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FRICTIONAL BEHAVIOUR OF RUBBER FLOORING MAT FITTED BY RECTANGULAR TREADS

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ABSTRACT

There is an increasing demand to reduce the risk of slipping and enhance walking safety in indoors and workplaces. Wet floors are the main source of slip accidents. Rubber mats have become a popular flooring materials due to the increased comfort, by adding a cushioning effect to the knees when walking. In the present work, the effect of rectangular and cross treads introduced in the rubber mats on friction coefficient when sliding against footwear is investigated.

It was found that friction coefficient displayed slightly decreased with increasing tread groove at dry, detergent wetted and oily sliding due to the decreased contact area accompanied to the increased groove width of the rubber. At water wetted sliding friction coefficient remarkably increased with increasing the tread groove. Oily sliding displayed very low values of friction coefficient. As the tread width decreased the friction values decreased due to the decrease of the contact area at dry, detergent wetted and oily sliding. At sliding against water wetted flooring, friction coefficient significantly increased with increasing both of the width of the tread and the groove due to the easier water escape from the contact area, where the groove volume was relatively higher. Friction coefficient of the displayed by cross tread rubber sliding against dry, detergent wetted and oily sliding showed drastic decrease with increasing tread groove. At sliding against water wetted flooring, friction coefficient displayed by cross tread rubber significantly increased with increasing the tread groove and displayed relatively higher values than that displayed by the longitudinal treads tested in the present work.

KEYWORDS

Friction coefficient, footwear, rubber mat, rectangular, cross treads.

INTRODUCTION

The risks associated with slipping and falling are related to the materials of footwear, floor, contamination condition, and geometric design of the rubber mat that has become a popular flooring materials due to the increased comfort, by adding a cushioning effect to the knees when walking, [1 – 6]. Recycled rubber is used over virgin rubber in flooring due to the high quality and durability. Rubber floorings are commonly used in home gyms, fitness centers, community centers, health clubs, schools and universities, play areas as well as fire and police stations. The better traction for walking on rubber matting compared with concrete is due to a more effective transmission of forces from the foot to the elastomer, dissipating the forces into deformation energy within the material, and thus impeding the effect of force, with less displacement of body centre of gravity and less forward and backward slip. Recent studies of rubber walkways in cubicle barns have confirmed the benefits for cow locomotion. It was showed in a study of six different rubber walkway covers that the degree of compressibility of rubber walkway cover was well adapted for walkway evaluation. A deformation of 1.4 mm gave good slip resistance. The effect of sand particles, on the friction coefficient displayed by rubber sliding against ceramic tiles at different sliding conditions, was investigated, [7]. Experiments were carried out under dry, water, detergent, oil, soap, and water oil emulsion. It was found that, at dry sliding, dust particles caused drastic decrease in friction coefficient. In this case, it is recommended to use circular protrusion in the rubber surface. In the presence of water, dust particles embedded in rubber surface increased friction coefficient. Based on the experimental results, wet square protrusions are recommended to have relatively higher friction values. For surfaces lubricated by detergent and soap, flat rubber embedded by dust particles gave higher friction compared with protruded surfaces, while dust particles embedded in rubber lubricated by oil showed higher friction values.

Circular protrusions gave higher friction than flat and square protrusions. Flat rubber surfaces, lubricated by water oil emulsion and contaminated by dust particles, displayed the highest friction coefficient. Dust particles on the floor prevent direct contact between the footwear pad and floor, [8]. The number of sand particles on the floor may affect the friction. However, the largest particles dominate the effects because they will be the first ones to contact the footwear pad. The rigidity, strength, and geometric characteristics of these critical particles will determine the type of interactions between the footwear pad and the particles and between the particles and the floor. The footwear pad contacts the solid particles first before it contacts the floor. For a solid with less rigidity, deformation occurs when a shoe sole presses it. For a more rigid particle, it may be broken into smaller pieces when the stress exceeds its crushing strength. At the moment of the contact of the two surfaces, rolling and sliding, of either the footwear pad on the particle, or the particle on the floor, or both, could occur for a rigid particle with high strength especially when both surfaces are hard and smooth. It was suggested that the adhesive friction is significantly affected by particulate contaminants, while the hysteretic component is not, [9]. Three lubrication mechanisms identified as sliding, shearing and rolling have been observed depending on floor roughness, particle size and shape factor.

The effect of the treads width and depth of the shoe sole on the friction coefficient between the shoe and ceramic floor interface was discussed, [10]. It was found that, at dry sliding, friction coefficient slightly increased with increasing treads height. In the presence of water on the sliding surface significant decrease in friction coefficient was observed as compared to the dry sliding. For detergent wetted surfaces, friction coefficient drastically decreased to values lower than that displayed by water. Oily smooth surfaces gave the lowest friction value as a result of the presence of squeeze oil film separating rubber and ceramic. Emulsion of water and oil shows slight friction increase compared to oil lubricated sliding. Furthermore, friction coefficient significantly increased up to maximum then slightly decreased with increasing the treads height. At water, detergent and oil lubricated sliding conditions, friction coefficient decreased as the tread width increased due to the increased area of the fluid film. The friction decrease may be due to the increased ability of the tread to form hydrodynamic wedge as the tread width increased. Tread groove designs are helpful in facilitating contact between the shoe sole and floor on liquid contaminated surface, [11 - 14]. 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 hardness of the rubber as well as the thickness and the groove width of the treads introduced in the rubber surface on friction coefficient was tested, [15]. It was found that friction coefficient decreased with increasing rubber hardness due to decrease of rubber deformation. Increasing rubber thickness increased deformation and friction coefficient. Presence of grooves in rubber surface facilitated increasing deformation so that the adhesion between rubber and ceramic increased which increased friction coefficient. The highest friction coefficient values were recorded for rubber of 8 mm thickness, 6 mm groove width and 30 Shore A hardness. This was due to the high rubber thickness and the wide groove width which increased rubber deformation.

In the present work the effect of rubber flooring mat provided by rectangular and cross treads of different width on the friction coefficient displayed by smooth rubber footwear is investigated in the present work.

EXPERIMENTAL

Experiments were carried out using a special test rig designed and manufactured to measure the friction coefficient between the rubber footwear and the tested flooring mats through measuring the friction and normal forces.

