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REDUCING ELECTRIC STATIC CHARGE GENERATED FROM EPOXY FLOORING MATERIALS

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ABSTRACT

The aim of the present work is to test proposed composites consisting of epoxy filled by metallic particles such as iron, brass and copper. The combination of the proposed materials can produce composites of minimum electric charge that can be used as flooring tiles. Experiments were carried out to measure the electric static charge and friction coefficient under varying load.

It was found that, epoxy free of filling materials generated the highest negative voltage when sliding against rubber, then drastically decreased with increasing the positive voltage generated from metallic particles. The addition of copper and brass particles into epoxy matrix displayed higher values of voltage than that observed for iron particles. Voltage was influenced by the load, where it increased with load increasing. Based on the present observations, it can be concluded that as the electrical conductivity of the metallic particles increased the metallic particles content to obtain the zero voltage decreased. Voltage generated from the sliding of the tested composites against rubber was much higher than that observed at contact and separation. Generally, values of metallic content that generated zero voltage at contact and separation were much lower than at sliding.

Friction coefficient slightly increased with increasing metallic content. Based on the quantification of floor slip-resistance, the static friction coefficient of 0.5 was recommended as the slip resistant standard for normal walking conditions. For all the test specimens friction coefficient exceeded 1.0 which confirmed that the floor made of the tested composites will be very safe for walking. At brass content where the generated voltage diminished, friction coefficient value approached 1.4. This observation recommends that composites to be used as flooring tiles. Besides, addition of copper particles caused significant friction increase.

KEYWORDS

Electric static charge, friction coefficient, epoxy flooring, metallic particles.

INTRODUCTION

Friction measurement is one of the major approaches to quantify floor slipperiness. Investigations on friction measurement have been focused on liquid-contaminated conditions. It was expected that wet surfaces had significant lower friction coefficient

values than those of the dry surfaces, [1, 2]. The friction coefficient difference between the dry and wet surfaces depended on the footwear material and floor combinations. Friction measurements under liquid-contaminated conditions are very common. The squeeze film theory explains the effects of the liquid on the measured friction.

Tread groove designs are helpful in facilitating contact between the mat sole and floor on liquid contaminated surface, [3]. The effectiveness of a tread groove design depends on the contaminant, footwear material and floor. Tread groove design was ineffective in maintaining friction on a floor covered by vegetable oil. Tread grooves should be wide enough to achieve better drainage capability on wet and water–detergent contaminated floors.

The effect of rubber flooring with cylindrical treads on the friction coefficient was investigated, [4]. It was found that parallel treads showed the highest friction coefficient, while perpendicular treads displayed the lowest friction values. Presence of oil on the sliding surfaces showed a decreasing trend of friction coefficient with increasing tread diameter as a result of the presence of squeeze oil film separating footwear and rubber flooring. The effect of the treads width and depth of the mat sole, on the friction coefficient between the mat and ceramic floor interface, was discussed, [5]. It was found that, at dry sliding, friction coefficient slightly increased with increasing treads height. Perpendicular treads displayed the highest friction coefficient due to their increased deformation, while parallel treads showed the lowest values.

The friction coefficient of rubber sliding against different types of flooring materials of different surface roughness was investigated under different sliding conditions: dry, water, water/detergent dilution, oil, water/oil dilution, [6]. The flooring materials are parquet, polyvinyl chloride (PVC), epoxy, marble, cement and ceramic. It was found that sliding of rubber against water/detergent wetted tiles caused drastic decrease of friction coefficient. Parquet displayed the highest friction values followed by cement and marble. PVC, epoxy and ceramic represented relatively lower friction values.

The effect of semispherical cavities introduced in the rubber flooring mats on the static friction coefficient obtained during their sliding against ceramic flooring under dry, water, water + 5.0 vol. % detergent, oil and water + 5.0 vol. % oil lubricated sliding conditions was investigated, [7]. Based on the experimental observation, it can be concluded that at dry sliding, smooth rubber displayed the lowest friction, while semispherical cavities showed an increased trend of friction. As the height of the cavity increased friction increased.

