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ELECTROSTATIC CHARGE GENERATED FROM BARE FOOT AND FOOT WEAR SLIDING AGAINST FLOORING MATERIALS

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ABSTRACT

Electrostatic charges building up on human skin and or clothes in direct contact with human body are very harmful and can create serious health problems. The electrostatic charge and friction coefficient of bare foot and foot wearing socks sliding against different types of flooring materials were investigated under dry sliding condition. The tested flooring materials were ceramic, marble, parquet, moquette and rubber.

It was found that rubber flooring showed the highest generated voltage among the tested floorings. The highest voltage values were displayed by polyester socks, while cotton socks showed the lowest one. This observation can confirm the necessity of careful selection of the flooring materials. Parquet flooring showed the lowest voltage among the all tested flooring, where the maximum voltage did not exceed 520 volts at 800 N load. Friction coefficient displayed by sliding against rubber flooring represented the highest values of friction coefficient compared to the other tested floorings. Bare foot showed the highest values followed by cotton and polyester socks. The lowest values were 0.6 for polyester socks at 800 N.

Voltage generated from sliding against all the tested floorings significantly increased with increasing load. Bare foot conducts the electric static charge, while cotton and polyester socks as insulating materials could store the charge. It is expected that electrical field will be formed due the electric charge formed on the sock and floor surfaces.

KEYWORDS

Electrostatic charge, friction coefficient, ceramic, marble, parquet, moquette, rubber floors.

INTRODUCTION

Tribo-electricstatic charges building up on human skin and or clothes in direct contact with human body are very harmful and can create serious health problems. It is of considerable concern particularly for elderly people and infant. Walking and creeping on flooring can generate electric static charge of intensity depends on the material of flooring. Bare foot and the materials of socks can affect the generated charge. Charge generated from rubbing between shoes and carpet were discussed, [1, 2]. The effect of

humidity was explained on the basis that water molecules on the surfaces convey charges in the form of ions to enhance charge relaxation, [3, 4]. The effect of the static charge generation on the environment is influenced by electrical conductivity of the sliding surfaces.

The wide use of polymer fibers in textiles necessitates studying its electrification when rubbing other surfaces. The electric static charge generated from the friction of different polymeric textiles sliding against cotton textiles, which used as a reference material, was discussed, [5]. Experiments were carried out to measure the electric static charge generated from the friction of different polymeric textiles sliding against cotton under varying sliding distance, velocity and load. It was found that increase of cotton content decreased the generated voltage. Besides, as the load increased voltage generated from rubbing of 100 % spun polyester specimens increased. Besides, mixing polyester with rayon (viscose) showed the same behavior of mixing with cotton. Generally, increasing velocity increased the voltage. The voltage increase when increasing velocity may be attributed to the increase of the mobility of the free electrons to one of the rubbed surfaces. The fineness of the fibers greatly influences the movement of the free electrons.

Friction coefficient is the major scale to quantify floor slipperiness. The friction coefficient of rubber sliding against polymeric indoor flooring materials of different surface roughness was investigated, [6]. It was found that, at dry sliding, the friction coefficient decreased with increasing surface roughness and applied load. At water lubricated sliding, the friction coefficient increased up to maximum then decreased with increasing surface roughness. At water–soap lubricated sliding, the friction coefficient drastically decreased with increasing the surface roughness. At oil lubricated sliding, the maximum friction values were noticed at 4.0 µm R_a surface roughness. At water and oil lubricated sliding, smooth flooring surface displayed very low values of friction coefficient (0.08) close to the ones observed for mixed lubrication where the two sliding surfaces are partially separated by a fluid film. At dry sliding, friction coefficient of bare foot and polymeric socks, friction coefficient decreased down to minimum then increased with increasing the surface roughness, [7]. In water lubricated sliding, cotton socks showed the highest friction coefficient. Friction coefficient drastically decreased with increasing surface roughness at water and detergent lubricated sliding. For the tested flooring materials lubricated by oil, bare foot displayed drastic reduction in friction coefficient, while cotton socks showed the highest values.

The changes in the surface properties and frictional characteristics of flooring materials are expected in practical use due to mechanical wear, ageing, soiling and maintenance, [8]. In the sport halls the flooring surfaces are probably changed mainly through mechanical wear, periodic cleaning processes and material transfer from shoe soles (elastomer abrasions and contaminating particles). Coefficients of friction were measured periodically over a period of 30 months on the surfaces of five types of floor coverings in a new sport complex, [9]. Surface changes through mechanical wear range from smoothing to roughening, [10, 11], depending on flooring material and surface characteristics.

Surface roughness is known to be a key factor in determining the slip resistance of floors. The effect of surface roughness of ceramic on the friction coefficient, when sliding against rubber and leather, was investigated, [12]. Glazed floor tiles of different roughness ranging from 0.05 and 6.0 µm were tested. The test results showed that,

friction coefficient decreased down to minimum then increased with increasing the surface roughness of the ceramic surface.