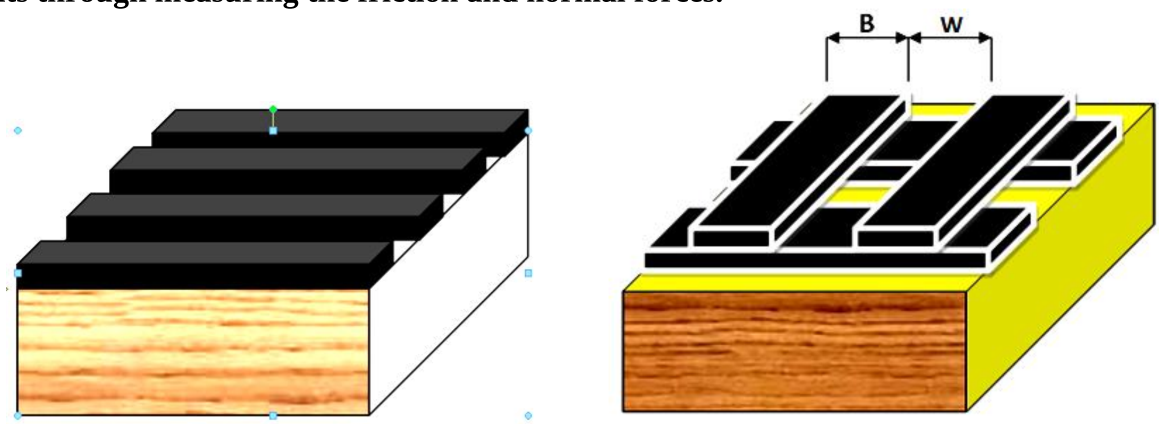

Fig. 1 Rubber test specimens of rectangular and cross treads.

The tested flooring mat was of wooden rectangular of 60 × 60 mm and 20 mm thickness. The wooden rectangular was fitted by rubber rectangular treads of 5, 7 and 10 mm width and 3 mm depth. The rubber rectangular were backed on one surface of wooden rectangular in longitudinal and cross directions, Fig. 2. The hardness of the rubber was 33 ± 2 Shore A. The counterface which represented the footwear sliding surface was smooth rubber of 67 ± 2 Shore A hardness. The surfaces of the test specimens and rubber were thoroughly cleaned with soapy water to eliminate any dirt and dust and carefully dried before the tests. The working testing conditions were dry, water, water + 5.0 vol. % detergents and oil (Sunflower oil). Tests were carried out at different values of load. In the present work, the results of the selected values of load of 40, 80 and 120 N were considered.

RESULTS AND DISCUSSION

The Effect of the tread groove width on the friction coefficient displayed by 10 mm tread width sliding against dry flooring materials is illustrated in Fig. 2. It is clearly shown that friction coefficient slightly decreased with increasing tread groove. This behavior may be attributed to the decreased contact area accompanied to the increased groove width of the rubber.

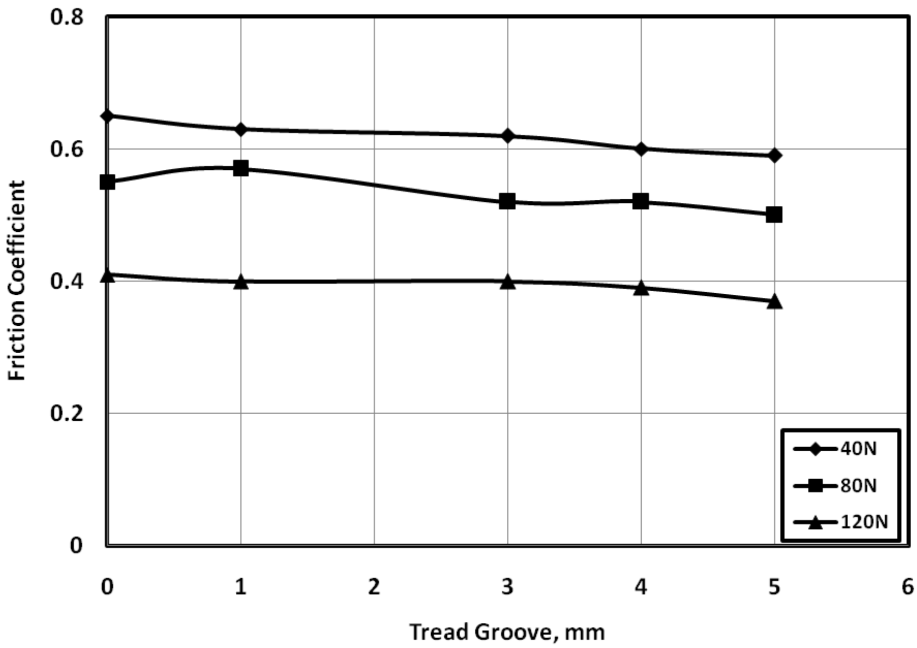

Fig. 2 Effect of tread groove width on the friction coefficient displayed by 10 mm tread width sliding against dry flooring materials.

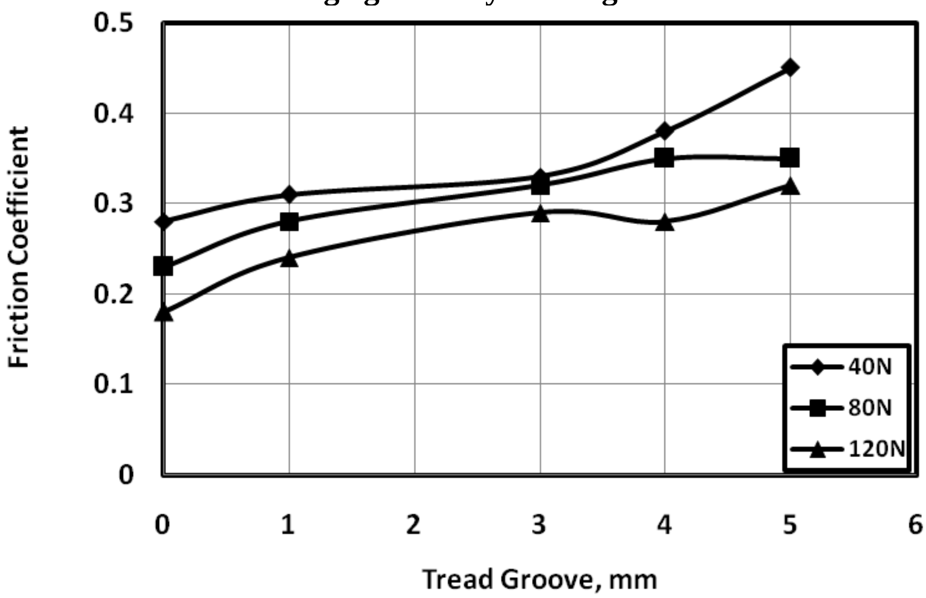

Fig. 3 Effect of tread groove width on the friction coefficient displayed by 10 mm tread width sliding against water wetted flooring materials.

