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ELECTROSTATIC CHARGE GENERATED FROM SLIDING OF RUBBER ON EPOXY FILLED BY NATURAL FIBERS

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ABSTRACT
The present study investigates the effect of filling epoxy resins by natural fibers on the generation of the electrostatic charge (ESC) from the dry sliding of rubber on the proposed composites. Fine fibers of wood, rice straw and palm were added as filling material in contents of 2.5, 5.0, 7.5, 10, 12.5, 15, 17.5 and 20 wt. %. The tested composites were loaded and slid on rubber at 2, 4, 6 and 8 N normal loads to measure ESC at contact/separation and sliding.

It was found that filling epoxy composites by wood, palm and rice straw fibers reduced ESC generated after contact/separation and sliding. ESC decreased with increasing the content of the tested fibers that fill epoxy matrix. The optimal fiber content was ranging between 5.0 to 7.5 wt. %. It was observed that epoxy free from fibers displayed the highest ESC values. Besides, wood fibers showed lower ESC values than that observed for palm and rice straw fibers after contact/separation. While after sliding, palm displayed lower ESC than wood fibers. ESC generated on the rubber showed the same trend observed for the tested composites. The reduction of ESC can be explained on the position of wood and cellulose in the triboelectric series that suggests the contact of the tested fibers with rubber generates positive and negative ESC on the fibers and rubber surfaces respectively. As result of that, the values of ESC decreased. It is recommended to apply wood and palm fibers to fill epoxy to reduce the generation of ESC in floor material application.

KEYWORDS
Electrostatic charge, floor, rubber, epoxy, wood, rice straw, palm fibers.

INTRODUCTION
Epoxy has extensive applications in floors, [1]. The brittleness of epoxy limits its application, [2]. Recycled rubber (butadiene-acrylonitrile) was applied as filler in epoxy to reduce its brittleness, [3 – 5], because rubber granulates enhanced the ductility. The increase of rubber granulates size increased friction of epoxy filled by oil, [6]. Recently, epoxy resins floor materials filled by recycled rubber granulates and paraffin oil to increase the toughness as well as the viscoelastic property of the

composites, [7]. It was observed that rubber granulates significantly affected ESC, where minimum ESC values were measured for composites filled by rubber content up to 80 wt. % and 10 wt. % oil, [8]. The sign and magnitude of ESC generated from the sliding on floor in hospitals, [9], should be controlled. It was recommended that shoes and shoe covers used inside hospitals should be made of polypropylene (PP) and polyethylene (PE) respectively to repel most of the viruses away from the wearers. In addition to that, it is recommended to use epoxy floor instead of polyvinyl chloride (PVC) tiles in order that the floor gains positive ESC to attract the viruses of negative ESC, where disinfection and cleaning are easier.

Safe walking on the floor was applied to evaluate static friction coefficient. It is observed that walking and creeping on floor generate ESC, where the magnitude and sign depend on the materials of the floor and footwear. ESC generated from bare foot and foot wearing socks sliding against rubber, parquet, ceramic, moquette and marble was measured, [10 - 15]. It was observed that rubber floor generated the highest ESC.

The relationship between friction coefficient and ESC was investigated, [16]. It was observed that ESC controls friction coefficient, where the increase of ESC increases the adhesion force between the two contact surfaces and consequently friction coefficient increases, [17]. It was revealed that filling epoxy by copper and brass particles showed relatively higher values of ESC, [18]. Bessides, ESC increased as the load increased, [19, 20]. When the sliding surfaces were insulated, friction coefficient showed relatively lower than that measured for the connected contact surfaces due to the action of ESC.

ESC built up on human skin has harmful effect on health, [21]. ESC drastically decreased with increasing iron nanoparticles content in epoxy. Bare foot sliding against epoxy floor showed lower ESC than that displayed by rubber footwear due to the good electrical conductivity of human body, [22]. ESC is generated during contact and sliding on the surface. Besides, ESC influences adhesion and friction, [23 - 32]. ESC strongly depends on the load, sliding distance and contact area.

In the present work, ESC, generated from the sliding of rubber on epoxy filled by natural fibers such as wood, rice straw and palm, was investigated.

EXPERIMENTAL

The aim of the present experiments is to measure the ESC generated from sliding of rubber on the tested tiles made of epoxy resin filled by natural fibers. ESC was measured by DC voltmeter used to measure the electrostatic field. Readings measured from the surfaces of the rubber and the tested composites were performed after contact/separation and sliding. The tested composites were prepared and deposited on the surface of a wooden block of 50 × 50 × 50 mm^3, Fig. 1. The epoxy composites were in 5.0 mm thickness, while the counterface was rubber sheet of 10 mm thickness and 50 Shore D hardness. Tested composites consisted of epoxy filled by wood, rice straw and palm fibers of (0 - 3.0) mm size added in contents of 2.5, 5.0,

7.5, 10, 12.5, 15, 17.5 and 20 wt. %. The photomicrographs of the tested composites are shown in Fig. 2. Tests were carried out under 2, 4, 6 and 8 N normal loads at room temperature. At contact/separation, the test specimens were loaded on rubber surface for five seconds followed by the measurement of ESC generated on the surfaces of composites and rubber. Every experiment was repeated five times then the average values were considered. ESC measured for sliding at approximately 20 mm/sec velocity and distance of 200 mm.