Slip resistance of flooring materials is one of the major environmental factors affecting walking and materials handling behaviors. Floor slipperiness may be quantified using the static and dynamic friction coefficient, [13]. Certain values of friction coefficient were recommended as the slip-resistant standard for unloaded, normal walking conditions, [14, 15]. Relatively higher static and dynamic friction coefficient values may be required for safe walking when handling loads.

Researches revealed significant correlations between surface roughness of shoes and friction coefficient for a given floor surface, [16 - 19]. Abrasion of rubber soling in steps with increasingly coarse grit gradually raised the roughness in parallel with a rise in the friction coefficient on water wet surfaces. Dense rubbers never developed the same order of roughness, and they became smooth and polished when worn on ordinary floors or with mechanical polishing.

In the present work, electrostatic charge and friction coefficient of bare foot and foot wearing socks sliding against different types of flooring materials were investigated under dry sliding condition.

EXPERIMENTAL

Experiments were carried out to measure the friction coefficient displayed by the sliding of bare foot and foot wearing socks against different types of flooring materials, under dry sliding condition through measuring the friction force and applied normal load. The tested materials are placed in a base supported by two load cells, the first measures the horizontal force (friction force) and the second measures the vertical force (applied load). Friction coefficient was determined by the ratio between the friction force and the normal load.

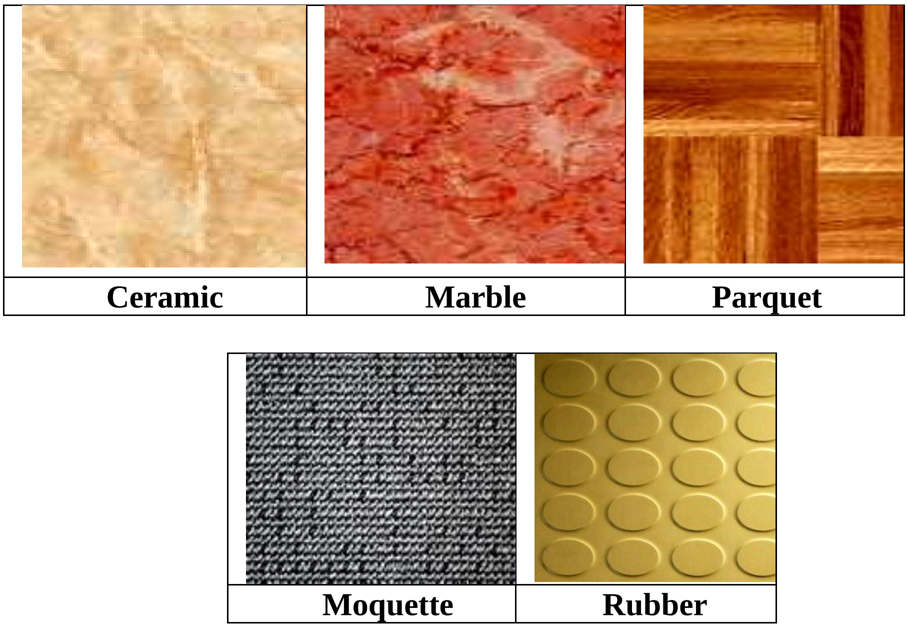

Fig. 1 The tested flooring materials.

The tested flooring materials were ceramic, marble, parquet, moquette and rubber in form of a quadratic sheet of 0.4 m × 0.4 m, Fig. 1. The sliding surfaces were thoroughly cleaned with soap water to eliminate dirt as well as dust and carefully dried before the tests. Bare foot and foot wearing socks were loaded against the tested flooring materials. Friction test was carried out at normal load varying from 0 to 800 N at dry sliding condition. After each measurement, all contaminants were removed from the flooring materials and the rubber specimens using absorbent papers.

The electrostatic fields (voltage) measuring device (Ultra Stable Surface DC Voltmeter) was used to measure the electrostatic charge (electrostatic field) for test specimens, Fig. 1. It measures down to 1/10 volt on a surface, and up to 20 000 volts (20 kV). Readings were normally done with the sensor 25 mm apart from the surface being tested.

RESULTS AND DISCUSSION

The experimental measurements of the present work are illustrated in Figs. 2 – 11. Voltage generated from sliding against ceramic flooring significantly increased with increasing load, Fig. 2. Polyester sock displayed the highest voltage at the highest load (800 N) followed by bare foot, while cotton sock showed the lowest voltage. The measured voltage values were relatively high, where the maximum value reached 2850 volts. Bare foot conducts the electric static charge, while cotton and polyester socks as insulating materials could store the charge. It is expected that electrical field will be formed due the electric charge formed on the sock and floor surfaces.