The effect of tread groove width on the friction coefficient displayed by 10 mm tread width sliding against water wetted flooring materials is illustrated in Fig. 3. It is clearly shown that friction coefficient remarkably increased with increasing the tread groove. This behavior occurred from the action of tread groove which allowed the water to escape from the contact area. As the load increased friction coefficient decreased due to water film trapped in the rubber surface. The experiments recorded maximum value of friction coefficient (0.45) at 5 mm tread groove and 40 N normal load.

Effect of tread groove width on the friction coefficient displayed by 10 mm tread width sliding against detergent wetted flooring materials is illustrated in Fig. 4. It is clearly shown that friction coefficient slightly decreased with increasing groove width. This behavior may be attributed to the strong adhesion of the molecules of the detergent into the contact area. At smooth surface, friction coefficient showed the highest values then decreased with increasing groove width due to retaining higher amount of trapped detergent which facilitated detergent feed back to the contact area.

Sliding against oily flooring displayed very low values of friction coefficient, Fig. 5. It is clearly shown that friction coefficient drastically decreased with increasing tread groove. At smooth surface, friction coefficient displayed the highest values due to the easy escape of oil from the contact area. The minimum values of friction coefficient were 0.08, 0.07 and 0.06 at 40, 80 and 120 N load respectively. Based on those values, the sliding condition was considered as very slippery.

As the tread width decreased to 7 mm friction coefficient decreased with increasing tread groove, Fig. 6. The values were lower than that observed for 10 mm tread width due to the decrease of the contact area. The lowest friction values were displayed by 5 mm tread groove.

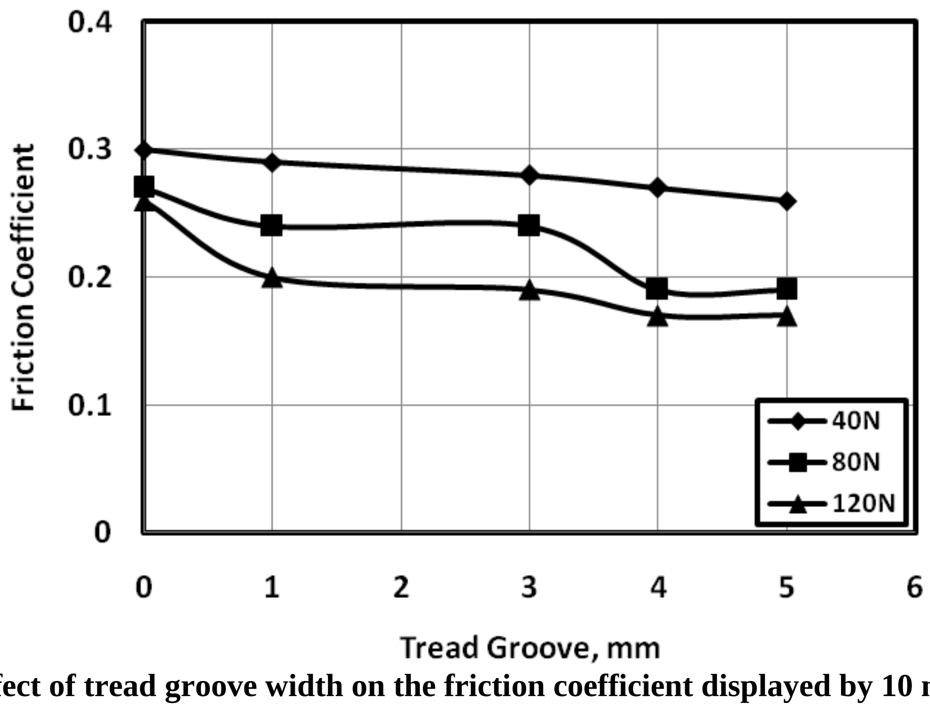

Fig. 4 Effect of tread groove width on the friction coefficient displayed by 10 mm tread width sliding against detergent wetted flooring materials.

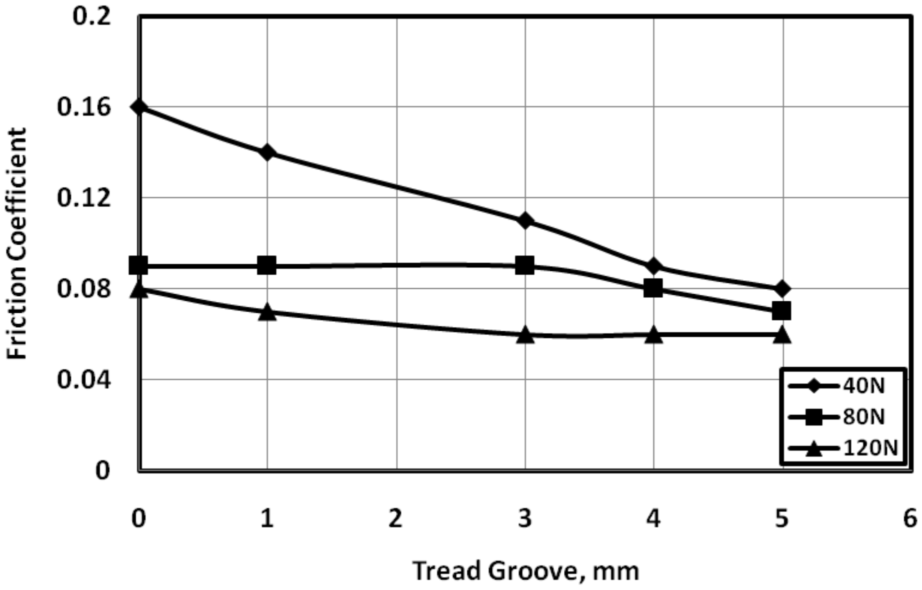

Fig. 5 Effect of tread groove width on the friction coefficient displayed by 10 mm tread width sliding against oily flooring materials.

