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ELECTROSTATIC CHARGE GENERATED FROM SLIDING OF RUBBER ON EPOXY FILLED BY RECYCLED RUBBER GRANULATES

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ABSTRACT
Floor materials made of epoxy resins were filled by recycled rubber granulates and paraffin oil to reduce their brittleness. The present study measures the electrostatic charge (ESC) generated from the dry sliding of rubber shoe on the proposed composites. The function of the oil that filled the composites in contents of 5.0 and 10.0 wt. % was to enhance the viscoelastic property. Different sizes of recycled rubber granulates were used as filling material in contents of 20, 40, 60 and 80 wt. %. The proposed composites slid against rubber surface at different normal loads, where coefficient of friction was determined.

It was found that ESC generated on rubber sole sliding on epoxy filled by recycled rubber particles increased with increasing normal load due to the increased contact area. As the rubber content increased, the number of surface asperities increased leading to the increase of friction that increased the triboelectrified contact area. It is observed that particle size of rubber granulates significantly affected ESC. As the particle size increased, the deformation of rubber asperities increased the friction and therefore ESC increased. The minimum ESC values were measured for composites filled by 80 wt. % rubber of particle size up to 3.0 mm and 10 wt. % oil. Therefore, that composites can be recommended in floor tile applications.

KEYWORDS
Floor, rubber shoe, epoxy, recycled rubber, paraffin oil.

INTRODUCTION
Epoxy has wide applications in floor materials, [1]. The major disadvantage of epoxy is its brittleness that limits the application, [2]. Recycled rubber (butadiene-acrylonitrile) was used as filler to reduce the brittleness of epoxy, [3 – 5], where the ductility was enhanced because rubber granulates developed the plastic deformation and concentrated the stress in the matrix. When the epoxy filled by rubber granulates was filled by oil, friction decreased compared to composites free of oil. Further increase in rubber granulate size was accompanied by friction increase for epoxy filled by oil, [6]. It

was recommended to use the proposed composites in different applications, where addition of oil into epoxy decreased the abrasion of the proposed composites.

The electrostatic charge (ESC) generated during walking on the floor had little attention. Static friction coefficient was used to evaluate safe walking. Walking and creeping on floor generate ESC. The intensity depends on the materials of the floor and footwear. ESC and friction of bare foot as well as foot wearing socks sliding against floors such as parquet, marble, ceramic, moquette and rubber, where rubber floor showed the highest ESC among the tested floors. ESC generated from sliding of shoes on carpet was discussed, [7 - 12].

The dependency of friction coefficient on ESC was confirmed, [13]. It was revealed that specific data about the value of ESC can be beneficial in controlling friction coefficient, where increasing ESC increases the adhesion between the contact surface and therefore friction coefficient increases. The type of floor materials affects the generation of ESC and friction coefficient, [14]. It was found that addition of copper and brass particles into epoxy displayed relatively higher values of ESC, [15]. ESC was influenced by the load and increased as the load increased, [16, 17]. Insulating the sliding surfaces showed relatively lower friction coefficient than that observed for the connected ones due to the effect of ESC.

ESC built up on human skin is harmful and create serious health problems, [18]. It was found that, at dry sliding, iron nanoparticles filled epoxy matrix increased friction coefficient with increasing iron content. ESC drastically decreased with increasing iron content, where the maximum values displayed by epoxy free of iron. Bare foot sliding against epoxy floor showed relatively lower voltage than that displayed by rubber footwear, [19]. The dependency of ESC and friction between the two insulating materials was proved for alumina sliding against polytetrafluoroethylene (PTFE), [20, 21]. ESC occur during contact or sliding on the surface by charge trapping. ESC plays effective role in adhesion and alters friction, [22 - 28]. Triboelectrification strongly depends on the contact area, friction, load and sliding distance. ESC generated during shearing depended on the normal pressure.

In the present work, ESC generated from the sliding of rubber footwear on epoxy tiles filled by rubber granulates and paraffin oil was investigated.