Recently, flooring tiles made of recycled rubber were tested, [8 - 10]. The effect of surface roughness on the frictional behavior of recycled rubber tiles was discussed. It was found that, for tiles made of recycled rubber, surface roughness had insignificant effect on the frictional behavior. Friction coefficient slightly increased with increasing the tile thickness. In the presence of water on the sliding surface, rough surface displayed higher friction values than the smooth one. Values of friction for detergent lubricated surfaces were lower than that observed for water lubricated surface. At dry sliding, friction coefficient slightly increased with increasing the content of the filling materials. At water lubricated sliding, friction coefficient significantly decreased with increasing filling material content. Detergent decreased friction coefficient lower than water. The lowest friction values were observed for tiles filled by 70 wt. % polyurethane.

Friction coefficient and electrostatic charge of epoxy composites filled by nanoparticles of aluminium (Al) sliding against rubber were investigated to develop proper materials to be used as flooring materials of high friction coefficient and low electrostatic charge, [11]. It was observed that at dry, water and detergent wetted surfaces, Al nanoparticles addition into epoxy matrix decreased friction coefficient with increasing Al content. At water contaminated by sand, detergent, oil, water/oil emulsion, oil contaminated by sand and water/oil emulsion contaminated by sand wetted surfaces, friction coefficient increased with increasing Al. It was observed that at dry sliding, voltage decreased with increasing Al content. Voltage showed the maximum values for epoxy free of filling materials and decreased with decreasing load. Voltage showed drastic decrease with increasing Al contents. In the presence of sand particles, water contaminated by sand, detergent contaminated by sand and water/oil emulsion contaminated by sand on the sliding surfaces, voltage increased with increasing Al. For surfaces wetted by detergent contaminated by sand, oil and oil contaminated by sand, voltage drastically decreased with increasing Al.

It was observed that at dry, water and detergent wetted surfaces, Al_2O_3 nanoparticles addition into epoxy matrix decreased friction coefficient with increasing Al_2O_3 content, [12]. When sand particles were covering the sliding surfaces, no change was observed for friction coefficient with increasing Al_2O_3 content. Atwater contaminated by sand, detergent, oil, water/oil emulsion, oil contaminated by sand and water/oil emulsion contaminated by sand wetted surfaces, friction coefficient increased with increasing Al_2O_3. As for voltage as a measure of the electrostatic charge generated from friction, it was observed that at dry sliding, voltage decreased with increasing Al_2O_3content.

It was found that, at dry sliding, iron nanoparticles addition into epoxy matrix increased friction coefficient with increasing iron content, [13, 14]. Voltage drastically decreased with increasing iron content. Voltage showed the maximum values for epoxy free of iron. Significant friction coefficient increase was observed at water wetted surfaces. Epoxy free of iron showed relatively lower voltage than that observed for dry sliding. As iron content increased voltage drastically decreased. Voltage drastically decreased with increasing iron. At oil/water emulsion, voltage and friction coefficient significantly increased with increasing iron.

In the present work, electric static charge and friction coefficient generated from the sliding of rubber against epoxy flooring filled by metallic particles were investigated.

EXPERIMENTAL

The test specimens were molded of epoxy in form of cylindrical disc of 50 mm diameter and 20 mm height. They were filled by iron, brass and copper particles of 30 – 50 µm particle size and 5, 10, 15, 20, 25, 30, 40 and 50 wt. % metallic content . They were loaded against rubber surface. 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 are normally done with the sensor 25 mm apart from the surface being tested.

Fig. 1 Electrostatic field measuring device.

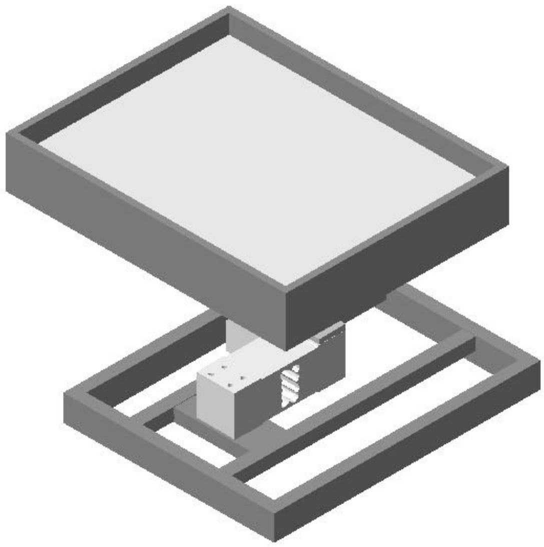

Fig. 2 Arrangement of the test rig.