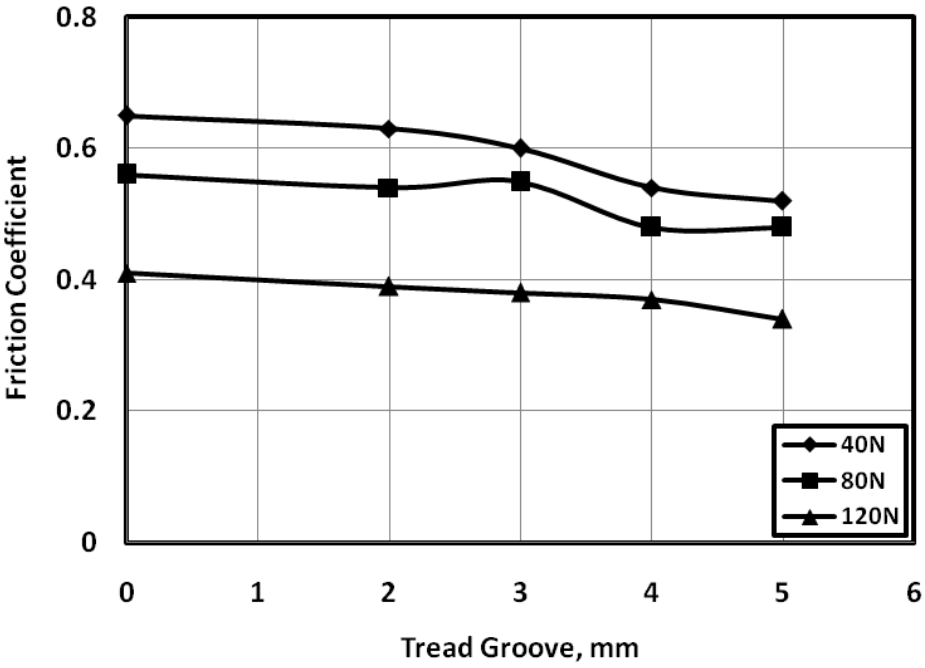

Fig. 6 Effect of tread groove width on the friction coefficient displayed by 7 mm tread width sliding against dry flooring materials.

At sliding against water wetted flooring, Fig. 7, friction coefficient significantly increased with increasing tread groove. The friction values were relatively higher than that observed for 10 mm tread width due to the easier water escape from the contact area, where the groove volume was relatively higher.

The effect of tread groove width on the friction coefficient displayed by 7 mm tread width sliding against detergent wetted flooring is illustrated in Fig. 8, where friction

coefficient slightly decreased with increasing tread groove width. Compared to 10 mm tread width, 7 mm gave lower friction values due to the decrease of the contact area.

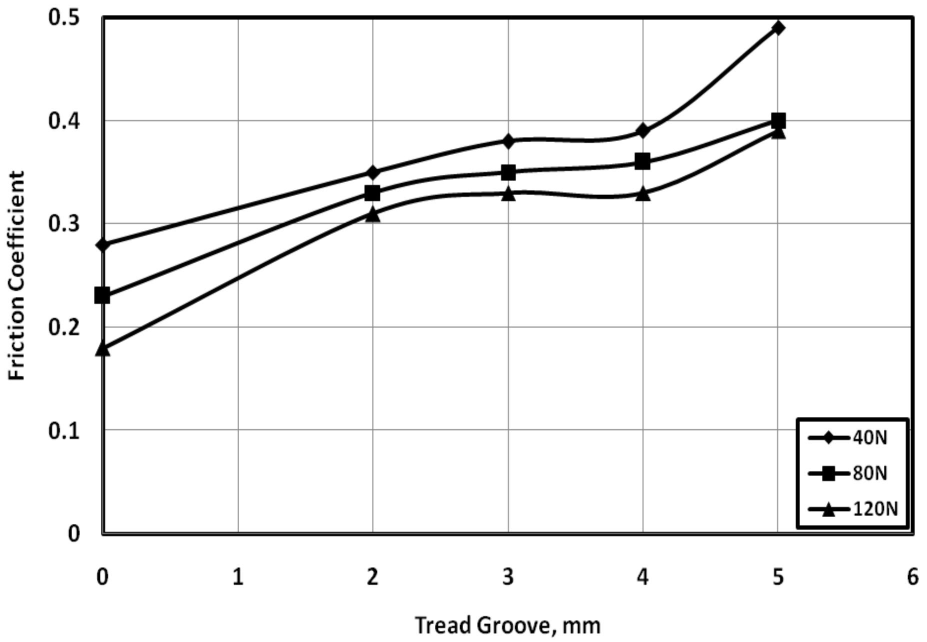

Fig. 7 Effect of tread groove width on the friction coefficient displayed by 7 mm tread width sliding against water wetted flooring materials.