EXPERIMENTAL

Experiments were carried out to measure the ESC generated from sliding of rubber sole on the tested tiles. Special dc voltmeter was used to measure the electrostatic field in volts, Fig. 1. Readings measured from the surface of the shoe sole are performed after the sliding the rubber shoe on the tested tiles.

The rubber shoe had rubber sole made from soft rubber of 2 MP_a modulus of elasticity and 27 Shore-A hardness. The test specimens were in form of tile of 400 × 400 mm^2 and 5.0 mm thickness, Fig. 2. Test specimens were prepared by filling epoxy by rubber granulates of (0.5 - 1.0), (1.0 - 2.0) and (2.0 - 3.0) mm of 20, 40, 60, 80 wt. % content. The

rubber granulates size will be referred in the text as 0.5, 1.0, 2.0 and 3.0 mm respectively. Paraffin oil was used to fill the epoxy, where two concentrations were used 5.0 and 10.0 wt. %. Rubber granulates and oil were added during molding epoxy. Friction tests were carried out at varying load from 100 to 900 N, then the readings detected at load values of 200, 400, 600 and 800 N were considered. The rubber shoe was loaded against the tested tiles. The sliding surfaces were cleaned before the test.

Fig. 1 Electrostatic field measuring device.

Fig. 2 Arrangement of the test procedure.

RESULTS AND DISCUSSION

ESC generated by the sliding of epoxy filled by recycled rubber particles of size up to 0.5 mm is shown in Fig. 3. ESC decreased down to minimum at rubber content of 40 wt. % then increased with further increase of rubber content. Besides, ESC increased with increasing normal load due to the increased contact area. ESC values measured for composites filled by 80 wt. % rubber were higher than that observed of composites free of rubber. It was proved that, [6], presence of rubber particles in of epoxy caused relatively higher friction that that displayed by epoxy due to the lower elastic modulus

and higher internal friction. As rubber content increased the number of rubber asperities increased and consequently friction increased leading to the increase of the area of the triboelectrified sliding surfaces. The contact area between rubber particles and rubber surface decreased with increasing particle size.

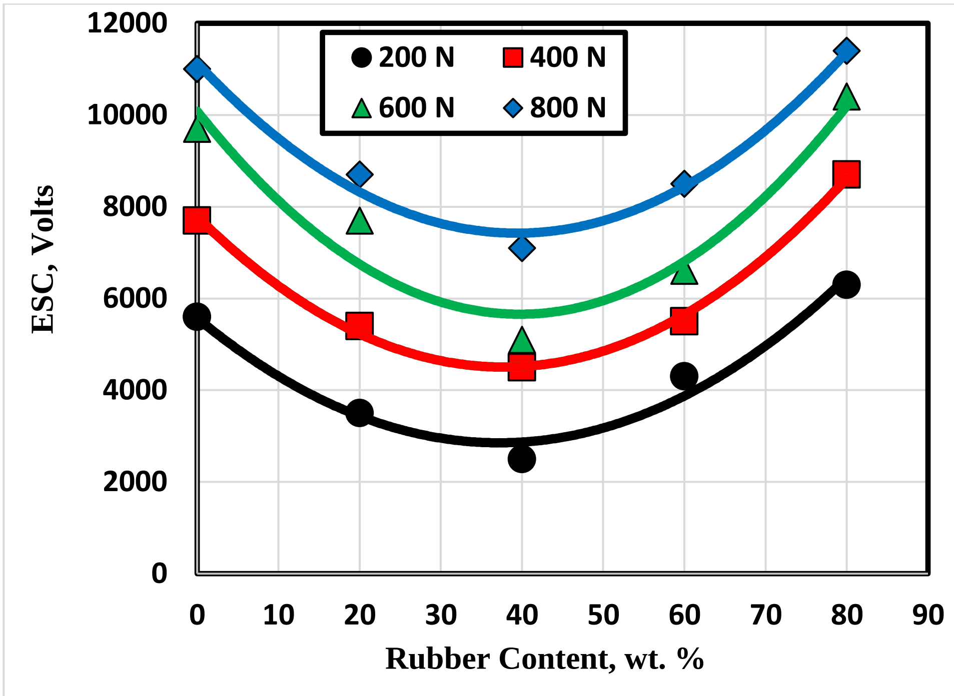

Fig. 3 ESC generated from the sliding of rubber sole on epoxy composites filled by rubber granulates of (0 – 0.5) mm size.