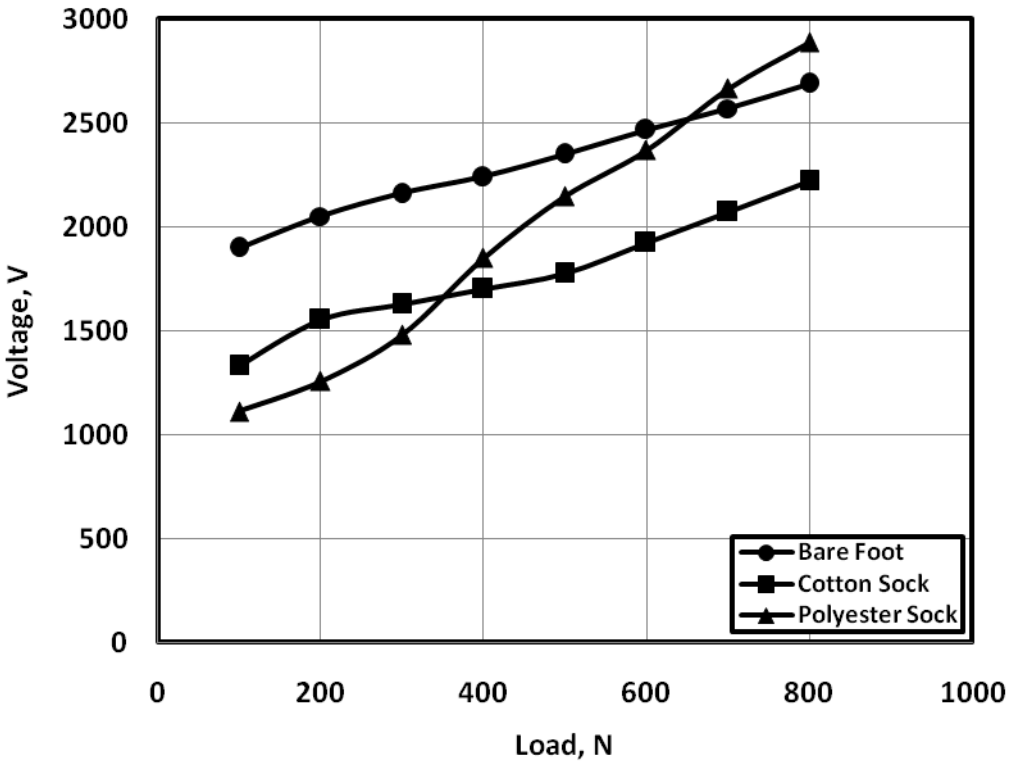

Fig. 2 Voltage generated for sliding against ceramic floor.

Slip resistance of flooring materials can be enhanced by increasing friction coefficient. The values of friction coefficient displayed by sliding against ceramic flooring is shown in Fig. 3, where bare foot displayed the highest values followed by cotton and polyester

socks. Friction coefficient decreased with increasing load. The highest friction coefficient value was 0.57 at 100 N load for bare foot.

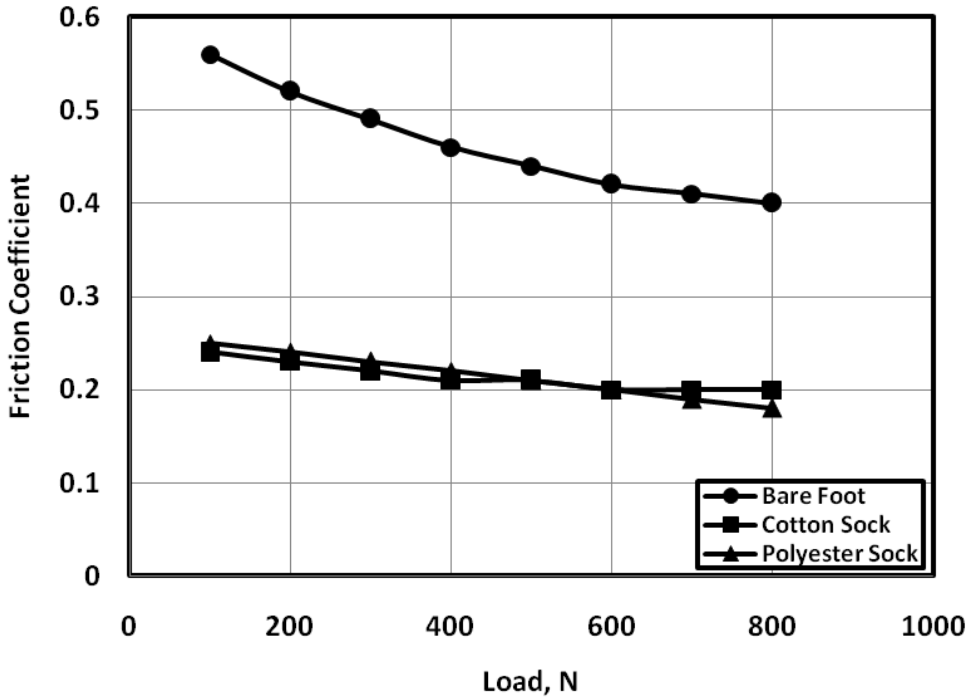

Fig. 3 Friction coefficient displayed for sliding against ceramic floor.