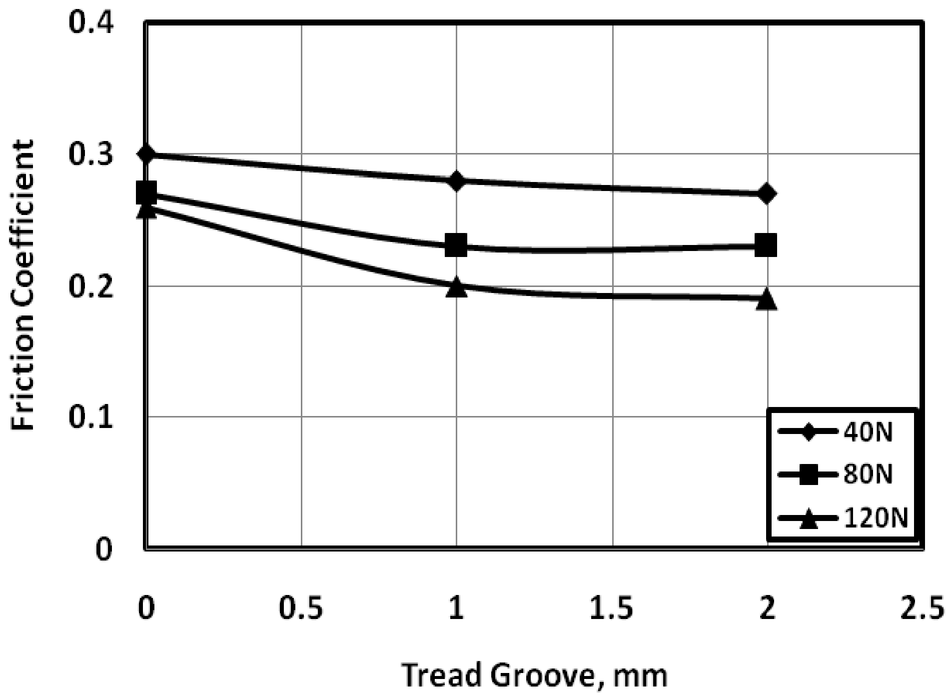

Fig. 8 Effect of tread groove width on the friction coefficient displayed by 7 mm tread width sliding against detergent wetted flooring materials.

Oily flooring showed the higher friction values than that observed for 10 mm tread width, Fig. 9. Friction coefficient slightly decreased down to minimum then slightly

increased with increasing tread groove width. The friction values were considered as very slipper sliding condition.

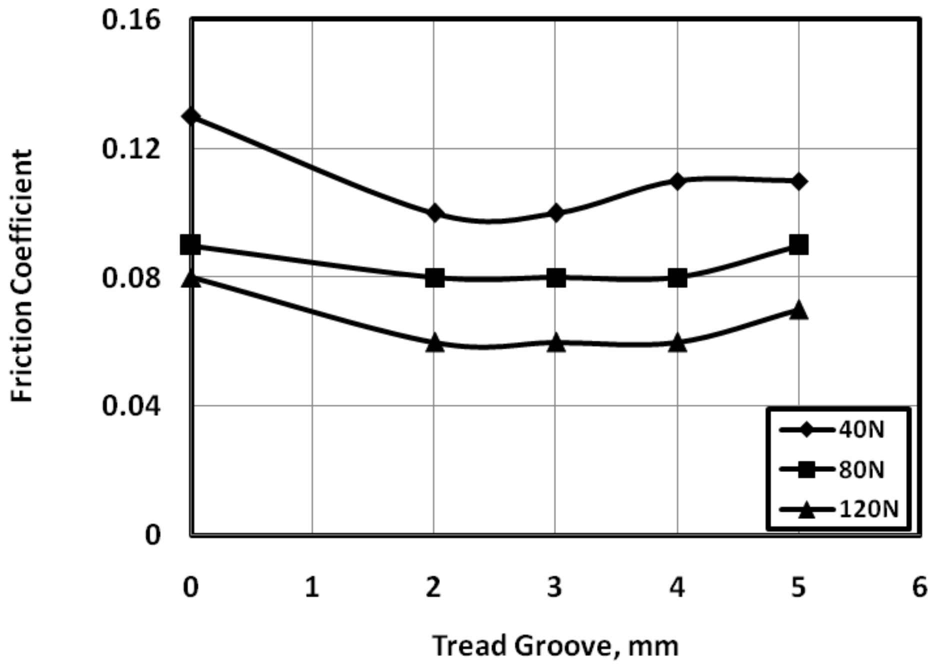

Fig. 9 Effect of tread groove width on the friction coefficient displayed by 7 mm tread width sliding against oily flooring materials.

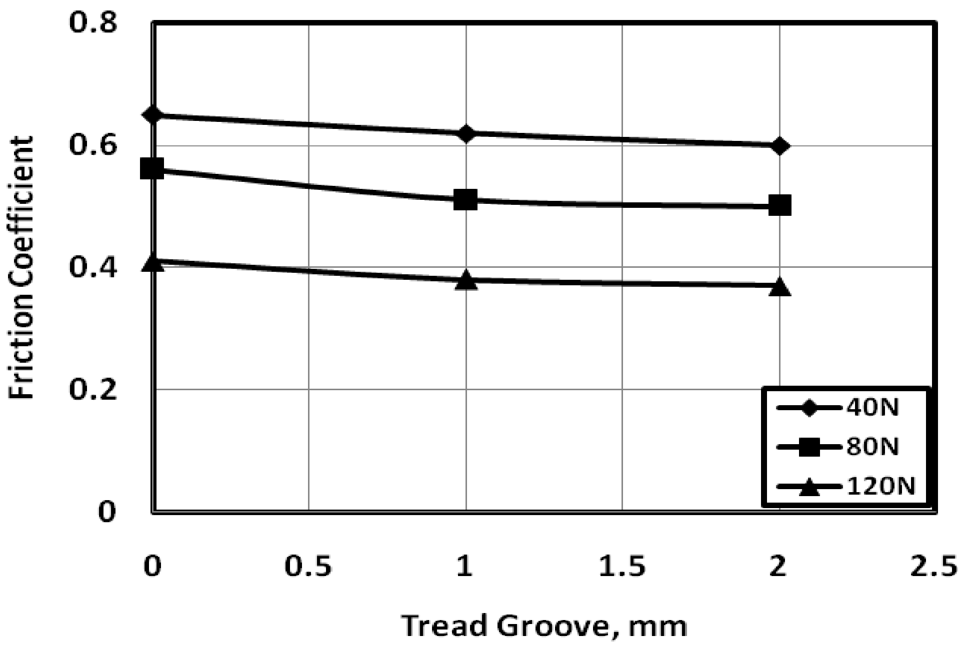

Fig. 10 Effect of tread groove width on the friction coefficient displayed by 5 mm tread width sliding against dry flooring materials.