Rubber sheet was adhered to the base supported by two load cells, the first can measure the horizontal force (friction force) and the second can measure the vertical force (normal load), Fig. 2. Friction coefficient was determined by the ratio between the friction force and the normal load. Tests were carried out at room temperature under varying normal loads, then the results were plotted for 50, 75 and 100 N load. Experiments were carried out by sliding the epoxy test specimens against the rubber sheet which resembled the sole of the footwear.

RESULTS AND DISCUSSION

The results of experiments measuring electric static charge due to contact and separation are illustrated in Figs. 3 – 5. Voltage generated from the contact and separation of epoxy filled by iron particles with rubber is shown ion Fig. 3. Epoxy free of filling materials generated -350, -40 and -60 volts at 50, 75 and 100 N respectively. Then the generated negative voltage drastically decreased with the increase of the positive voltage generated from iron particles. At 3, 7 and 9 wt. % of iron content, voltage approached zero value at 50, 75 and 100 N respectively, then the specimens gained positive charge with further increase of iron content.

The addition of brass particles into epoxy matrix displayed higher values of voltage than that observed for iron particles, Fig. 4. The values of brass content at which voltage reached zero were 2, 5 and 6 at at 50, 75 and 100 N respectively. Voltage was influenced by the load, where it increased with increasing load. The highest voltage was observed at 50 wt. % brass content.

Voltage generated from the contact and separation of rubber with epoxy filled by copper particles is illustrated in Fig. 5. The contents of copper particles that generated no voltage were 2, 4 and 5 wt. % at 50, 75 and 100 N respectively. Based on the previous observations in Figs. 3 – 5, it can be concluded that the metallic particles are strongly affecting the relaxation of the electric static charge generated from friction. Besides, as the electrical conductivity of the metallic particles increased the metallic particles content, to obtain the zero voltage, decreased.

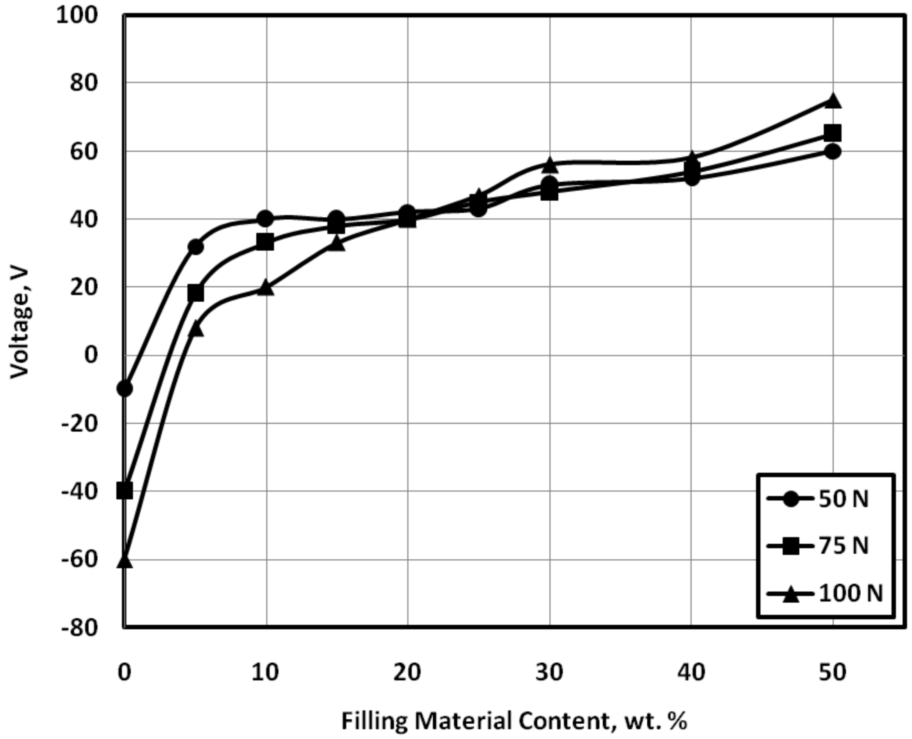

Fig. 3 Voltage generated from the contact and separation of rubber with epoxy filled by iron particles.