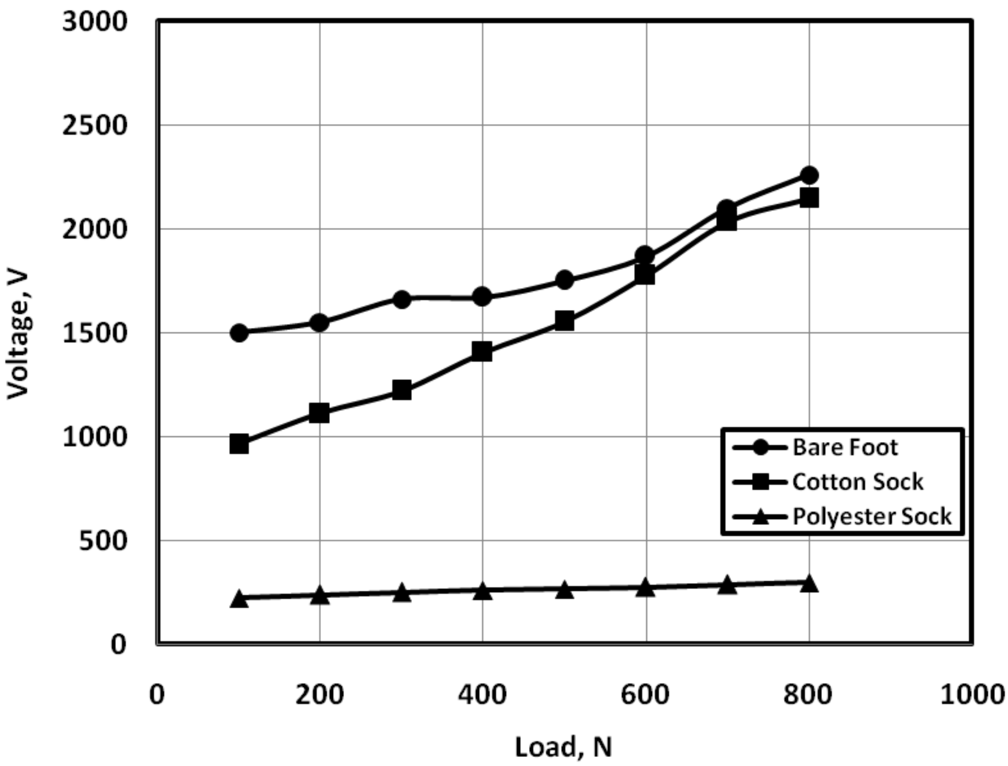

Fig. 4 Voltage generated for sliding against marble floor.

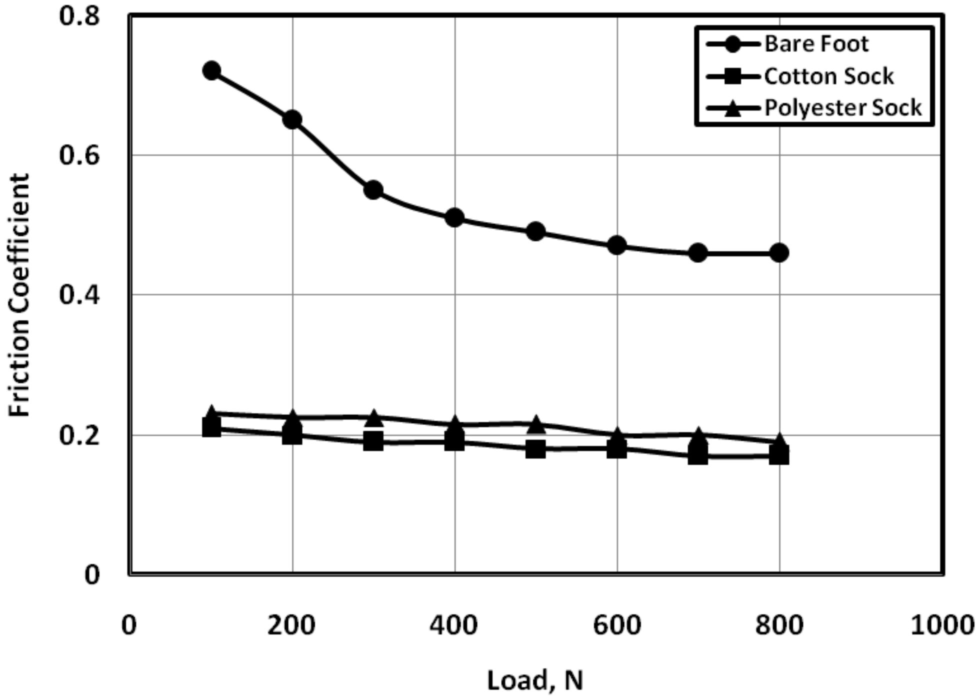

Fig. 5 Friction coefficient displayed for sliding against marble floor.