Friction coefficient displayed by 5 mm tread width sliding against dry flooring, Fig. 10, showed slight decrease with increasing tread groove width due to the decrease of the contact area. The friction values were higher than that observed for 10 mm tread width

due to the extra rubber deformation. Friction coefficient displayed at sliding against water wetted flooring materials showed significant increase with increasing tread groove, Fig. 11. Friction values were higher than those observed for 7 and 10 mm tread groove.

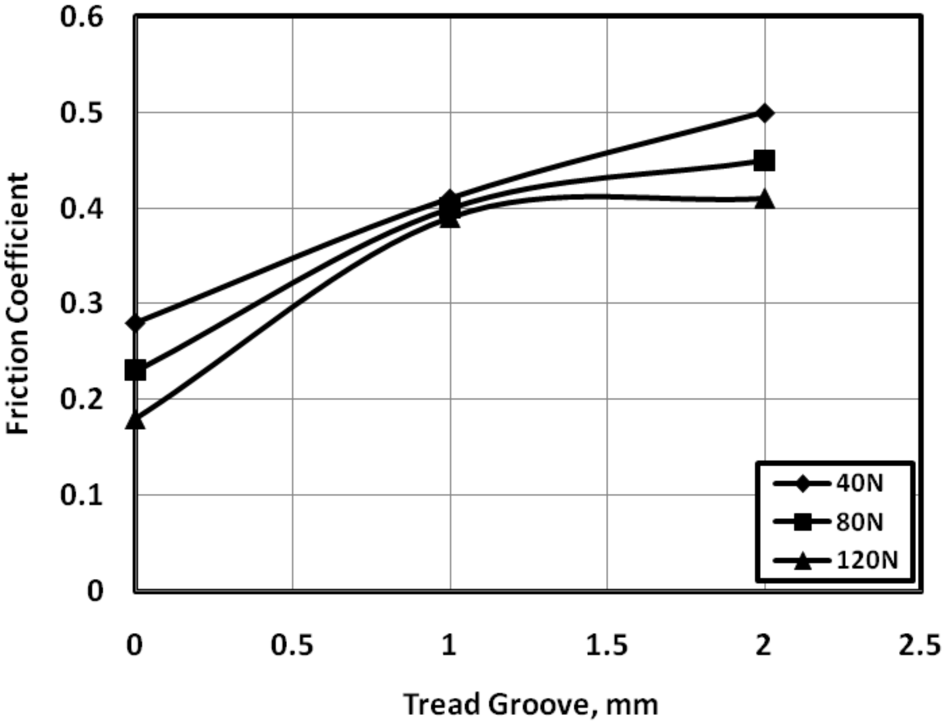

Fig. 11 Effect of tread groove width on the friction coefficient displayed by 5 mm tread width sliding against water wetted flooring materials.

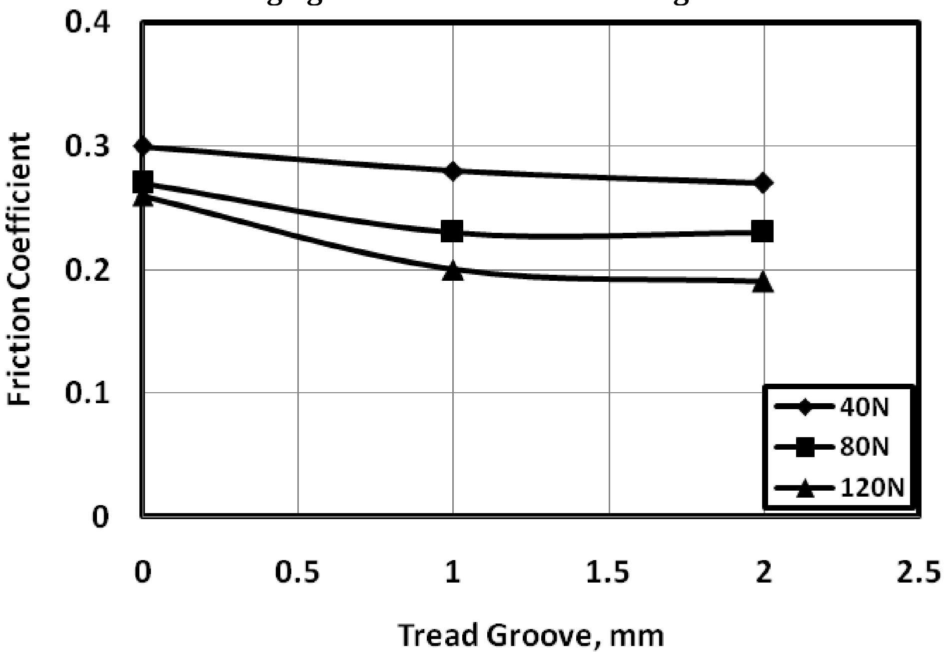

Fig. 12 Effect of tread groove width on the friction coefficient displayed by 5 mm tread width sliding against detergent wetted flooring materials.

Effect of tread groove width on the friction coefficient displayed by 5 mm tread width sliding against detergent wetted flooring is shown in Fig. 12. Friction values were the

same like those observed for 7 and 10 mm tread width. It seems that the effect of the adhesion of the detergent molecules into the sliding surface had the same weight of the contact area.

