EGTRIB Journal

JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 19, No. 4, October 2022, pp. 1 - 10 **ISSN 2090 - 5882**
(Received April 12. 2022, Accepted in final form July 06. 2022) **jest.journals.ekb.eg**

TRIBOLOGICAL PERFORMANCE OF EPOXY FLOOR FILLED BY RECYCLED RUBBER PARTICLES

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ABSTRACT
It is essential to reduce the brittleness that limits the applications of floor materials made of epoxy resins. In the present work, recycled rubber particles and paraffin oil are filling epoxy. Recycled rubber of different sizes were used as filling material, while oil content was 5.0 and 10.0 wt. %. The rubber is added to increase the toughness, while oil is to increase the viscoelastic property of the proposed composites. The tribological properties of the tested composites are investigated.

The experimental observation showed that increasing the rubber content significantly increased friction coefficient. The highest friction values were observed for rubber particle size ranging between 1.0 to 2.0 mm. Composites filled by oil showed that further increase in rubber particle size was accompanied by friction increase. Generally, the values of friction coefficient were much higher than that recommended for safe floor materials. In abrasion test, wear increased as the rubber content increased due to the weakening of the epoxy matrix, where the highest friction coefficient and lowest wear were displayed by the tested composites filled by 5.0 wt. % oil and 80 wt. % rubber content of (2.0 – 3.0) mm particle size. According to the experimental results, those composites can be recommended as floor materials, where the addition of oil enhanced the viscoelastic property of the rubber and consequently the abrasion resistance increased.

KEYWORDS
Recycled rubber particles, friction coefficient, wear, epoxy, oil.

INTRODUCTION
The brittleness of floor materials made of epoxy resins is one of their major drawbacks. It limits its application in floor materials, [1]. Although epoxy has several applications, it suffers from brittleness that limits its use, [2]. The mechanical properties of epoxy matrix filled by rubber were investigated, [3 – 5]. It was revealed that rubber particles could enhance the ductility of epoxy, where they concentrate the plastic deformation and stress in epoxy matrix.

It was found that significant enhancement of fracture toughness could be achieved by block copolymer, [6]. They reduce the voids and shear yielding of the matrix, [7, 8]. The cavitation of the rubber inside epoxy resins leads to the shear deformation and improves

fracture toughness. It was noticed that, [9], rubber addition into epoxy matrix was able to reduce the brittleness of epoxy resins.

The mechanical and tribological behavior of recycled polymeric materials were investigated, [10, 11]. Recycled polymers were applied due to their mechanical and tribological properties. Toughening of epoxy by filling with waste rubber particles was investigated, [12 - 17], where the composites found wide application in automotive industry. Rubber has pronounced deformation and higher contact area when loaded against the surface asperities of rigid surface. Relatively higher values of friction coefficient could be observed, [18 - 20]. In addition, abrasion resistance of epoxy floor tile surface can be developed by rubber. When impregnating epoxy by oil, where oil is trapped inside the matrix in form of infinite number of pores, they work as oil reservoirs. Oil leaks up to the friction surface and forms oil film. Significant friction decrease was displayed by composites filled by oil, [21 – 25]. The oil trapped in pores after solidification of the composites is fed into the sliding surface. The present work investigates the friction and wear of epoxy composites filled by recycled rubber particles and paraffin oil. The friction coefficient and abrasive wear resistance of the tested composites have been investigated.

EXPERIMENTAL

Adhesion and abrasion tests have been carried out. The adhesion test aimed to measure the friction of the tested composites slid on rubber, Fig. 1. While the abrasion test measured the friction and abrasion wear resistance by scratching the tested composites. The epoxy composites were in 5.0 mm thickness adhered to one surface of wooden cube of 35 × 35 × 35 mm^3 and slid into rubber sheet of 10 mm thickness of 50 Shore D hardness. The rubber sheet was placed in a base supported by two load cells to measure the friction force and the applied load.