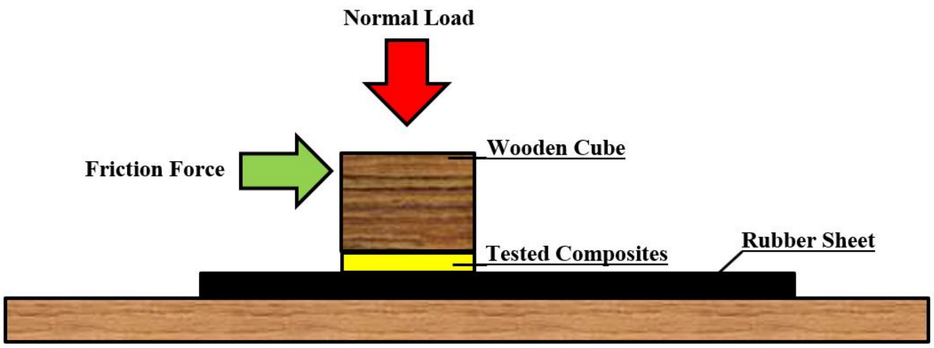

Fig. 1 Arrangement of the test procedure.

Fig. 2 Photomicrographs of the tested composites.

RESULTS AND DISCUSSION

The results of ESC generated on the surface of epoxy composites filled by wood fibers after contact/separation with rubber is shown in Fig. 3. It is shown that ESC drastically decreased with increasing wood fibers content. Epoxy free from fibers showed the highest ESC values for all load values. Generally, ESC increased with increasing load due to the increased contact area. Based on the triboelectric series, when epoxy contacts or slides on rubber, epoxy gains negative ESC while rubber gains positive ESC, Table 1 and Fig. 4. It seems that the observed ESC decrease may be from the effect of the presence of wood fibers. The position of wood and cellulose in the triboelectric series suggests that the contact of the tested fibers with rubber generates positive and negative ESC on the fibers and rubber surfaces respectively, Fig. 5. That behavior results in the decrease of the values of ESC. ESC values measured for composites filled by fibers were lower than that observed of composites

free of fibers. As fiber content increased, the contact area of fibers increased and consequently the negative ESC generated on the rubber surface increased leading to the decrease of resultant ESC.

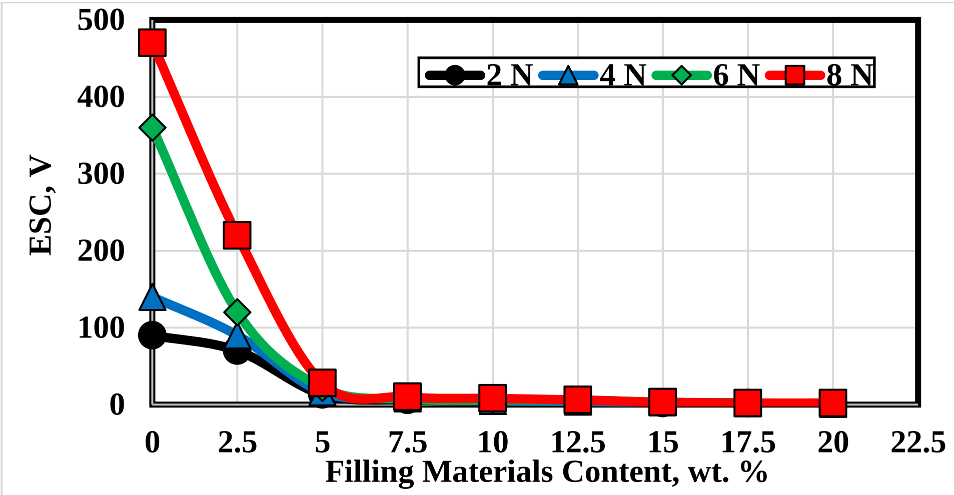

Fig. 3 ESC generated on the surface of epoxy composites filled by wood fibers after contact/separation with rubber.

Table 1 Triboelectric series of engineering materials, [9].