Voltage generated from the sliding of epoxy filled by iron particles against rubber is shown ion Fig. 6. Epoxy free of filling materials generated -350, -450 and -560 volts at 50, 75 and 100 N respectively. Then the generated voltage drastically decreased with increasing the iron particles. At 50, 45 and 44 wt. % iron particles, voltage approached zero value at 50, 75 and 100 N respectively, then the composites gained positive voltage with further increase of iron particles.

When rubber slid against epoxy filled by brass particles, voltage showed the same trend observed for epoxy filled by iron, Fig. 7. The content of brass particles that generated no voltage was 37, 36 and 43 wt. % at 50, 75 and 100 N load respectively. The brass content was lower than iron content that generated the lowest voltage.

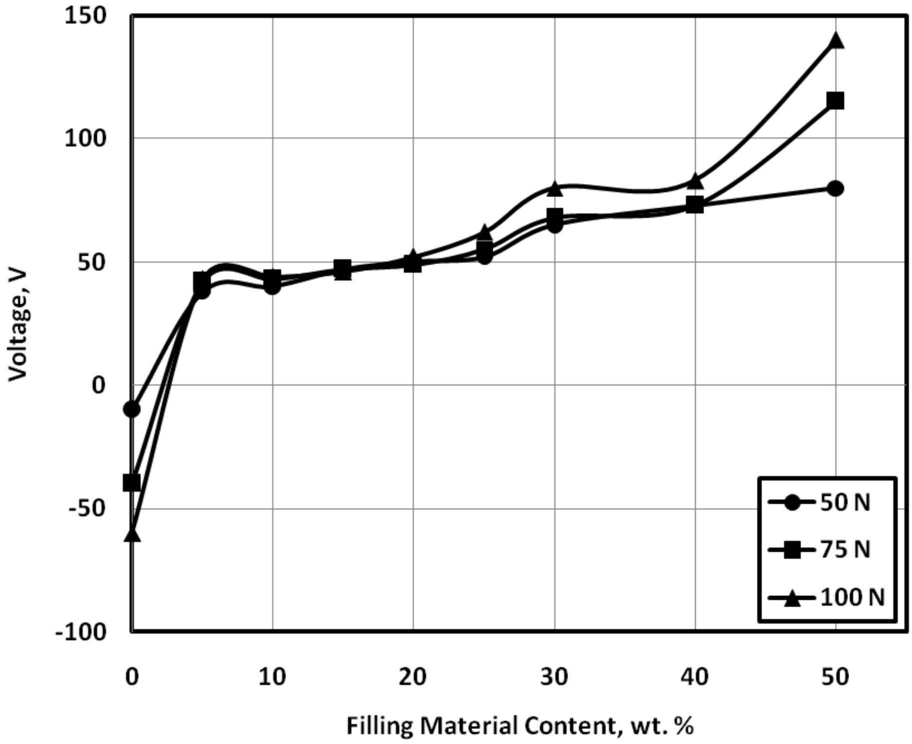

Fig. 4 Voltage generated from the contact and separation of rubber with epoxy filled by brass particles.