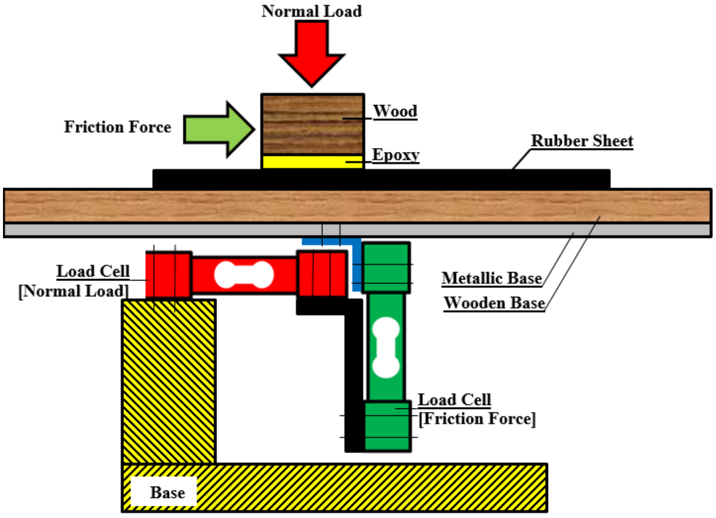


Fig. 1 Arrangement of the adhesive test rig.

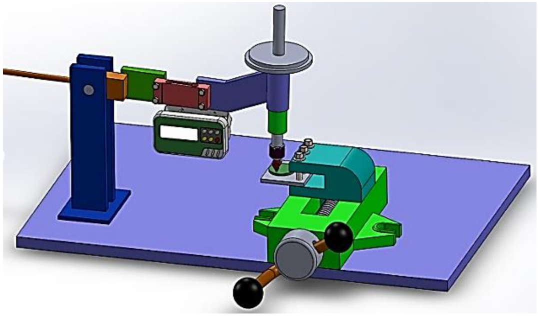
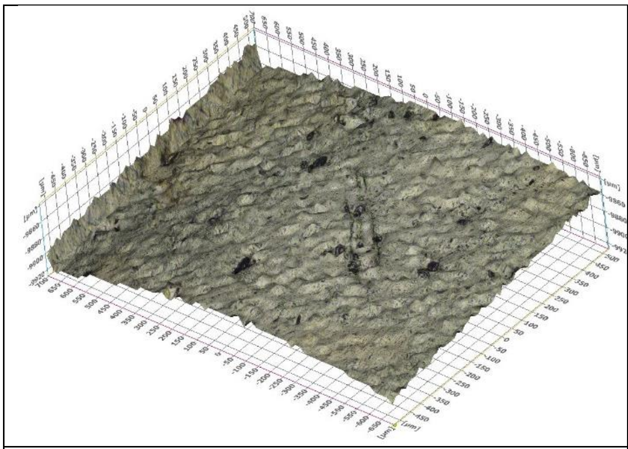
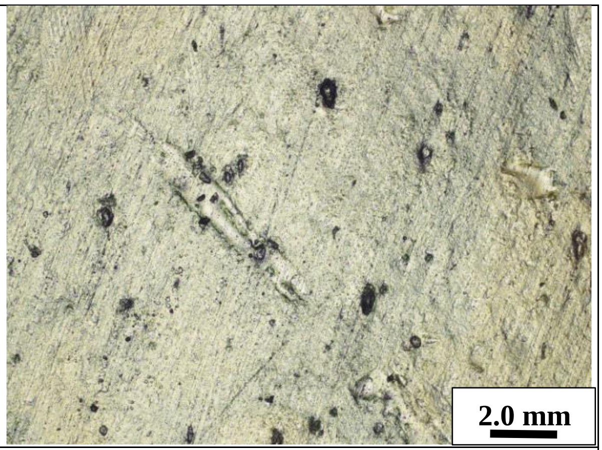


Fig. 2 Arrangement of scratch test rig.