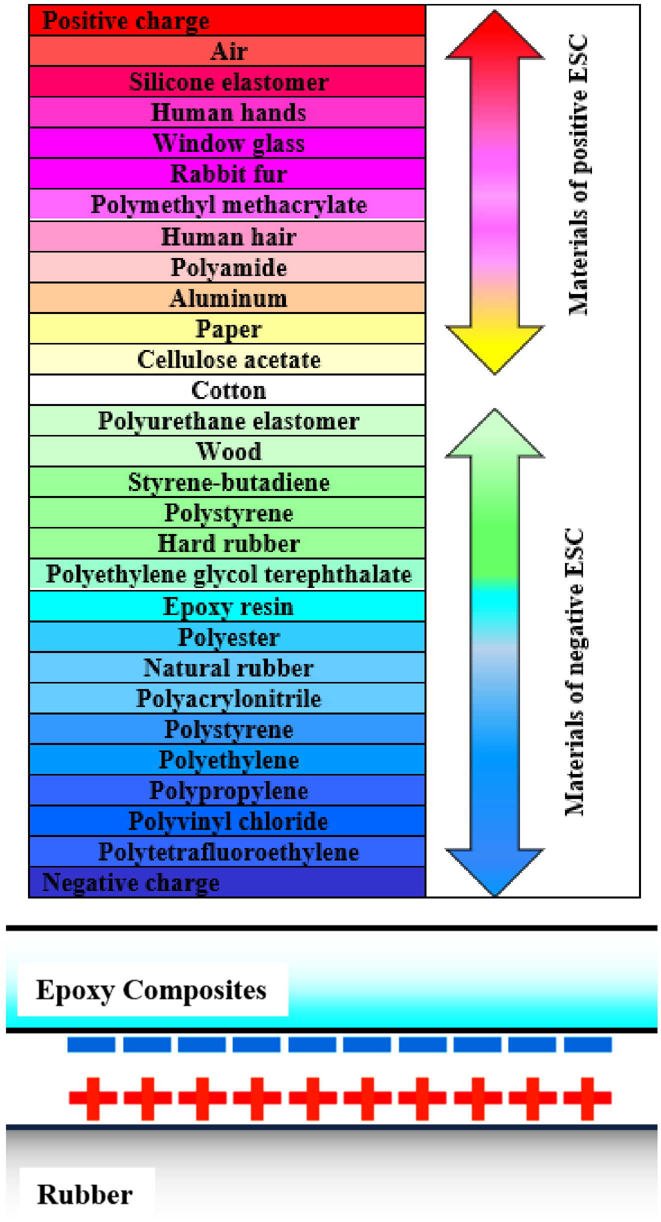

Fig. 4 Generation of ESC on the contacting surfaces of epoxy free of fibers and rubber.

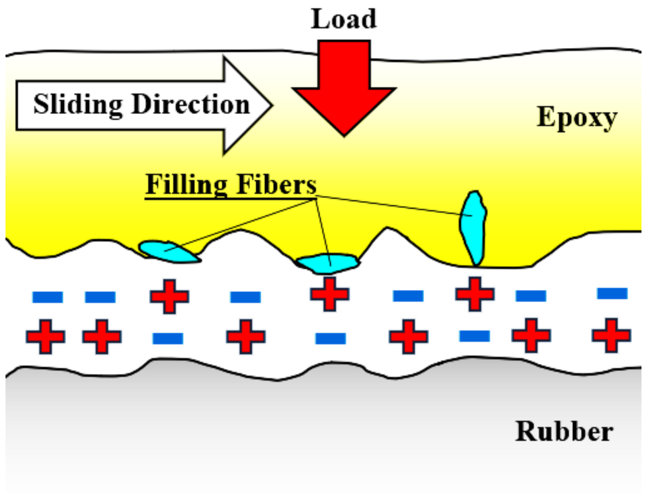

Fig. 5 Generation of ESC on the contacting surfaces of epoxy composites and rubber.

The measurement of ESC generated on the rubber surface is worthy to have specific information on the safety of wearer of shoes of rubber sole. Because ESC has double layer of different sign charge it is expected that wearer will be subjected to high electric field. At contact/separation, the same trend observed for the surface of the tested composites was shown for rubber surface, where ESC drastically decreased with increasing filling fibers content. The minimum ESC values were observed for the tested composites containing 7.5 wt. % fibers. The lowest ESC was shown for wood fibers, Fig. 11. Composites containing palm and rice straw showed higher ESC values, Figs. 12 and 13 respectively. Based on the experimental observations, it is obvious that wood fibers showed the optimal reduction of ESC compare to palm and straw fibers.