As the rubber particle size increased up to 1.0 mm, Fig. 4, the number of rubber asperities decreased and it was expected that ESC would decrease. ESC drastically decreased with increasing rubber content. The minimum ESC values were observed for composites containing 80 wt. % rubber. The values of ESC showed further decrease for rubber particle size up to 2.0 mm, Fig. 5. They were 4000, 4500, 5000 and 6800 volts at 200, 400, 600 and 800 N load respectively. Further increase in rubber particle size up to 3.0 mm caused drastic decrease in ESC, where the values were 2000, 3000, 3200 and 3500 volts respectively, Fig. 6. Based on the above observation, it is obvious that rubber particle size up to 3.0 mm showed the highest ESC. In addition, it is noticed that particle size of rubber granulates significantly influenced ESC. Because of the increase of the particle size, the deformation of rubber granulates increased the friction and therefore ESC increased.

Based on the triboelectric series, when rubber sole contacts or slides on epoxy, rubber sole will get positively charged while epoxy composites will be negatively charged, Fig. 7. It is known that the contact and separation as well sliding of similar materials generate the lowest ESC. It is proposed to increase the rubber sole/rubber asperities contact to reduce ESC. The decrease of ESC observed from the composites containing 80 wt. % rubber content may be explained on the bases of the relative decrease of the rubber sole/epoxy

contact area due to the presence of rubber granulates, Fig. 8. Therefore, increase of rubber content as well as particle size resulted in the decrease of ESC generated on the sliding surfaces.

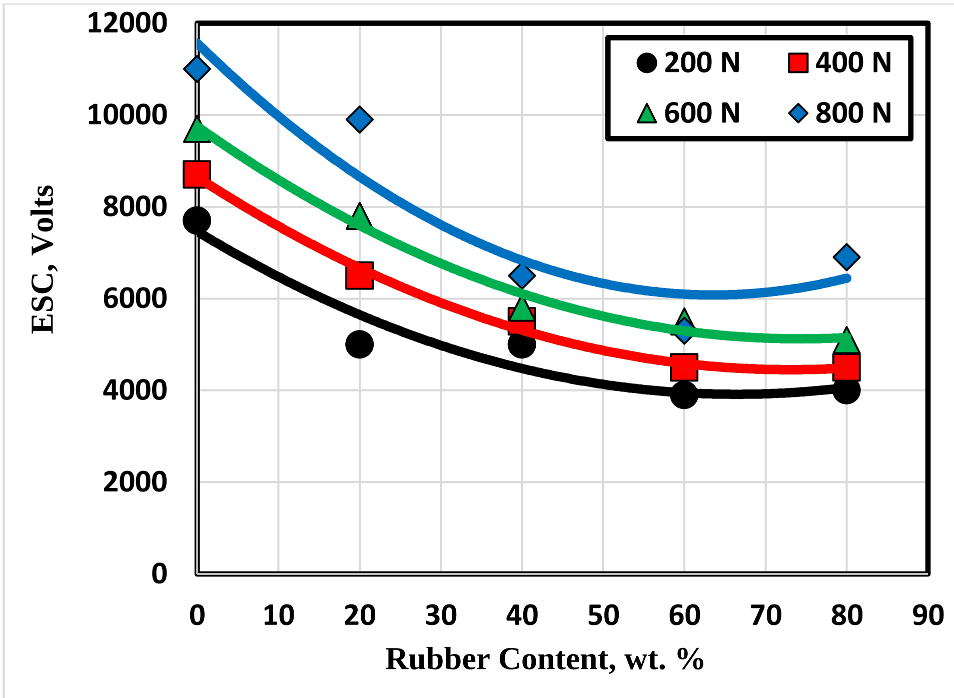

Fig. 4 ESC generated from the sliding of rubber sole on epoxy composites filled by rubber granulates of (0.5 – 1.0) mm size.