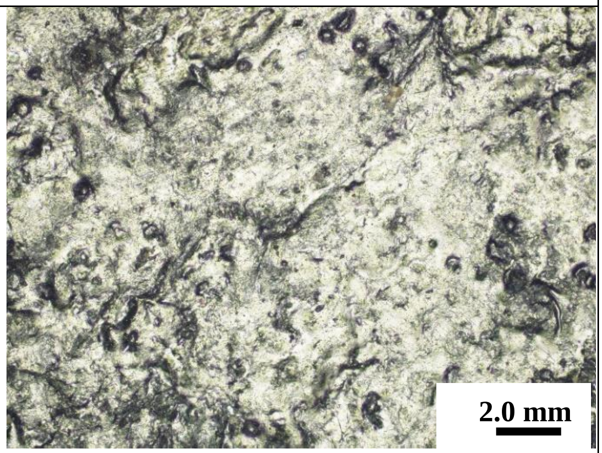


a. Surface topography of epoxy filled by 30 wt. % rubber and 5.0 wt. % oil.

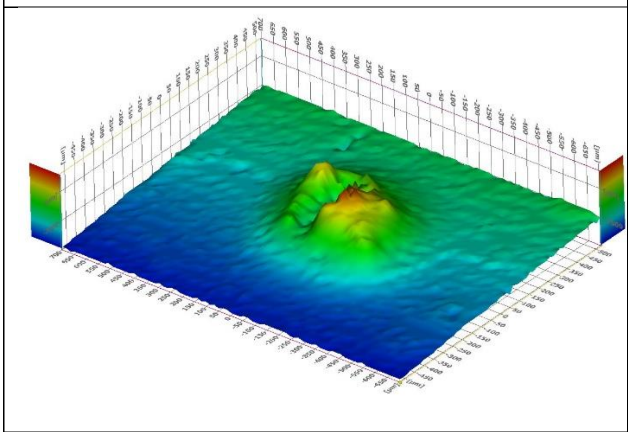


b. Photograph of the surface of epoxy filled by 30 wt. % rubber and 5.0 wt. % oil.

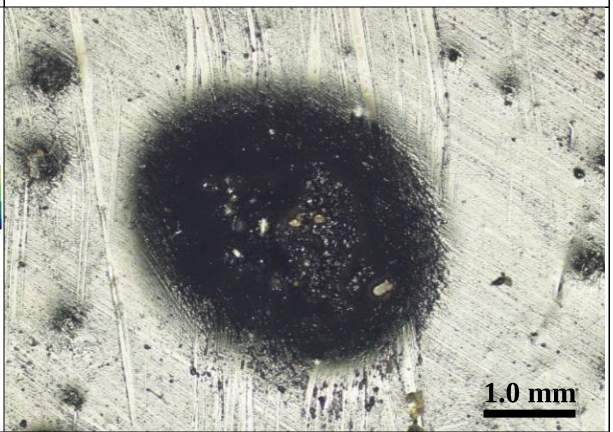
c. Surface topography of epoxy filled by 80 wt. % rubber and 5.0 wt. % oil.



d. Photograph of the surface of epoxy filled by 80 wt. % rubber and 5.0 wt. % oil.



e. Surface topography of epoxy filled by 80 wt. % rubber and free of oil.



f. Photograph of the surface of epoxy filled by 80 wt. % rubber and free of oil.

Fig. 3 Surface topography and photographs of the tested composites.

Figure 2 shows the the test rig of abrasion, where indenter of square TiC insert (12 × 12 mm) of tip radius of 0.1 mm and 2800 kp/mm^2 hardness was assembled to the loading lever. Loads were applied of values from 2.0 to 10.0 N in steps of 2.0 N. The scratch force was measured

by load cell. The tested composites were fixed in a movable base drived by manual screw mechanism. Wear scar width of the scratch was measured by optical microscope of an accuracy of ± 1.0 μm.

Epoxy was filled by recycled rubbers of different double cut particle size of (0 – 0.5), (0.5 – 1.0), (1.0 – 2.0) and (2.0 – 3.0) mm. Three sets of test composites were prepared, the first was free of oil, while the second and the third were filled by 5.0, 10.0 wt. % paraffin oil. The photomicrographs of the tested composites are shown in Fig. 3. Adhesive tests were carried out at different values of normal load exerted by hand, where the load value was ranging from 0 to 70 N. Friction coefficient was calculated and plotted against load. Then the values of friction coefficient were extracted at loads of 60 N.

Surface topography and photographs of the tested composites are illustrated in Fig. 3. It can be seen that composites filled by oil showed homogeneous distribution of rubber particle inside epoxy matrix, Fig. 3, (a, b, c and d), while that free of oil showed the agglomeration of rubber particles, Fig. 3 (e, f).