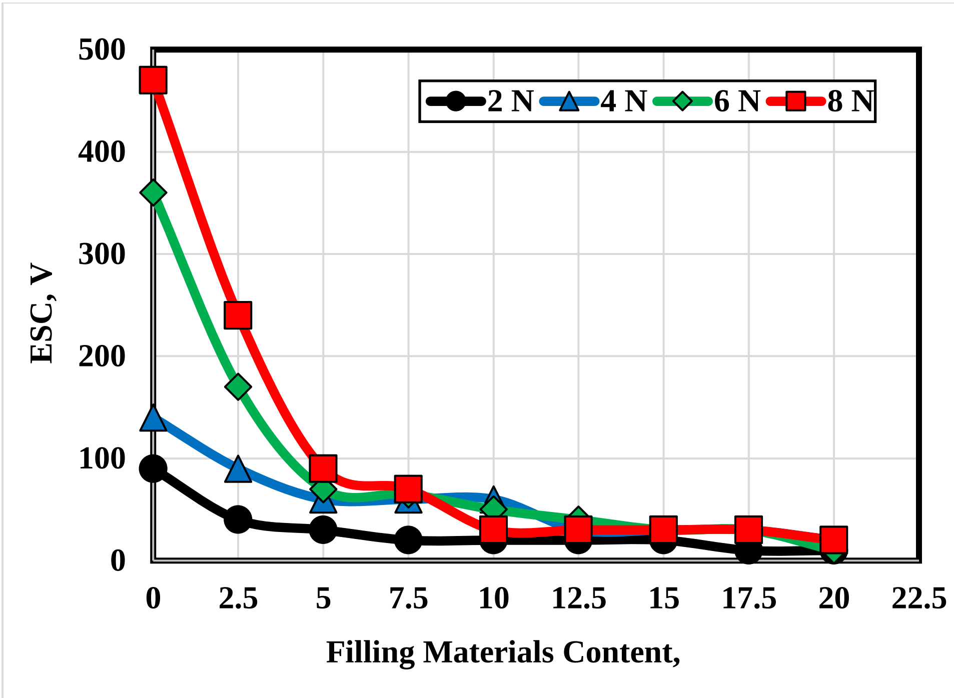

Fig. 6 ESC generated on the surface of epoxy composites filled by palm fibers after contact/separation with rubber.

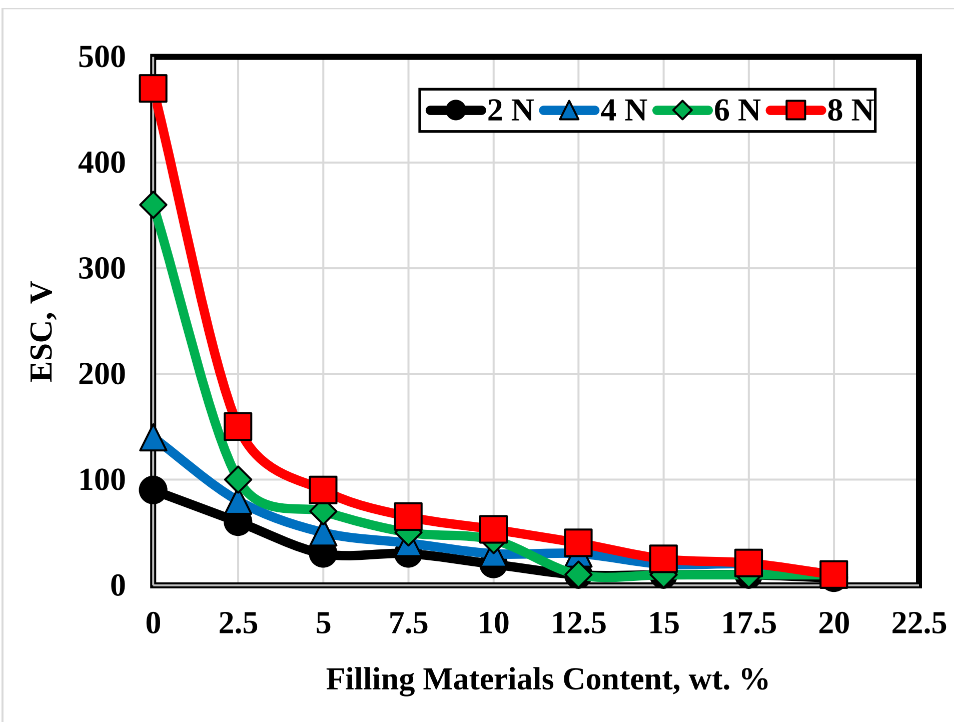

Fig. 7 ESC generated on the surface of epoxy composites filled by rice straw fibers after contact/separation with rubber.

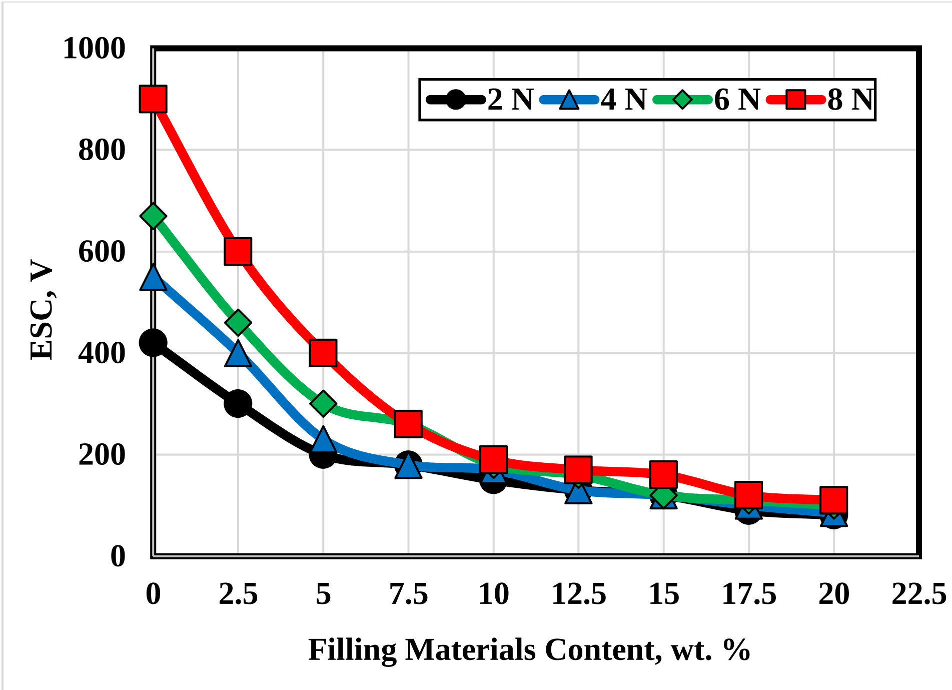

Fig. 8 ESC generated on the surface of epoxy composites filled by wood fibers after sliding on rubber.