Voltage generated from sliding against marble flooring displayed lower values than that observed for ceramic flooring, Fig. 4. The highest value was 2250 volts generated from the sliding of the bare foot. Cotton socks showed lower values, while polyester ones generated very low voltage. Based on this observation it can be concluded that polyester socks are suitable for walking on marble flooring.

Bare foot sliding against marble flooring, Fig. 5, experienced relatively higher friction coefficient than that observed on ceramic one. The highest friction value reached 0.72. Polyester and cotton socks showed lower values ranging from 0.23 to 0.18. Based on the American and European standards those values are not high enough for safe walking.

\Voltage generated from sliding of bare foot, foot wearing polyester and cotton socks against moquette flooring is illustrated in Fig. 6. Polyester socks showed the highest voltage values, while bare foot and cotton socks displayed lower values. Compared to ceramic and marble, moquette showed higher voltage. The moquette fibers were made of polyamide. When two materials contact each other, the upper one in the triboelectric series will get positively charged and the other one will be negatively charged. As the difference in the rank of the two materials increases the generated voltage increases, [3]. It is known that polyamide is ranked as positive charged material, while polyester is negative charged one and the gap is relatively long in the triboelectric series which increases the potential difference. Cotton and foot skin are much closer to polyamide. It is therefore necessary to select the materials based on their triboelectric charging.

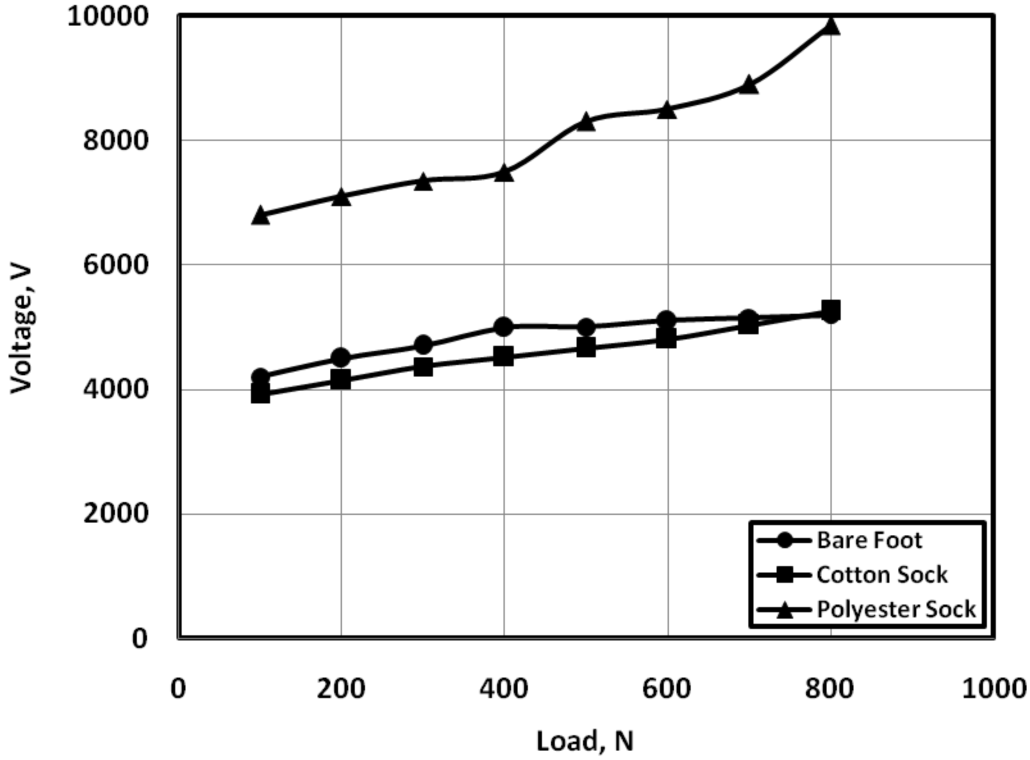

Fig. 6 Voltage generated for sliding against moquette floor.