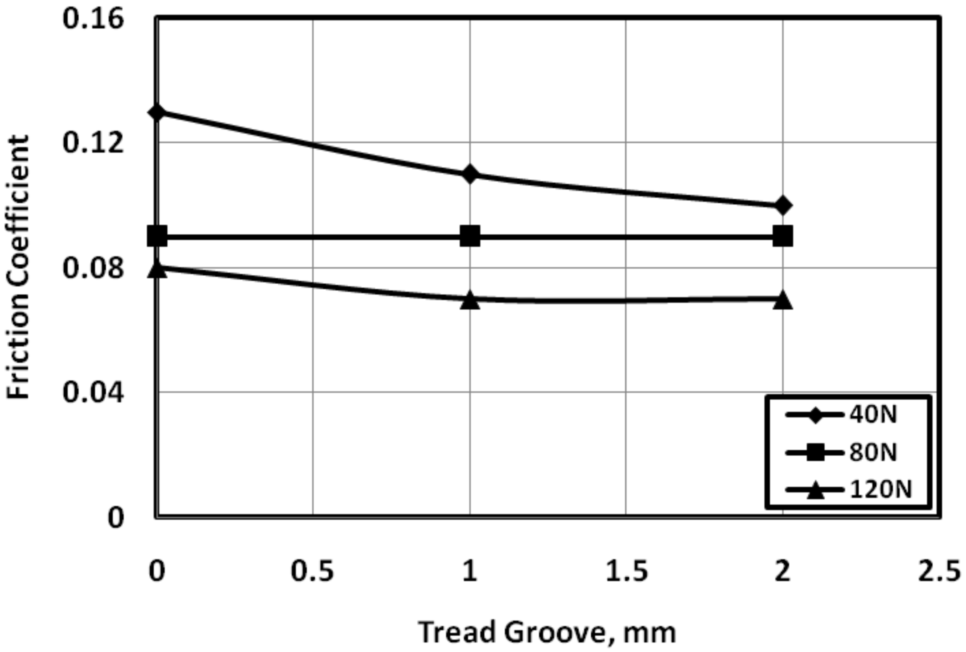

Fig. 13 Effect of tread groove width on the friction coefficient displayed by 5 mm tread width sliding against oily flooring materials.

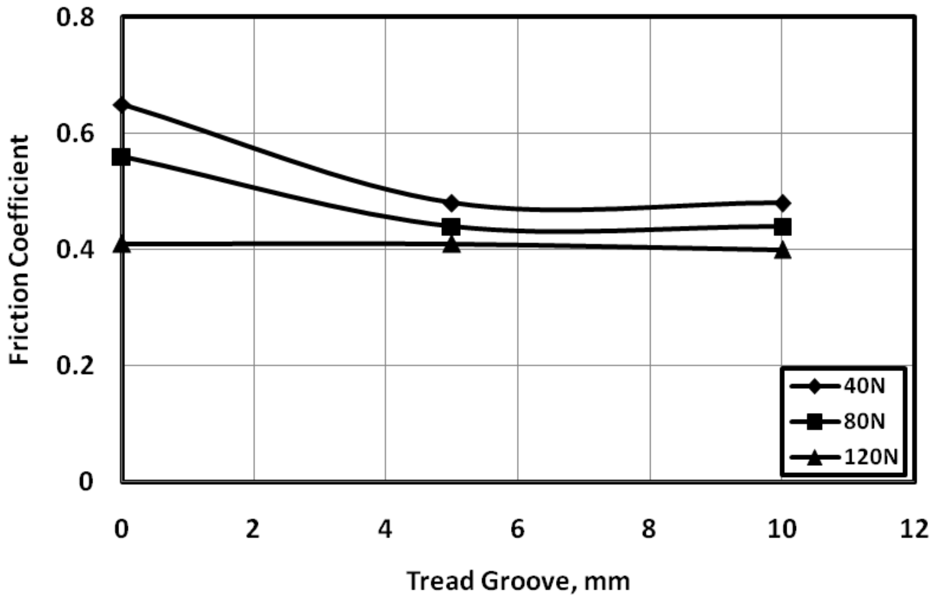

Fig. 14 Effect of tread groove width on the friction coefficient displayed by cross tread sliding against dry flooring materials.

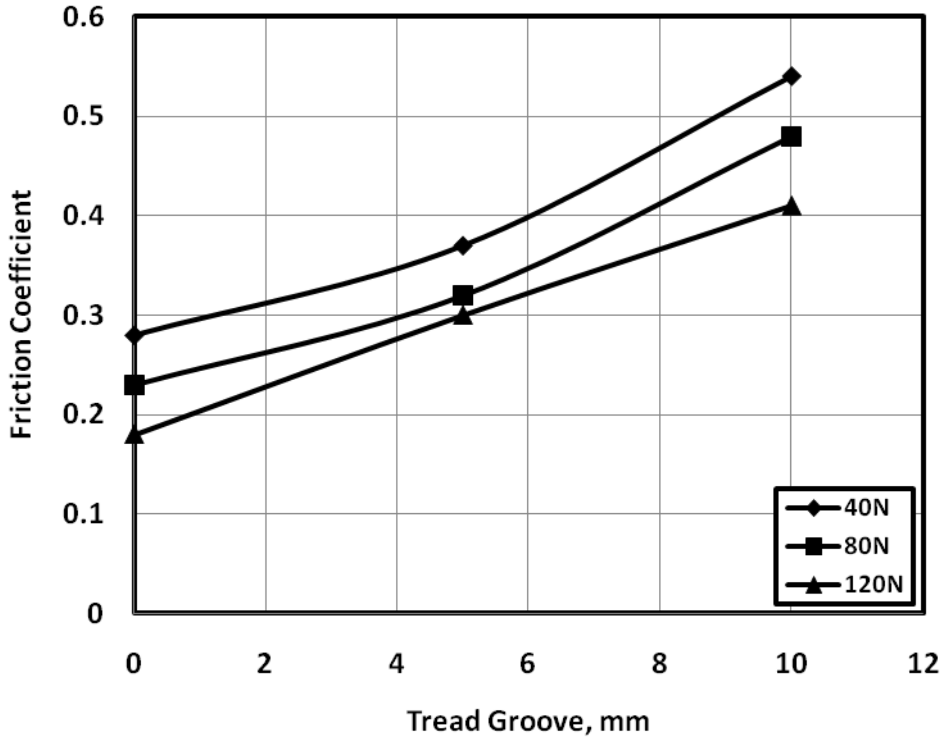

Fig. 15 Effect of tread groove width on the friction coefficient displayed by cross tread sliding against water wetted flooring materials.