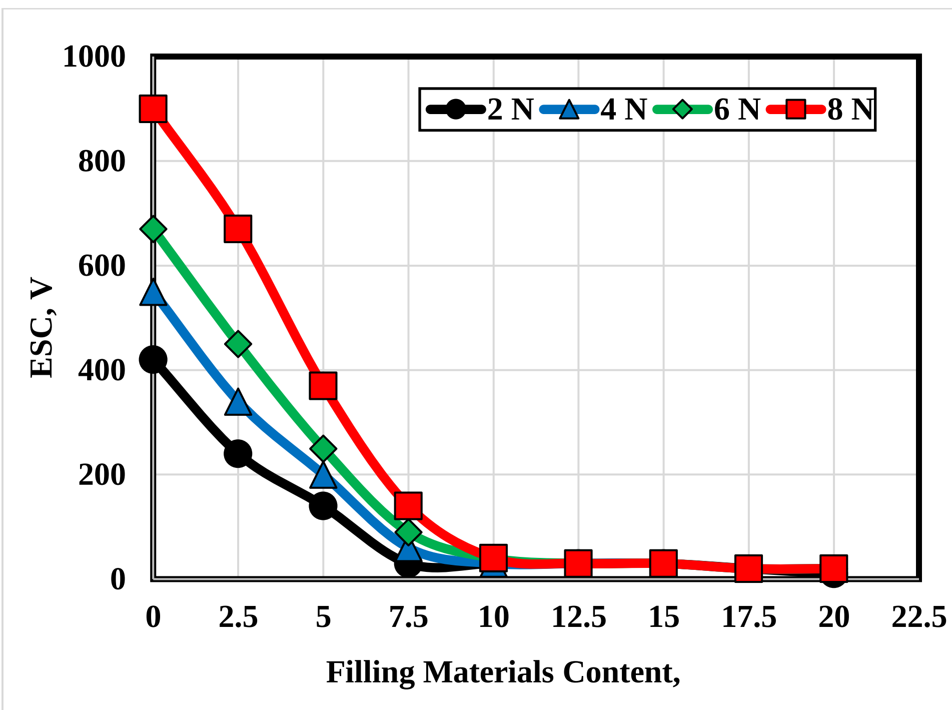

Fig. 9 ESC generated on the surface of epoxy composites filled by palm fibers after sliding on rubber.

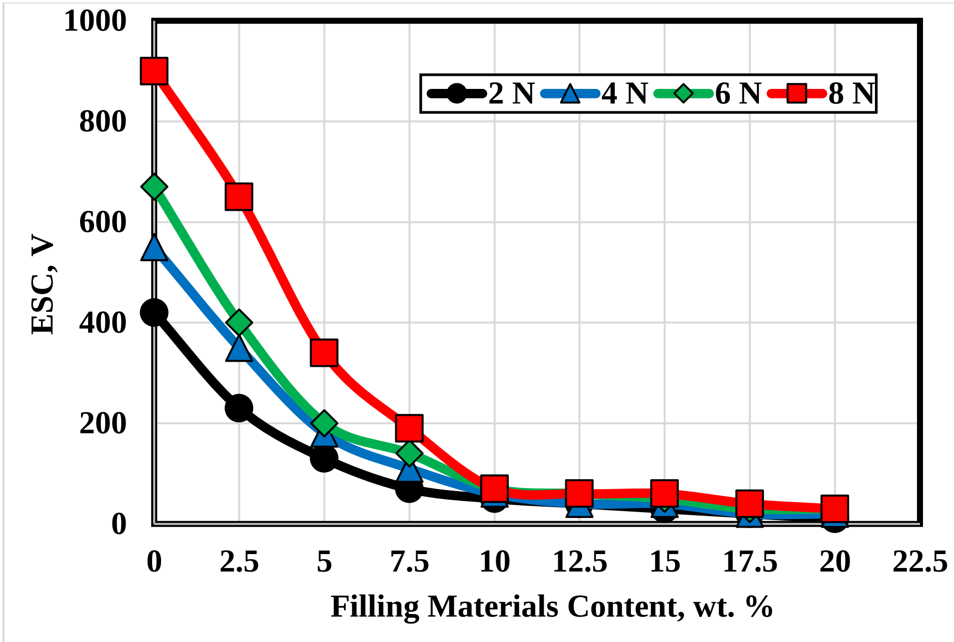

Fig. 10 ESC generated on the surface of epoxy composites filled by rice straw fibers after sliding on rubber.

