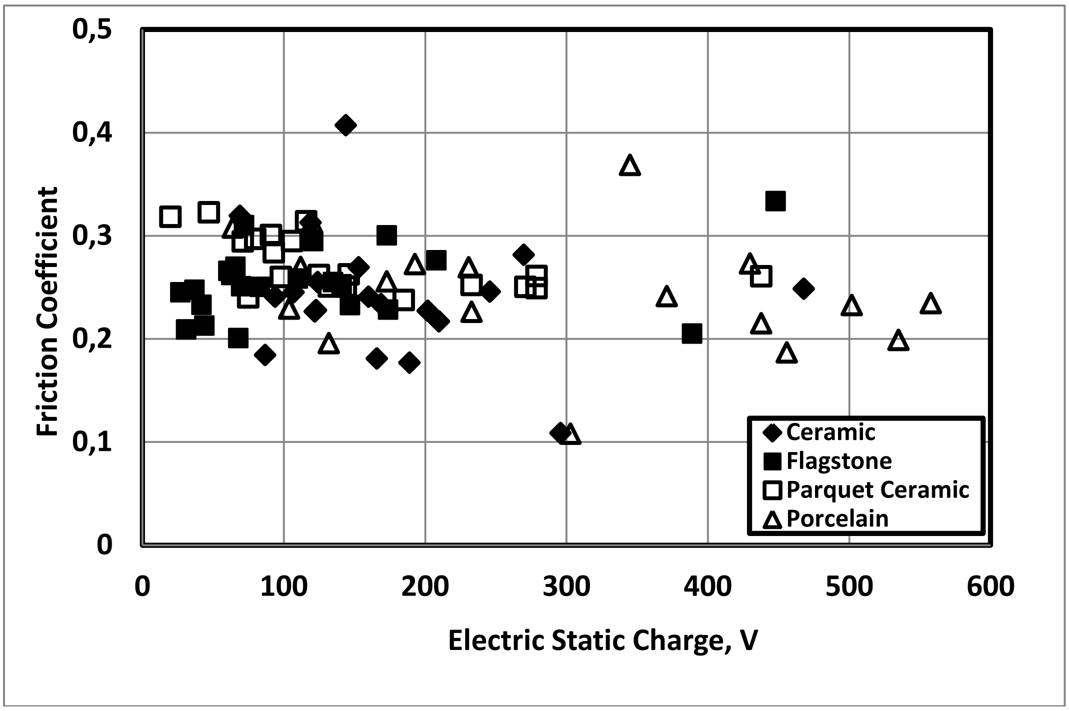

Figure-16. Friction coefficient of material (H) against different floor materials.

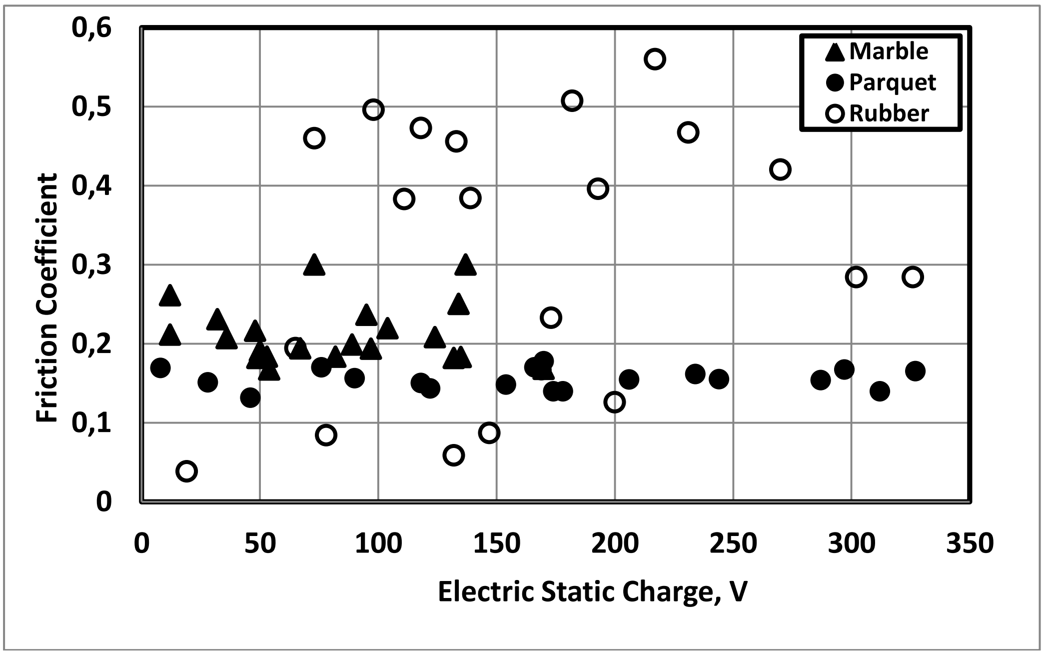

Figure-17. Friction coefficient of material (H) against different floor materials.

It seems that mixing polyamide of positive charge with Lycra of relatively negative charge decreased the generated electrostatic charge by friction. This behavior may be attributed to narrowing the gap between wearing material and flooring materials in the triboelectric series. Extra work should be done to determine the position of the floor materials in the triboelectric series to improve the selection process of the materials which avoids generation of excessive electro-static charge.

When two materials contact each other, the one in the top of the triboelectric series will assume to be positively charged, while the other one, relatively lower in the series, will assume negative charge. As the gap between the two materials increases the generated voltage increases. Therefore, it is necessary to select the materials according to its triboelectric positions within the series. Rubber flooring showed the highest elastic deformation among the tested flooring materials. Consequently, the contact area increased causing significant increase in the friction force.

CONCLUSIONS

a) It is important to establish codes for the electro-static charges generated from the friction of flooring materials.
b) Rubber showed the highest friction coefficients, while marble showed the lowest values.
c) Porcelain generated the highest electrostatic charge followed by ceramic, rubber, flagstone, parquet, parquet ceramic and marble.
d) Mixing polyamide of positive charge with Lycra of relatively negative charge decreased the electrostatic charge generated by friction.
e) Further experiments must be considered to define the position of the flooring materials within the triboelectric series. This helps in proper selection of the material of foot wear to avoid generation of excessive electrostatic charges which harm the human skin.

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