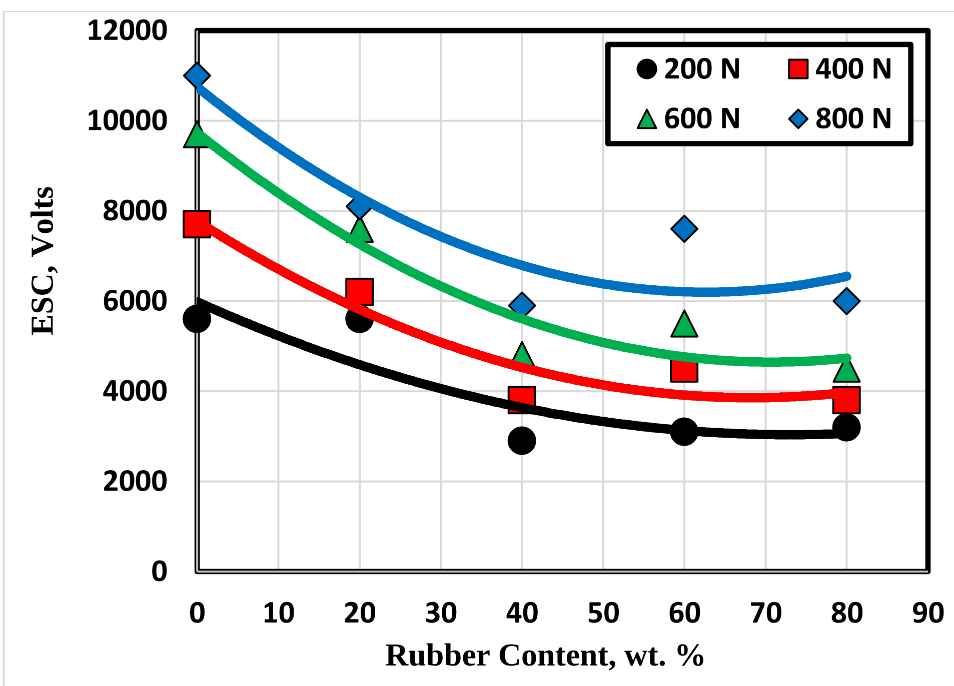

Fig. 5 ESC generated from the sliding of rubber sole on epoxy composites filled by rubber granulates of (1.0 – 2.0) mm size.