RESULTS AND DISCUSSION

The results of the adhesive tests are shown in Figs. 4 and 5. Friction coefficient displayed by the sliding of epoxy composites filled by rubber particles of size up to 0.5 mm as well as 5.0 and 10.0 wt. % paraffin oil is illustrated in Fig. 4. The highest friction values were displayed by composites free of oil. Friction decreased as the oil content increased. besids, friction significantly increased with increasing rubber content. Friction coefficient values displayed by composites free of oil and that filled by 80 wt. % rubber were 1.4 and 1.85 respectively. Figure 5 shows comparative frictional behavior of the tested composites filled by 5.0 wt. % oil as function of rubber content of different sizes. It is clearly shown that rubber particle size up to 2.0 mm represented the highest friction values followed by that filled by particle of size up to 1.0 mm. Based on the observations, it seems that particle size of rubber had significant effect on the friction coefficient, whereas the particle size increased, the deformation of rubber particles increased allowing the increase of the friction coefficient.

The lowest safe value of the static friction coefficient is 0.5 recommended for floor surfaces. This value should be increased for disables, walkways and elevators to 0.6 – 0.8. Rubber can provide relatively higher contact area and deformation, where relatively higher friction coefficient values can be obtained. The above friction behaviour of rubber was slightly reduced when epoxy was filled by oil. In spite of that, the values of friction coefficient observed for the proposed composites were much higher than the recommended values mentioned above. The slight friction decrease is attributed to the oil trapped in the pores inside epoxy matrix. When the trapped oil leaks to the surface, it forms oil film on the sliding surface and decreases the friction. It was found that oil film reduces epoxy transfer into the rubber surface and homogeneously distributed rubber particles inside epoxy matrix. The advantage of adding oil into epoxy is to decrease the abrasion of the proposed composites.

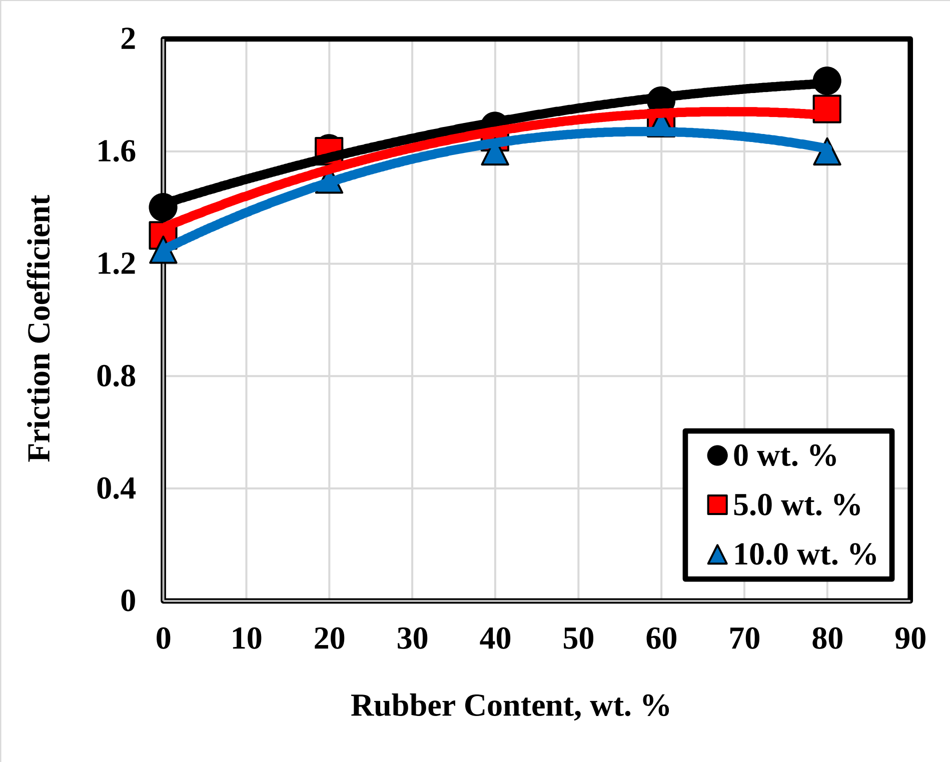


Fig. 4 Friction coefficient as a function of rubber content for (0 - 0.5) mm particle size.