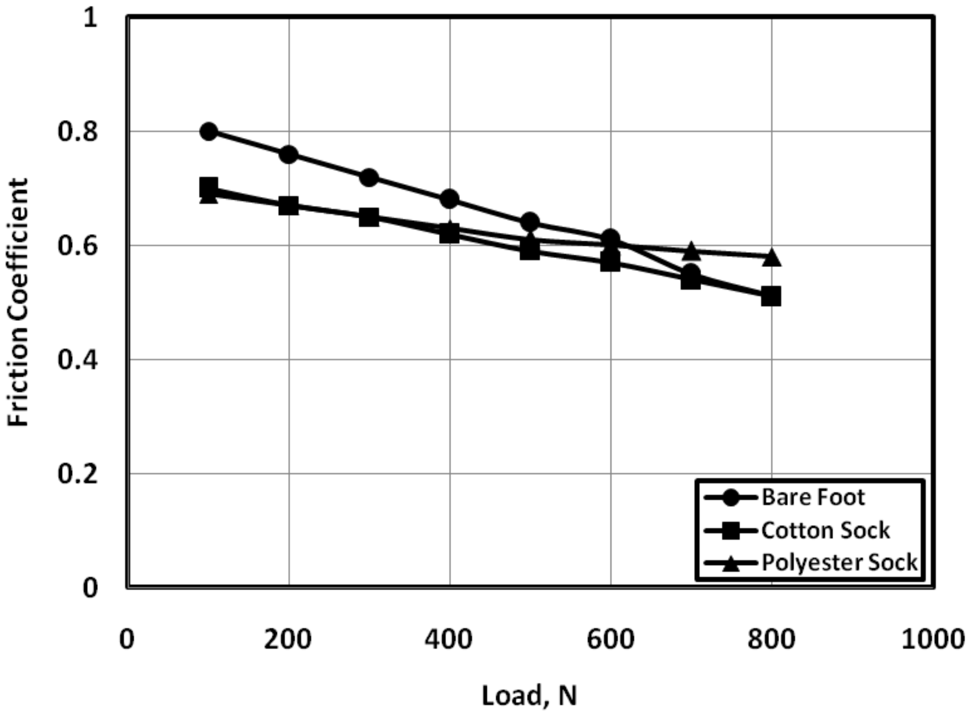

Fig. 7 Friction coefficient displayed for sliding against moquette floor.

Sliding against moquette flooring showed relatively higher friction values for bare foot, cotton and polyester socks, Fig. 7. Bare foot displayed friction value of 0.8 and 0.52 at

100 and 800 N respectively. The difference in the values generated from cotton and polyester socks were insignificant. It showed that the nature of moquette fibres strongly influenced friction coefficient regardless the counterface.

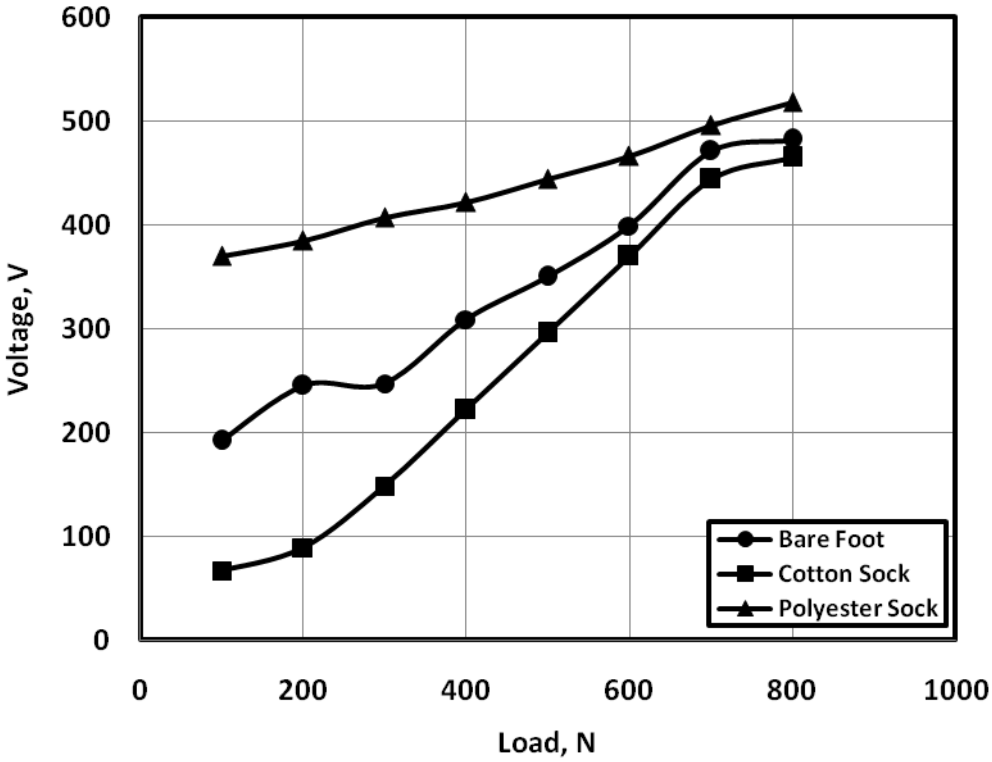

Fig. 8 Voltage generated for sliding against parquet floor.