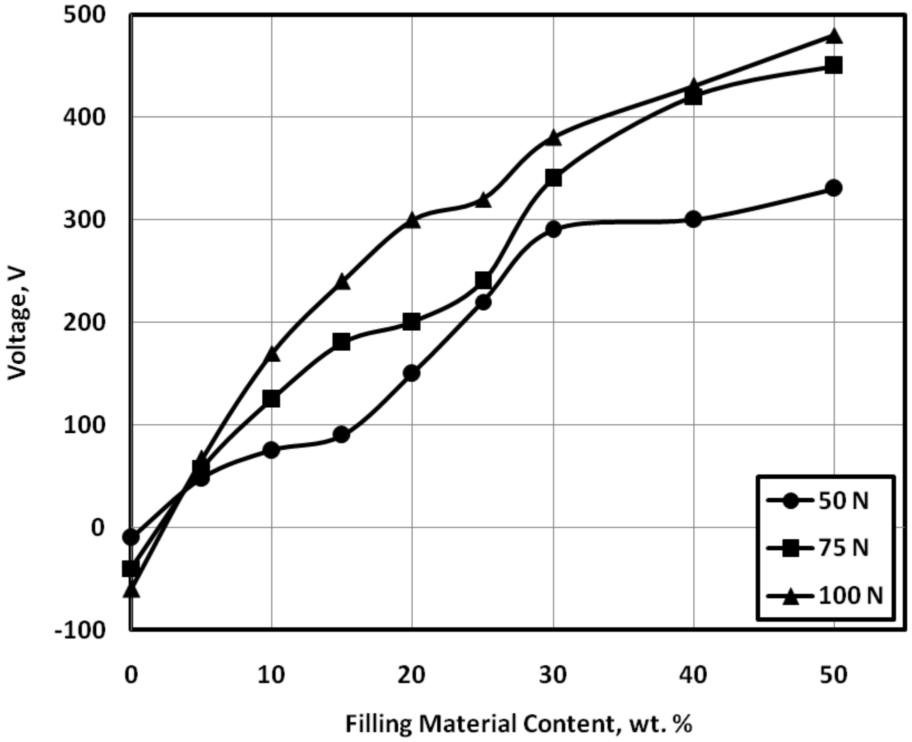

Fig. 5 Voltage generated from the contact and separation of rubber with epoxy filled by copper particles.

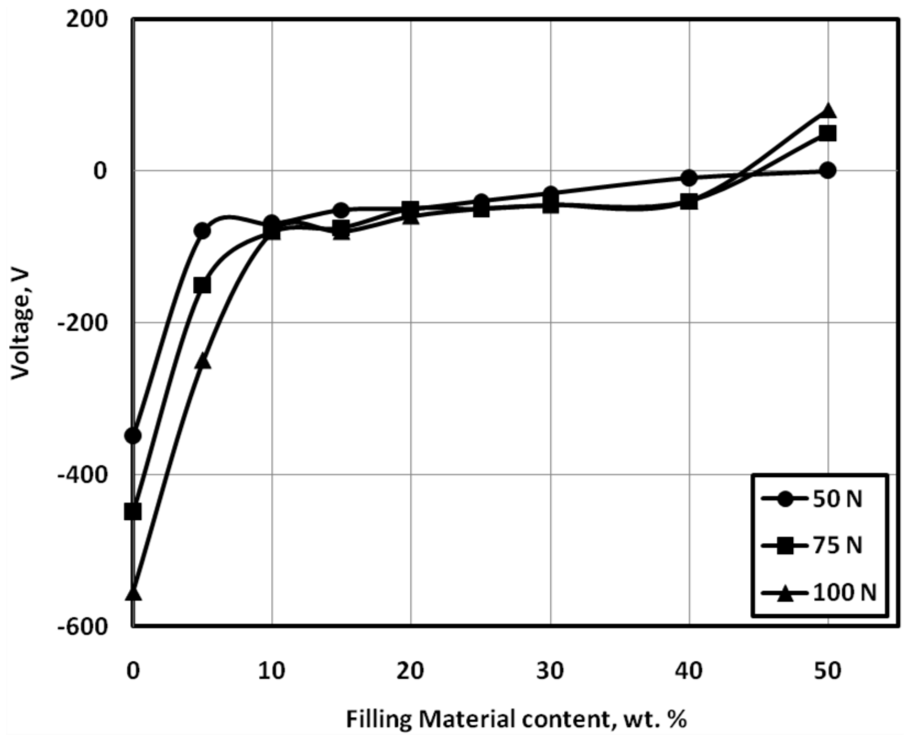

Fig. 6 Voltage generated from the sliding of rubber against epoxy filled by iron particles.