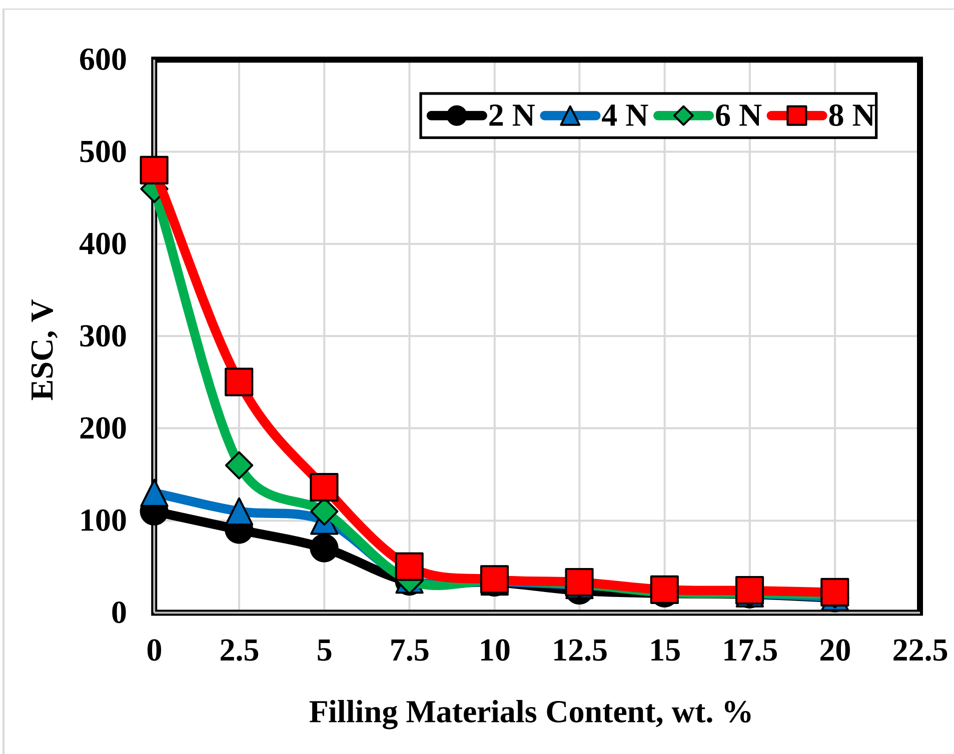

Fig. 11 ESC generated on the surface rubber after contact/separation with epoxy composites filled by wood fibers.

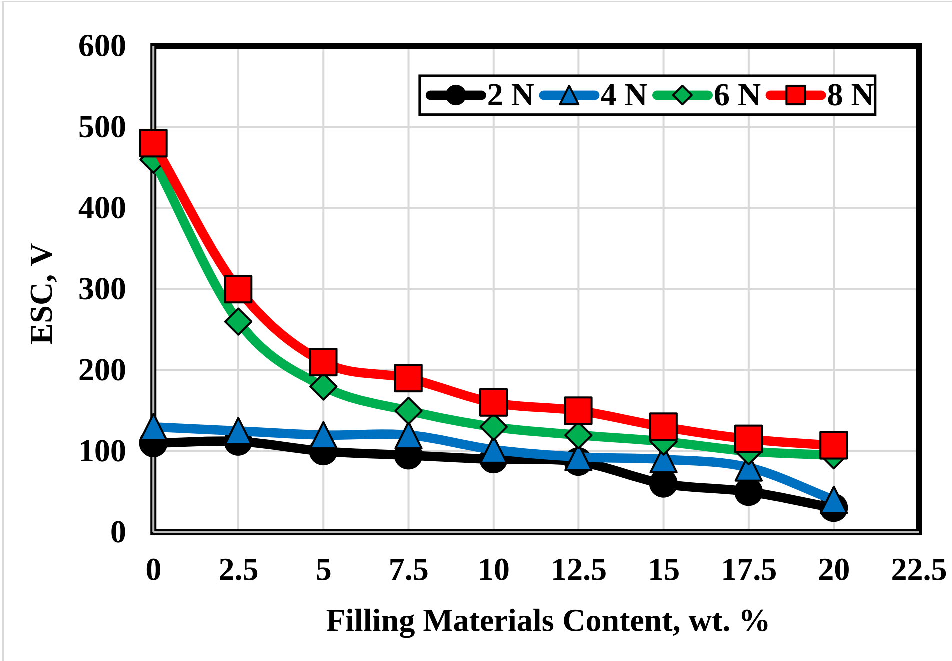

Fig. 12 ESC generated on the surface rubber after contact/separation with epoxy composites filled by palm fibers.