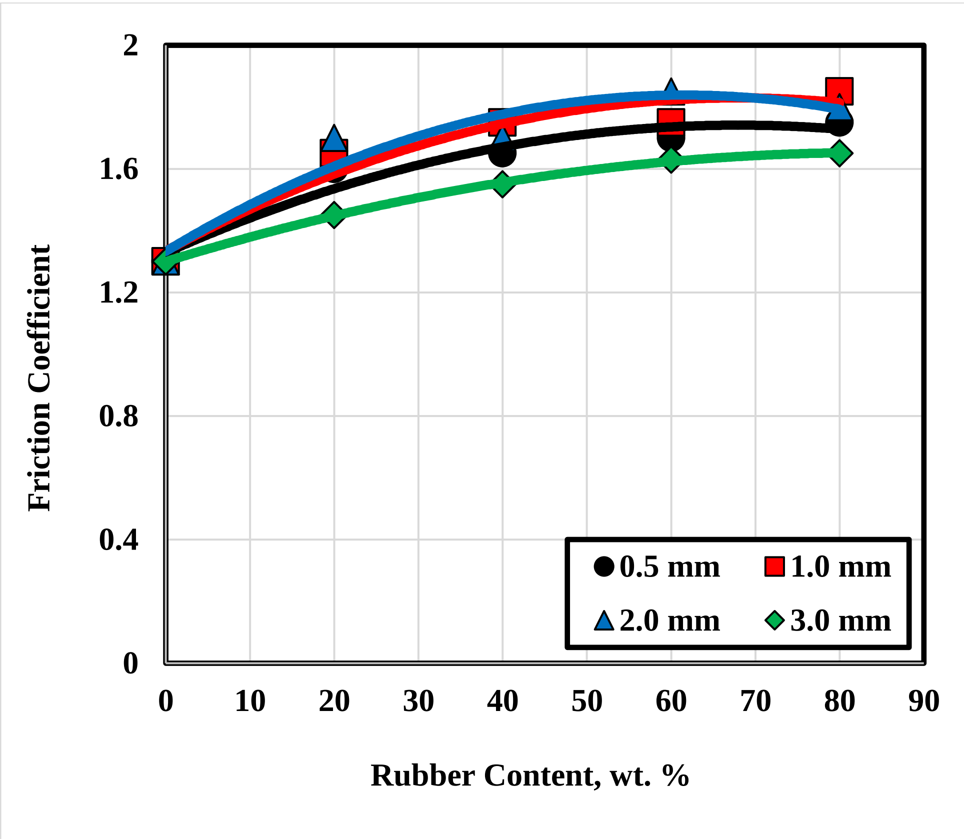


Fig. 5 Friction coefficient as a function of rubber content for the tested composites filled by rubber of different size.