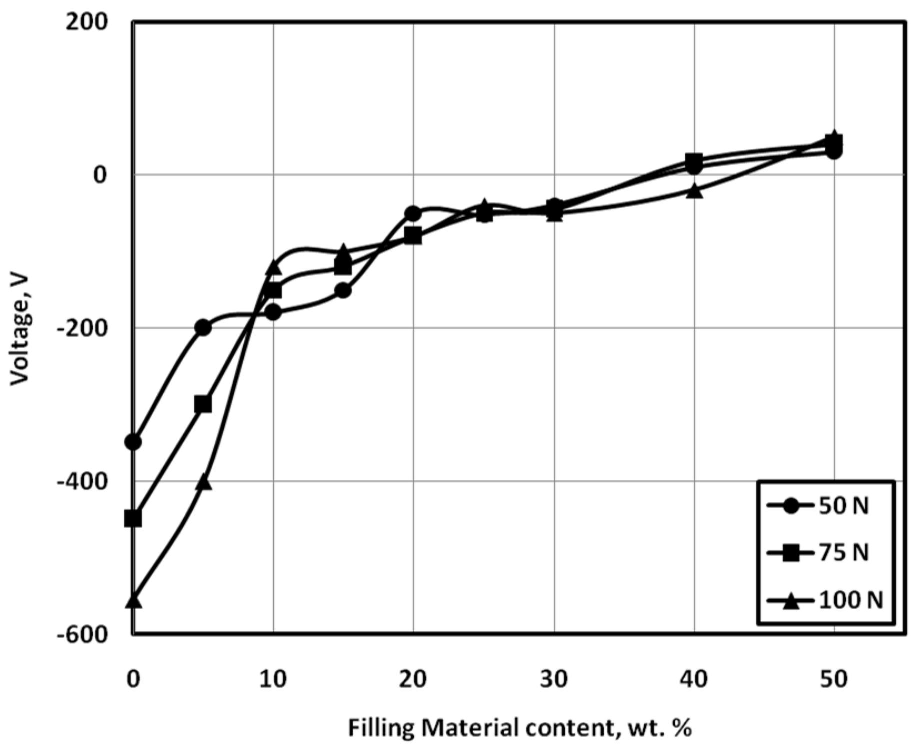

Fig. 7 Voltage generated from the sliding of rubber against epoxy filled by brass particles.

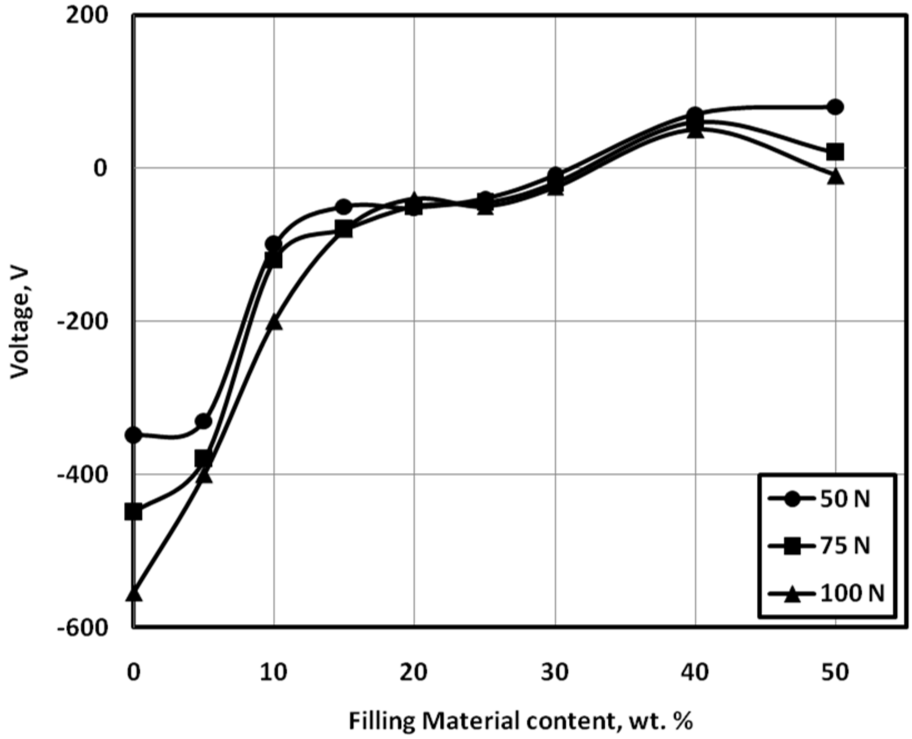

Fig. 8 Voltage generated from the sliding of rubber against epoxy filled by copper particles.