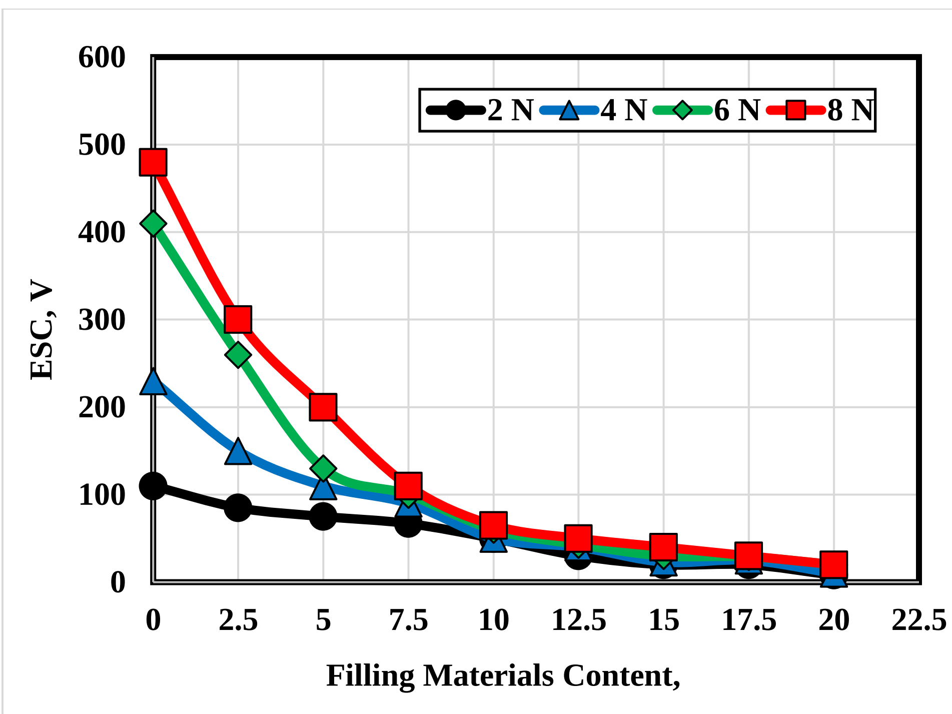

Fig. 13 ESC generated on the surface rubber after contact/separation with epoxy composites filled by rice straw fibers.

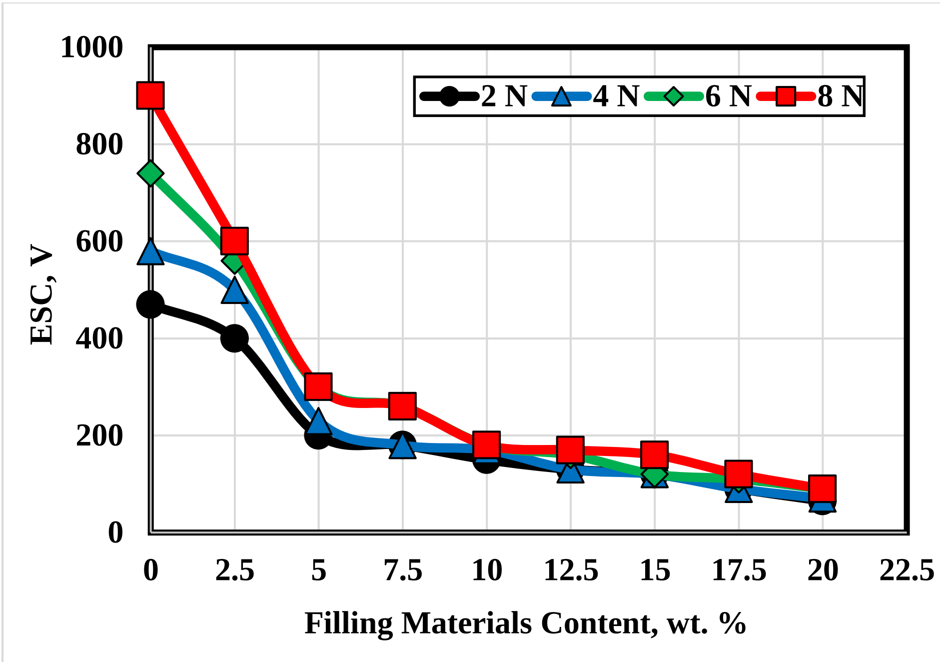

Fig. 14 ESC generated on the surface of rubber after sliding on epoxy composites filled by wood fibers.