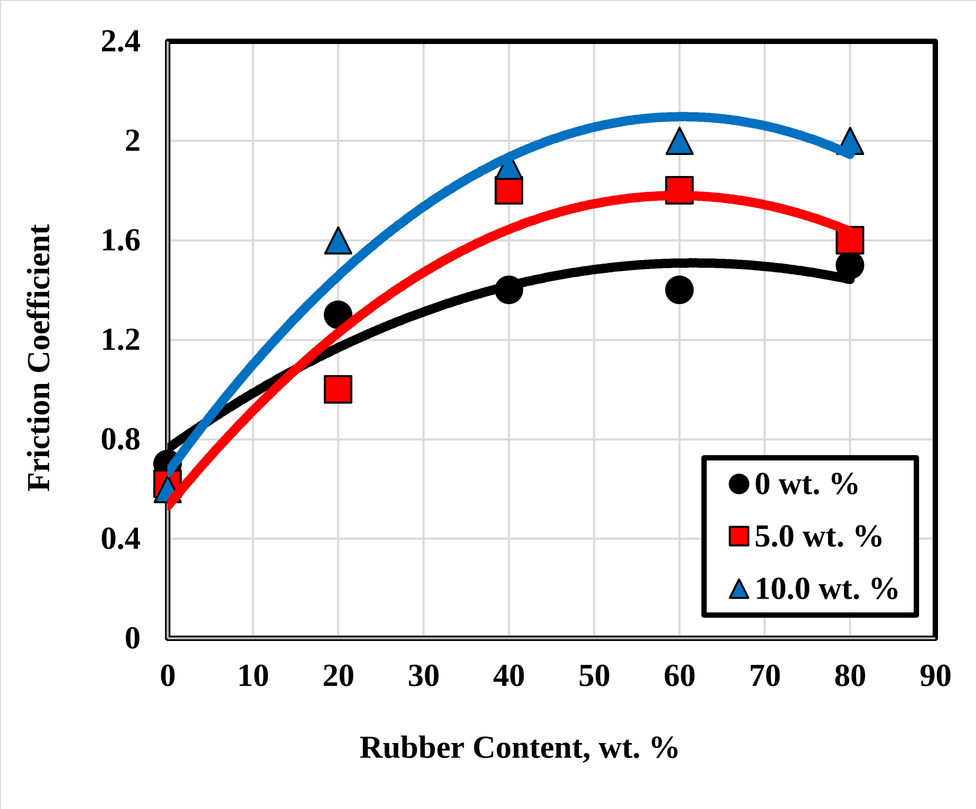


Fig. 6 Friction coefficient displayed by the scratch of the composites filled by rubber of (2.0 – 3.0) mm particle size.

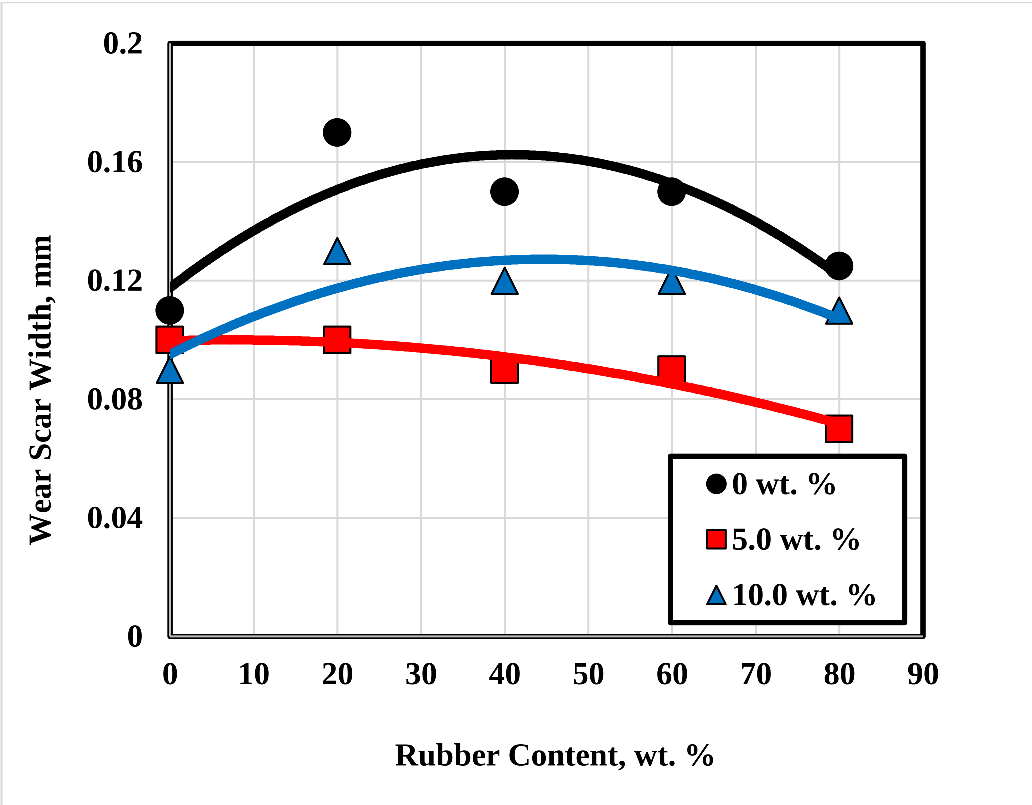


Fig. 7 Wear scar width displayed by the scratch of the composites filled by rubber of (2.0 – 3.0) mm particle size.