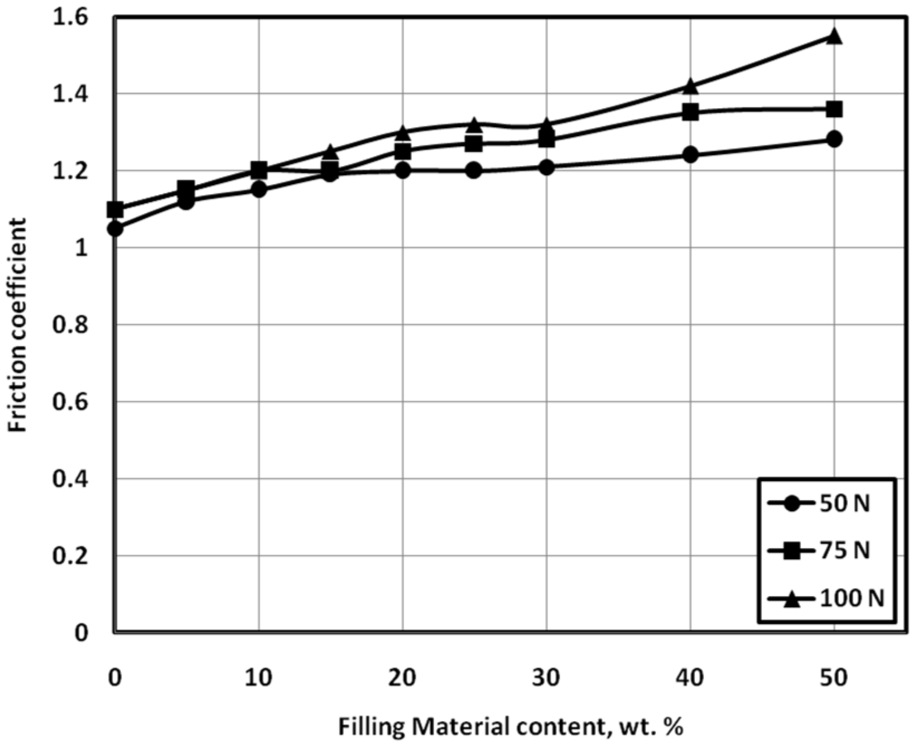

Fig. 9 Friction coefficient displayed by the sliding of rubber against epoxy filled by iron particles.

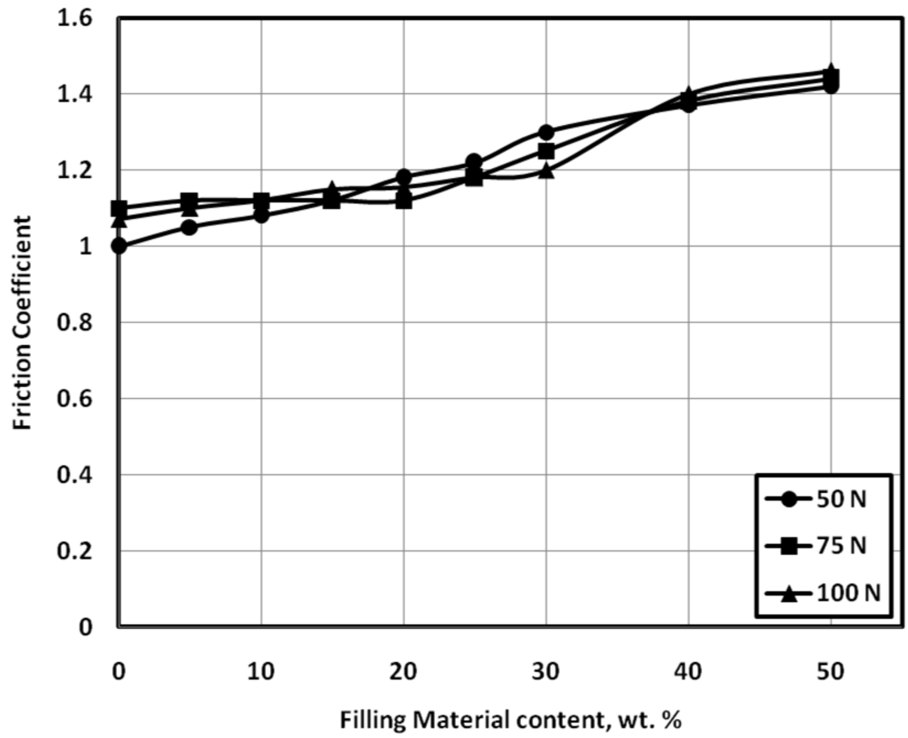

Fig. 10 Friction coefficient displayed by the sliding of rubber against epoxy filled by brass particles.