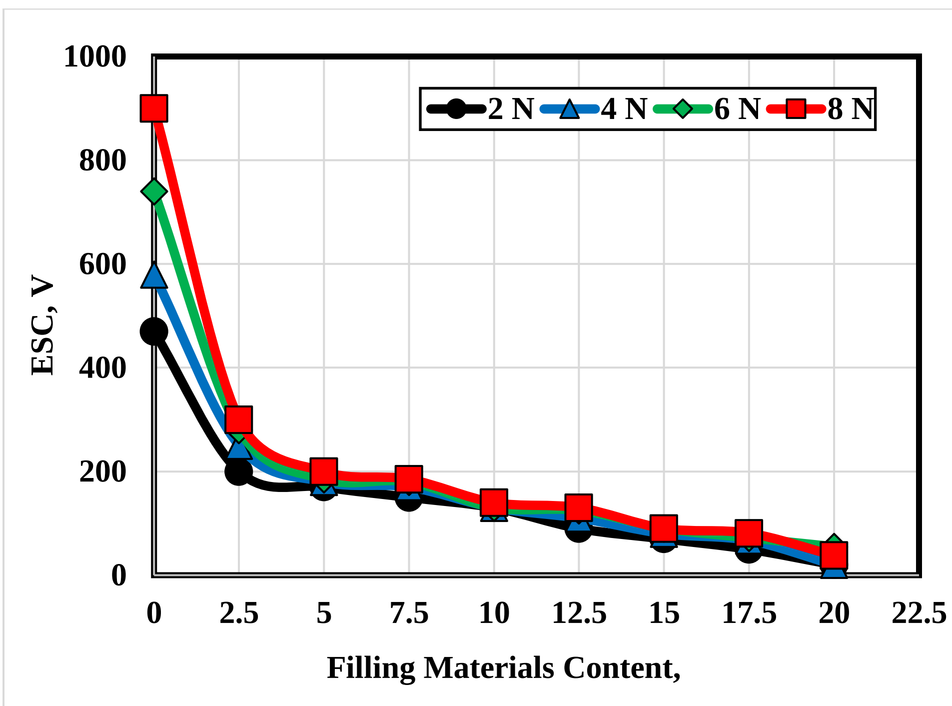

Fig. 15 ESC generated on the surface of rubber after sliding on epoxy composites filled by palm fibers.

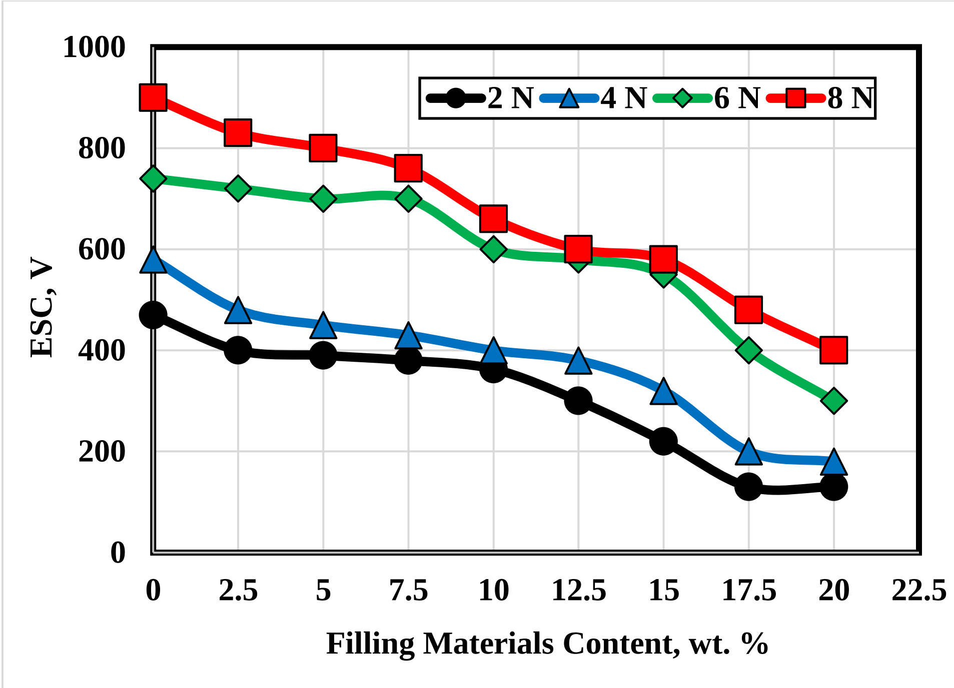

Fig. 16 ESC generated on the surface of rubber after sliding on epoxy composites filled by rice straw fibers.

At sliding, ESC generated on the rubber after sliding on epoxy surface, Figs. 14 - 16, decreased with increasing filling material content. Composites filled by rice straw showed significant increase in ESC, while composites filled by wood and palm fibers displayed lower ESC. At 7.5 wt. % fiber content, ESC values were 260, 185 and 760 volts at 8 N load for composites filled by wood, palm and straw fibers respectively. It is obvious shown that filling epoxy by 5.0 - 7.5 wt. % fiber content caused drastic ESC decrease. It seems that the reduction of ESC was due to the presence of fibers inside epoxy matrix. The fibers in the sliding surfaces decreased the contact area leading to the decrease of ESC. Besides, fibers can gain their own ESC, based on their position in the triboelectric series, after contact/separation and sliding against rubber causing significant decrease in the resultant ESC. It is proposed to fill epoxy composites by 7.5 wt. % of wood and palm fibers to be applied in floor materials.

CONCLUSIONS

1. Increasing the content of the tested fibers filling epoxy matrix drastically decreased ESC after contact/separation and sliding. The best fiber content was 5.0 – 7.5 wt. % for all applied load values.
2. Epoxy free from fibers showed the highest ESC values that increased with increasing load due to the increased contact area.
3. Wood fibers displayed relatively lower ESC values than that measured for palm and rice straw fibers after contact/separation. While after sliding, palm and rice straw displayed lower ESC than wood fibers.

4. ESC generated on the rubber surface had the same trend observed for the tested composites.
5. It is recommended to apply wood and palm fibers to fill epoxy to reduce the generation of ESC in floor material application.

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