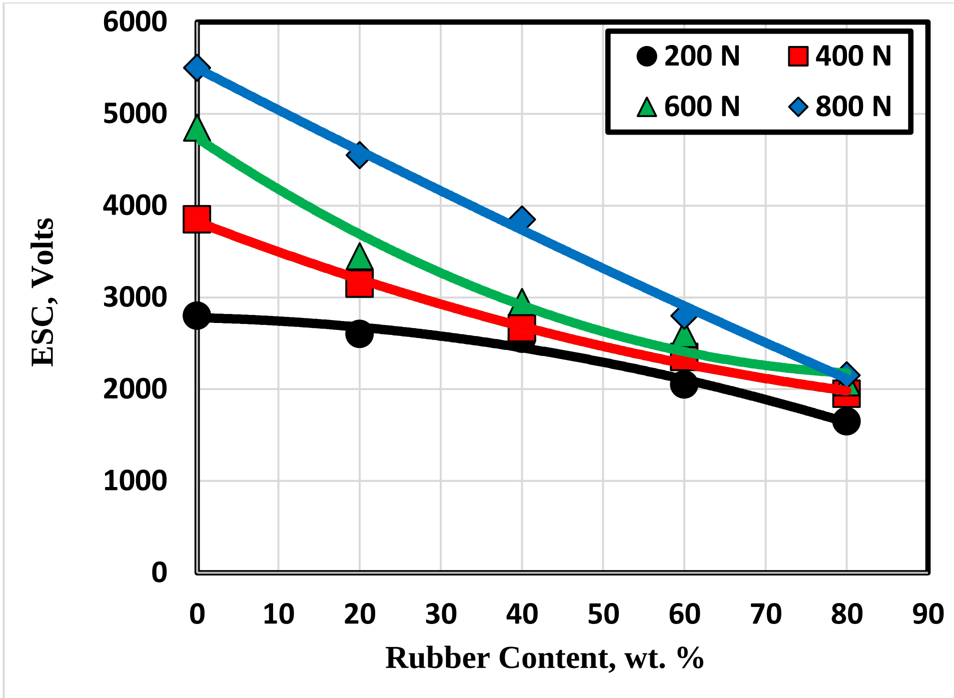

Fig. 6 ESC generated from the sliding of rubber sole on epoxy composites filled by rubber granulates of (2.0 – 3.0) mm size.

Fig. 7 Double layer of ESC generated on the tested surfaces.

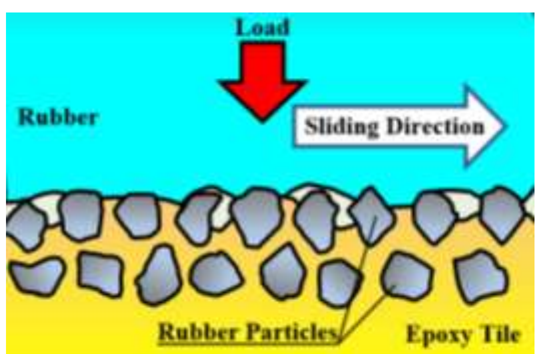

Fig. 8 Illustration of the contact area.

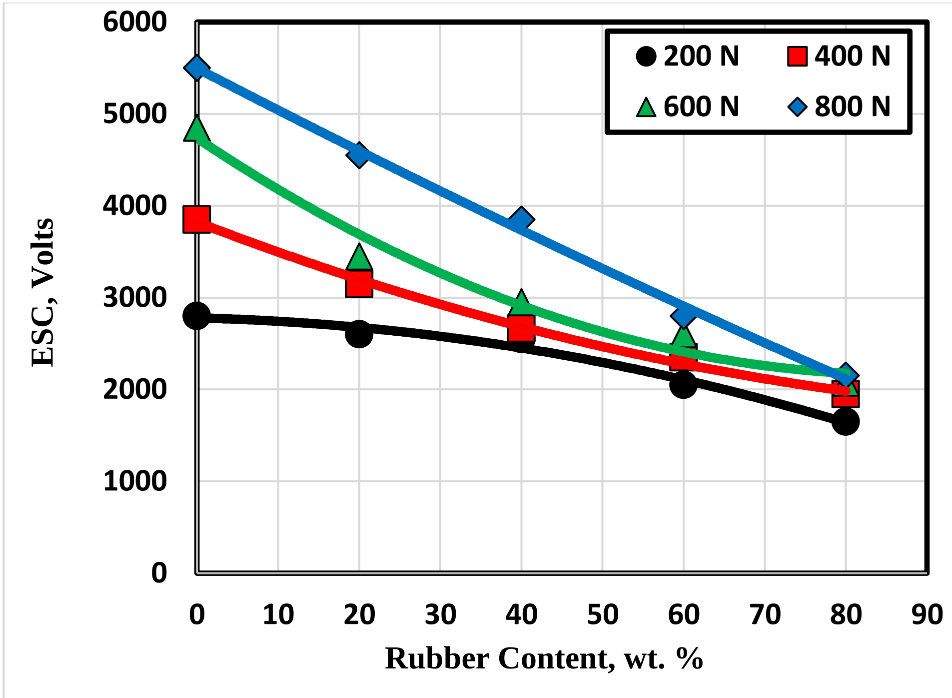

Fig. 7 ESC generated from the sliding of rubber sole on epoxy composites filled by rubber granulates of (2.0 – 3.0) mm size and 5.0 wt. % paraffin oil.