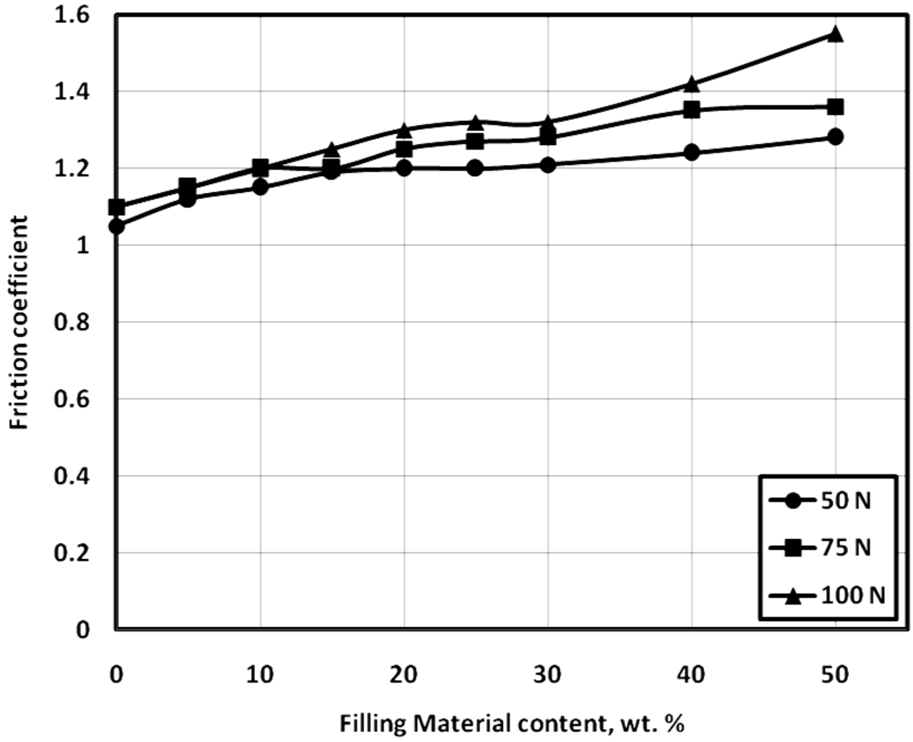

Fig. 11 Friction coefficient displayed by the sliding of rubber against epoxy filled by copper particles.

The addition of copper particles into epoxy matrix displayed the same trend of voltage generation, Fig. 8. The load influenced the copper content that caused the generated voltage to reach zero value. At 50, 75 and 100 N load, copper contents were 31, 33 and

34 wt. % respectively. Generally, values of metallic content that generated zero voltage at contact and separation were much lower than that generated at sliding.

The results of experiments carried out to measure friction coefficient displayed by tested composites sliding against dry rubber are illustrated in Figs. 9 – 11. Friction coefficient displayed by the sliding of rubber against epoxy filled by iron particles is shown in Fig. 9, where the friction values slightly increased with increasing iron content. Based on the quantification of floor slip-resistance, the static friction coefficient of 0.5 has been recommended as the slip resistant standard for normal walking conditions. For all the tested composites, friction coefficient exceeded 1.0, which confirmed that the floor made of the tested composites will be very safe for walking.

Friction coefficient displayed by the sliding of rubber against epoxy filled by brass particles showed further increase with increasing brass content, Fig. 10. At 37 – 44 wt. % brass content, where the generated voltage diminished, friction coefficient value approached 1.4. This observation recommends that composites to be used as flooring tiles. The same trend for friction coefficient was observed for epoxy filled by copper particles, Fig. 11. Addition of copper particles caused significant friction increase.

CONCLUSIONS

1. Epoxy free of filling materials generated the highest negative voltage, then drastically decreased with increasing the content of iron particles. At 50, 45 and 44 wt. % iron content, 37, 36 and 43 wt. % brass content, 31, 33 and 34 wt. % copper content, voltage approached zero value at 50, 75 and 100 N load respectively.
2. The load influenced the metallic content that caused the generated voltage to reach zero value.
3. The materials of the particle are strongly influencing the relaxation of the electric static charge generated from friction.
4. Friction coefficient displayed by the sliding of rubber against epoxy composites slightly increased with increasing iron content. For all the test specimens, friction coefficient exceeded 1.0 which confirmed that, the floor made of the tested composites will be very safe for walking.
6. Friction coefficient displayed by the sliding of rubber against epoxy composites showed further increase with increasing copper particles content. At 37 – 44 wt. % copper content, where the generated voltage diminished, friction coefficient value approached 1.4. This observation recommends that composites to be used as flooring tiles.

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