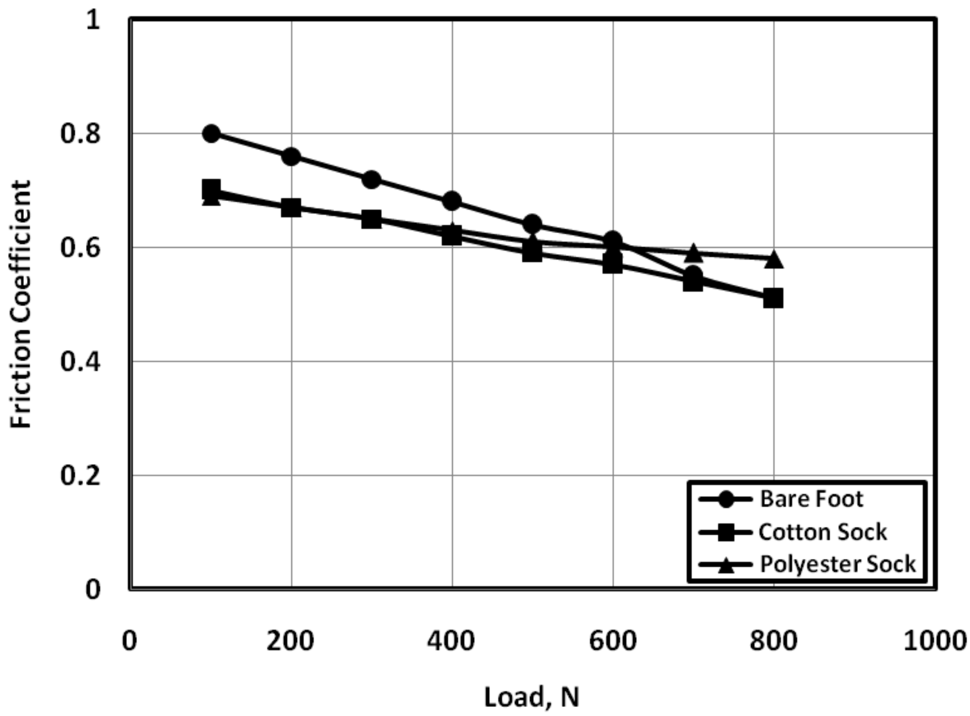

Fig. 9 Friction coefficient displayed for sliding against parquet floor.

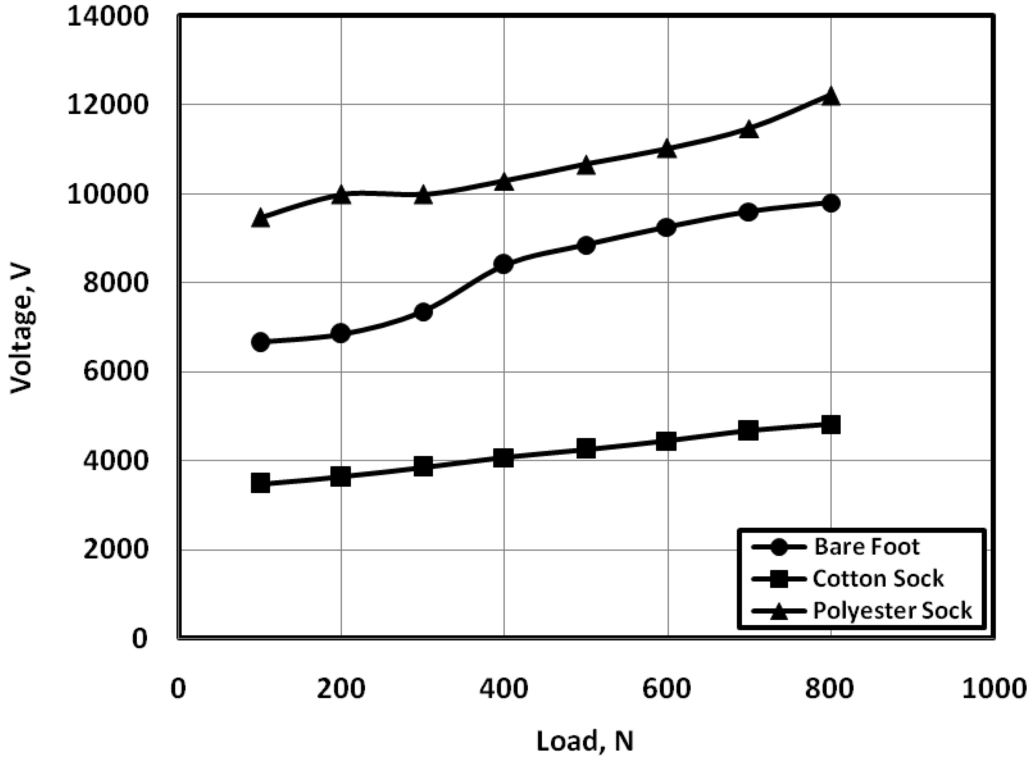

Fig. 10 Voltage generated for sliding against rubber floor.