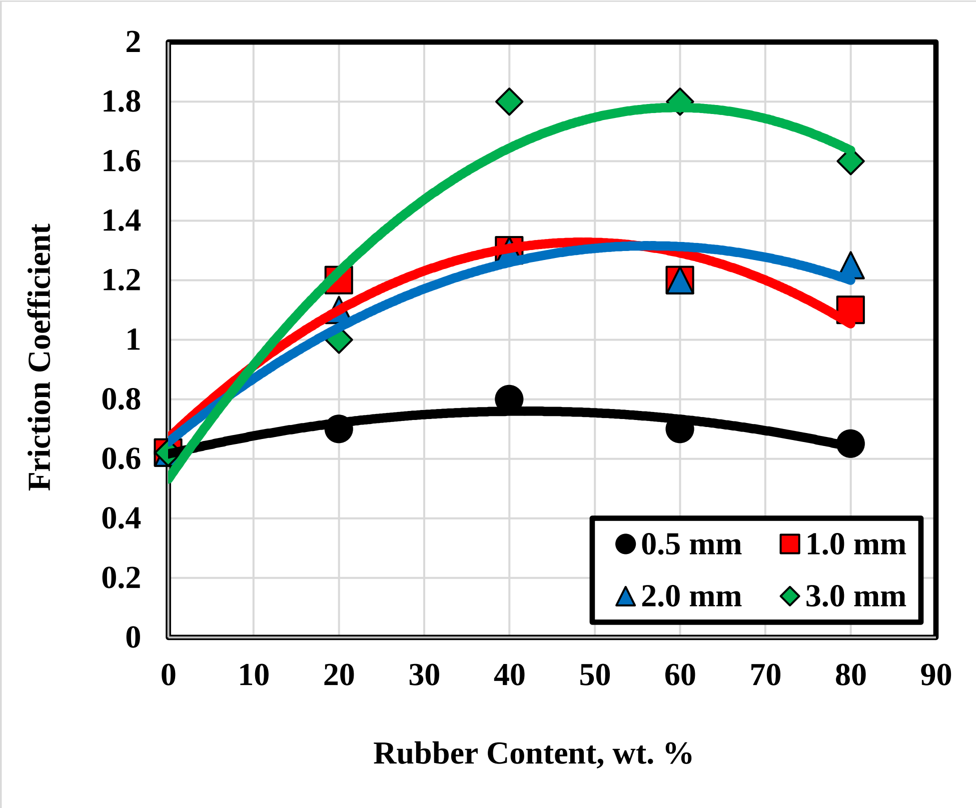


Fig. 8 Friction coefficient as a function of rubber content for the tested composites filled by rubber of different size.