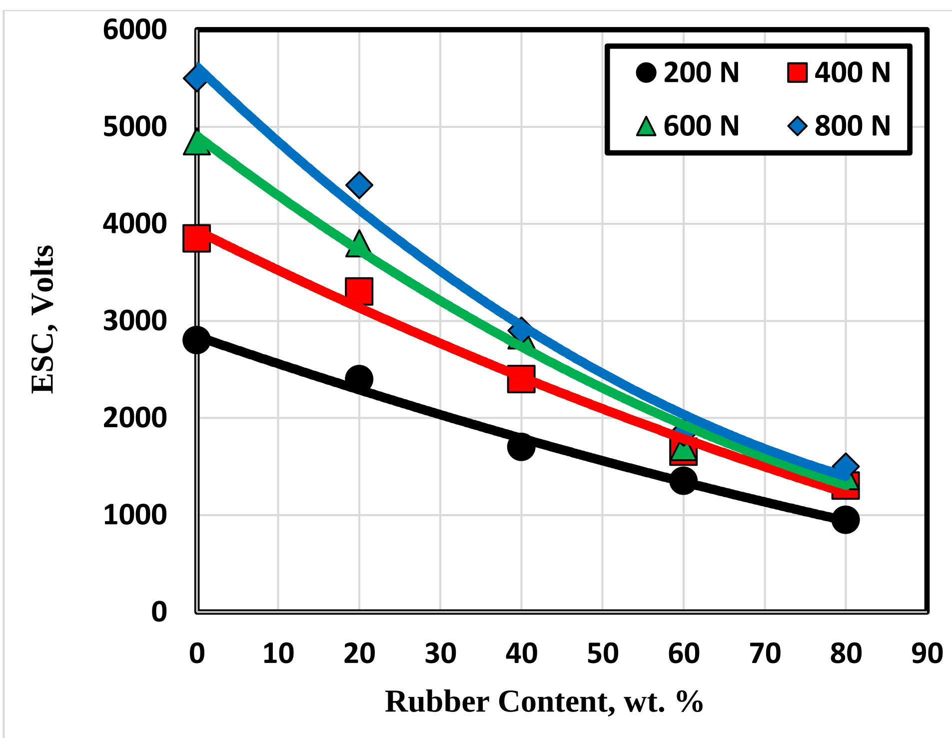

Fig. 8 ESC generated from the sliding of rubber sole on epoxy composites filled by rubber granulates of (2.0 – 3.0) mm size and 10.0 wt. % paraffin oil.

ESC generated on the rubber sole sliding on epoxy composites, Fig. 9, drastically decreased with increasing rubber content. The minimum ESC values were 1700, 2000, 2100 and 2200 volts at 200, 400, 600 and 800 N load respectively. It is clearly shown that filling epoxy by 5.0 wt. % oil caused drastic decrease in ESC. It seems that ESC decreased due to the presence of thin oil film on the contact area escaped from pores inside epoxy matrix. The oil film formed on the sliding surfaces separated the contacting asperities of the two sliding surfaces. Besides, oil film reduces the friction process that was responsible for the generation of ESC. Further increase of the oil content up to 10 wt. % filling epoxy matrix caused lower values of ESC, Fig. 10, where the lowest values reached 1000 volts. It was revealed, [6], that epoxy filled by oil showed slight decrease in friction values compared to composites free of oil. The values of friction coefficient were much higher than that recommended for safe floor materials, where the difference in the values displayed by unfilled and filled composites was slight. According to that, the composites filled by 80 wt. % rubber of particle size up to 3.0 mm and 10 wt. % oil can be recommended in floor applications.

CONCLUSIONS

1. ESC generated on rubber sole sliding on epoxy filled by recycled rubber particles of size up to 0.5 mm decreased down to minimum at rubber content of 40 wt. % then increased with increasing rubber content.
2. ESC increased with increasing normal load due to the increased contact area.
3. ESC values determined for composites filled by 80 wt. % rubber were higher than that observed of composites free of rubber.
4. The lowest values of ESC were observed for rubber particle size up to 3.0 mm.
5. The minimum ESC values were measured for composites filled by 80 wt. % rubber of particle size up to 3.0 mm and 10 wt. % oil. Therefore, those composites can be recommended in floor tile applications.

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