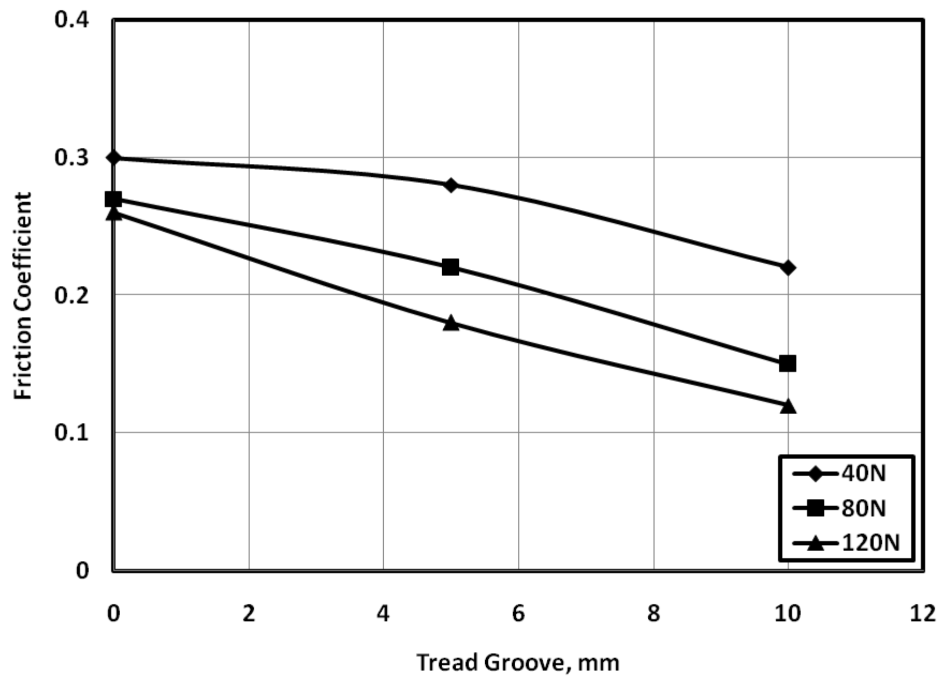

Fig. 16 Effect of tread groove width on the friction coefficient displayed by cross tread sliding against detergent wetted flooring materials.

At oily sliding, friction coefficient slightly decreased with increasing the tread groove, Fig. 13. Load had significant effect on the friction coefficient. Friction coefficient displayed by cross tread rubber sliding against dry flooring materials showed drastic

decrease with increasing tread groove, Fig. 14. The friction decrease might be from the decrease of the contact area. At the highest load (120 N) there was no effect of the tread groove on friction coefficient.

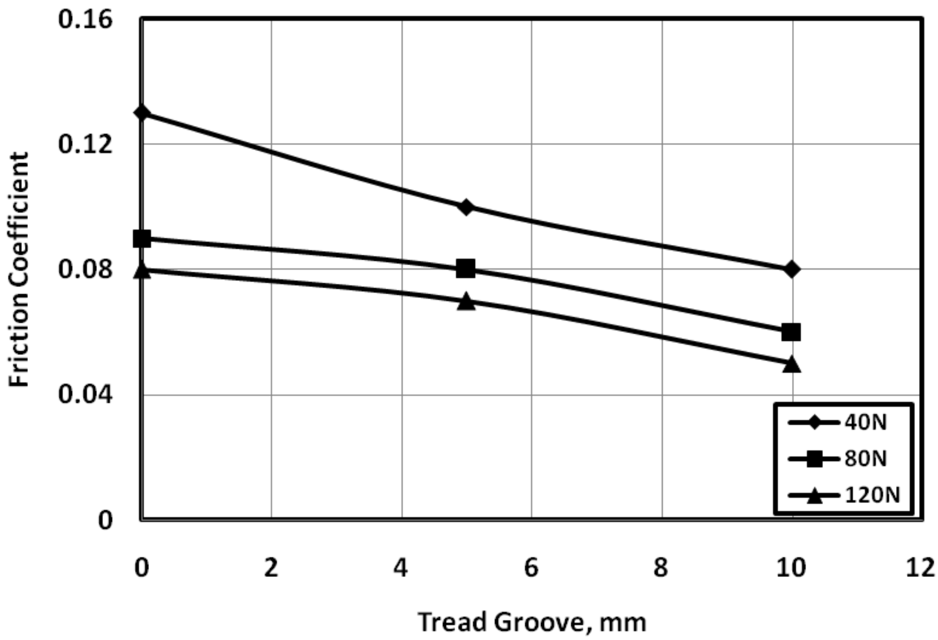

Fig. 17 Effect of tread groove width on the friction coefficient displayed by cross tread sliding against oily flooring materials.

At sliding against water wetted flooring, friction coefficient significantly increased with increasing the tread groove, Fig. 15. It seems that the groove of the cross tread allowed the easy escape of water from the contact area. Besides, the adhesion of water into the rubber and flooring surfaces was relatively weak. The friction values displayed by cross treads were relatively higher than the longitudinal treads of 5, 7 and 10 mm tread width.

The effect of tread groove width on the friction coefficient displayed by cross tread sliding against detergent wetted flooring materials is shown in Fig. 16. Although the gaps in the cross tread allowed the detergent to go out of the contact area, the adhesion of the detergent molecules into the sliding surfaces was too high to cause drastic friction decrease. The same trend was observed for oily sliding floorings, where friction coefficient drastically decreased with increasing tread groove, Fig. 17. It seems that as the tread groove increased the amount of oil stored increased. As the load increased the deformation of rubber increased and the oil was forced to flow again into the contact area. Smooth rubber showed the lowest friction coefficient due to the easy oil escape from the contact area.

CONCLUSIONS

1. Friction coefficient slightly decreased with increasing tread groove width at dry and detergent wetted sliding, while it remarkably increased with increasing the tread groove width. Sliding against oily flooring displayed very low values of friction coefficient.
2. As the tread width decreased to 7 mm, at dry and detergent wetted sliding values of friction coefficient were lower than that observed for 10 mm tread width due to the decrease of the contact area, while at water wetted sliding, friction values were relatively

higher than that observed for 10 mm tread width. Oily flooring showed the higher friction values than that observed for 10 mm tread width.

3. Friction coefficient displayed by 5 mm tread width sliding against dry flooring showed higher values than that observed for 10 mm tread width, while at water wetted sliding, it Showed higher than those observed for 7 and 10 mm tread groove.

4. Friction coefficient displayed by cross tread rubber sliding against dry flooring materials showed drastic decrease with increasing tread groove, while significantly increased with increasing the tread groove at water wetted sliding. The friction values displayed by cross treads were relatively higher than the longitudinal treads of 5, 7 and 10 mm tread width. Friction coefficient drastically decreased with increasing tread groove.

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