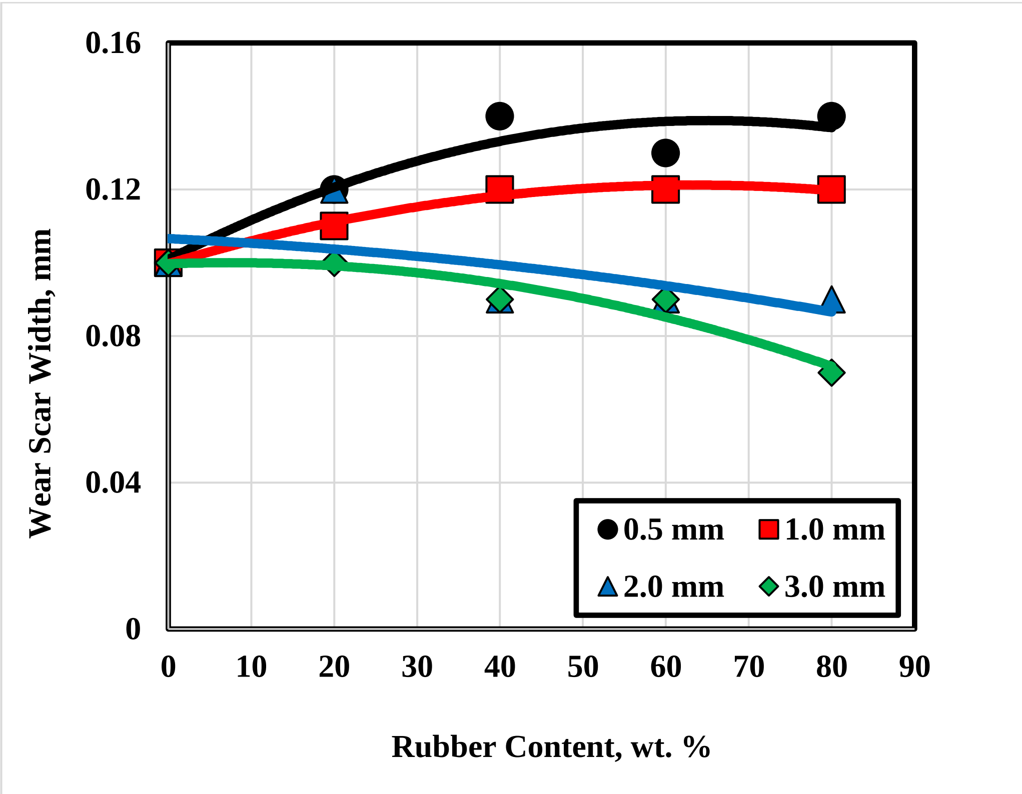


Fig. 9 Wear scar width as a function of rubber content for the tested composites filled by rubber of different size.

Friction coefficient displayed by the scratch of the tested composites filled by rubber of (2.0 – 3.0) mm particle size and filled by 5.0 and 10.0 wt. % oil is shown in Fig. 6. Epoxy composites filled by 10 wt. % oil showed the highest friction coefficient values, while composites free of oil showed the lowest friction. Friction significantly increased up to maximum at 60 wt. % rubber content then decreased. It seems that rubber withstands the scratch representing enhanced abrasion resistance. Further increase in rubber content weakened the epoxy matrix so that the scratch resistance slightly decreased. The highest value of friction coefficient determined by composites free of oil and filled by 40 wt. % rubber was 2.1. Wear scar width observed during the scratch of the composites is illustrated in Fig. 7. Wear increased with increasing rubber content due to the weakening of the epoxy matrix. Composites filled by 5.0 wt. % oil showed the lowest wear followed by composites filled by 10.0 wt. % oil, while composites free of oil showed the highest wear. It seems that the viscoelastic property of the tested composites was enhanced by the addition of oil and consequently the abrasion resistance increased.

The comparative performance of the friction and wear of the tested composites filled by 5.0 wt. % oil is illustrated in Figs. 8 and 9 respectively. The highest friction coefficient and minimum wear were observed for composites filled by rubber of (2.0 – 3.0) mm particle size, where the optimum rubber content was 80 wt. %. The decrease of wear can be attributed to that the oil increased the viscoelastic property of the tested composites and consequently the abrasion of rubber particles became more difficult. That explanation is confirmed by the results of wear, where composites filled by oil experienced lower wear values.

CONCLUSIONS

1. Adhesion tests revealed that composites free of oil showed relatively higher friction values than that filled by oil. As the oil content increased, friction decreased. Friction significantly increased with increasing rubber content. The highest friction values were displayed by composites filled by rubber particle size ranged between 1.0 to 2.0 mm. Further increase in rubber particle size increased friction values displayed by composites filled by oil. Values of friction coefficient observed for the proposed composites were much higher than the recommended values for safe floor materials.

2. Abrasion tests cleared that epoxy composites free of oil showed the highest values of friction coefficient. Friction coefficient increased up to maximum then decreased with increasing rubber content. The highest friction was observed at 40 wt. % rubber content. Wear increased as the rubber content increased due to the weakening of the epoxy matrix. The tested composites filled by 5.0 wt. % oil and rubber of (2.0 – 3.0) mm particle size displayed the highest friction coefficient and minimum wear. The optimum rubber content was 80 wt. %. Those composites can be recommended as floor materials.

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