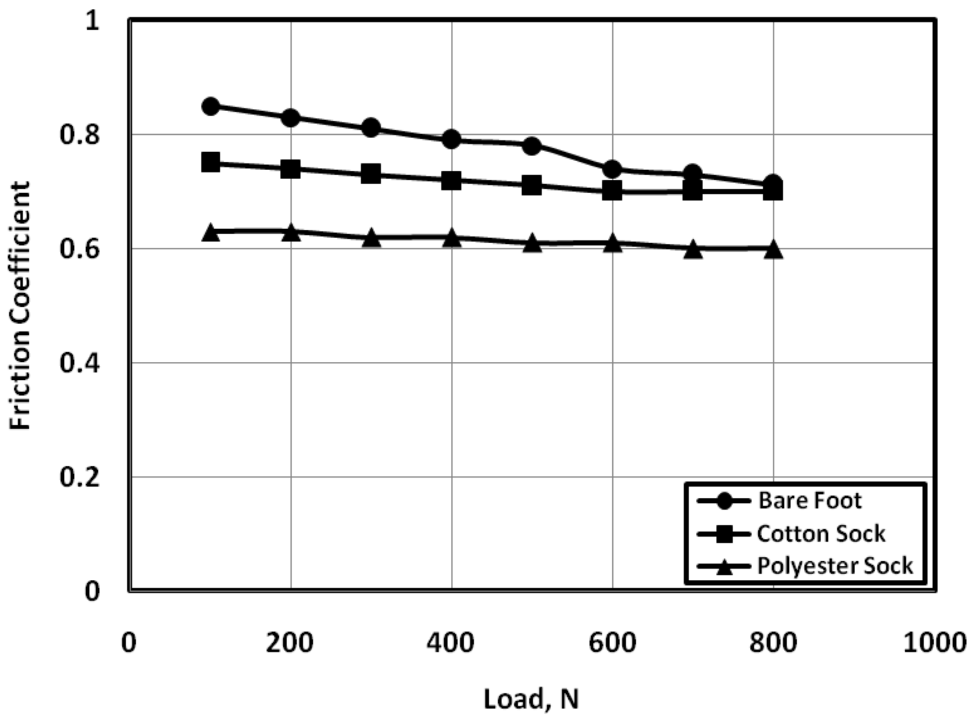

Fig. 11 Friction coefficient displayed for sliding against rubber floor.

Voltage generated from sliding against parquet flooring significantly increased with increasing load, Fig. 8. Polyester socks showed the highest voltage, followed by bare foot, while cotton socks displayed the lowest voltage. It is clearly noted that parquet flooring

resulted in the lowest voltage among the all tested flooring, where the maximum voltage did not exceed 520 volts at 800 N load.

Friction coefficient displayed by sliding against parquet flooring showed relatively higher values, Fig. 9. Bare foot displayed the highest values, followed by polyester and cotton socks. The friction values fulfill the American standards, where the static coefficient of friction of 0.5 has been recommended as the slip-resistant standard for unloaded, normal walking conditions, [20]. Higher static coefficient of friction may be required for safe walking when handling loads.

Rubber flooring showed the highest generated voltage for polyester socks, followed by bare foot and cotton socks, Fig. 10. The highest voltage values reached 12100 volts at 800 N load. The highest value for cotton socks was 4800 volts. This observation can confirm the necessity of careful selection of the flooring materials. It is recommended to replace the rubber floorings by suitable composites of low elastic modulus because they are used in hospitals and kid play areas.

Friction coefficient displayed by sliding against rubber flooring represented the highest values of friction coefficient compared to the other tested floorings, Fig. 11. Bare foot showed the highest values followed by cotton and polyester socks. The lowest values were 0.6 for polyester socks at 800 N.

CONCLUSIONS

1. Voltage generated from sliding against all the tested floorings significantly increased with increasing load.
2. When sliding against ceramic flooring, polyester socks displayed the highest voltage followed by bare foot, while cotton sock showed the lowest voltage. Bare foot displayed the highest values of friction coefficient followed by cotton and polyester socks. Friction coefficient decreased with increasing load.
3. Voltage generated from sliding against marble flooring displayed lower values than that observed for ceramic flooring. Polyester socks generated very low voltage. Based on this observation it can be concluded that polyester socks are suitable for walking on marble flooring. Bare foot experienced relatively higher friction coefficient than that observed on ceramic one, while polyester and cotton socks showed lower values.
4. Voltage generated from sliding of bare foot, foot wearing polyester and cotton socks are illustrated in Fig. 6. Polyester socks sliding against moquette flooring showed the highest voltage values, while bare foot and cotton socks displayed lower values. Compared to ceramic and marble, moquette showed higher voltage. Sliding against moquette flooring showed relatively higher friction values for bare foot, cotton and polyester socks.
5. Parquet flooring showed the lowest voltage among the all tested flooring. Friction coefficient displayed by sliding against parquet flooring showed relatively higher values, where bare foot displayed the highest values followed by polyester and cotton socks.
6. Rubber flooring showed the highest generated voltage among all the tested flooring. This observation can confirm the necessity of careful selection of the flooring materials. Friction coefficients displayed by sliding against rubber flooring are the highest values of friction coefficient compared to the other tested floorings.

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