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FRICTION COEFFICIENT DISPLAYED BY SLIDING AGAINST ARTIFICIAL GRASS

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ABSTRACT
The present work discusses the frictional behaviour displayed by the sliding of bare foot and different types of shoes against artificial grass. The effect of applied load on the static friction coefficient displayed by foot wear sliding against artificial grass is investigated. Friction tests were carried out at 50 to 300 N loads. Tests were carried out at dry sliding conditions as well as water wetted artificial grass. The tested artificial grass is made of polyethylene fibres of different length and thickness.

Based on the experimental results, It was found that, dry sliding of barefoot against artificial grass displayed friction coefficient which slightly decreased with increasing normal load. For smooth polyurethane sole (I), friction coefficient showed very low friction coefficient, which leads to slipping for the user was observed. Polyurethane flat sole was influenced by the number of fibres, where friction coefficient decreased with decreasing number of fibres. Friction coefficient decreased with decreasing number of fibres. Friction coefficient increased as the fibre length and thickness increased. Sole fitted by studs displayed low friction values due to decrease in the contact area.

At sliding against water wetted artificial grass, the thickness of the fibres showed significant effect on friction coefficient for bare foot. It seems that the deflection of the fibres subjected to the contact area was affected by the fibre thickness. It can be recommended to extend this investigation to test the effect of the fibre thickness on friction coefficient. For flat sole, friction coefficient showed drastic decrease compared to bare foot sliding due to formation of water film on the contact area. Presence of protrusions in the sole surface allowed the water leakage from the contact area so that friction coefficient increased. The difference in friction coefficient among the tested fibres confirmed the significant effect of the number of fibres.

KEYWORDS
Friction coefficient, bare foot, foot wear, artificial grass.

INTRODUCTION
Artificial grass is a surface of synthetic fibres made to replace natural grass,]1]. It is most often used in arenas for sport yards. Domed, covered, and partially covered

stadiums may require artificial grass because of the difficulty of getting grass enough sunlight to stay healthy. One of the advantages of artificial grass that it can be a better solution when the environment is particularly hostile to natural grass. Besides, artificial grass can withstand more use than natural. It is suitable for roof gardens and swimming pool surrounds. Very low maintenance required compared to natural grass.

The disadvantages of artificial grass that it requires infill such as silicon sand and/or granulated rubber. Some granulated rubber is made from recycled car tires and may carry heavy metals which can leach into the water table, [2, 3]. There is evidence showing higher player injury on artificial turf. Friction between skin and older generations of artificial turf can cause abrasions and/or burns to a much greater extent than natural grass. This is an issue for some sports: for example, football in which sliding maneuvers are common and clothing does not fully cover the limbs. However, some third-generation artificial grasses almost completely eliminate this risk by the use of polyethylene yarn.

Friction coefficient is the major scale to quantify floor slipperiness. The friction coefficient of rubber sliding against polymeric indoor flooring materials of different surface roughness was investigated, [4]. It was found that, at dry sliding, the friction coefficient decreased with increasing surface roughness and applied load. At water lubricated sliding, the friction coefficient increased up to maximum then decreased with increasing surface roughness. At water–detergent lubricated sliding, the friction coefficient drastically decreased with increasing the surface roughness. At oil lubricated sliding, the maximum friction values were noticed at 4.0 µm R_a surface roughness. At water and oil lubricated sliding, smooth flooring surface displayed very low values of friction coefficient (0.08) close to the ones observed for mixed lubrication where the two sliding surfaces are partially separated by a fluid film. At dry sliding, friction coefficient of bare foot and polymeric socks, friction coefficient decreased down to minimum then increased with increasing the surface roughness, [5]. In water lubricated sliding, cotton socks showed the highest friction coefficient. Friction coefficient drastically decreased with increasing surface roughness at water and detergent lubricated sliding. For the tested flooring materials lubricated by oil, bare foot displayed drastic reduction in friction coefficient, while cotton socks showed the highest values.

The changes in the surface properties and frictional characteristics of flooring materials are expected in practical use due to mechanical wear, ageing, soiling and maintenance, [6]. In the sport halls the flooring surfaces are probably changed mainly through mechanical wear, periodic cleaning processes and material transfer from shoe soles (elastomer abrasions and contaminating particles). Coefficients of friction were measured periodically over a period of 30 months on the surfaces of five types of floor coverings in a new sport complex, [7]. Surface changes through mechanical wear range from smoothing to roughening, [8, 9], depending on flooring material and surface characteristics.

Surface roughness is known to be a key factor in determining the slip resistance of floors. The effect of surface roughness of ceramic on the friction coefficient, when sliding

against rubber and leather, was investigated, [10]. Glazed floor tiles of different roughness ranging from 0.05 and 6.0 µm were tested. The test results showed that, friction coefficient decreased down to minimum then increased with increasing the surface roughness of the ceramic surface.

Slip resistance of flooring materials is one of the major environmental factors affecting walking and materials handling behaviors. Floor slipperiness may be quantified using the static and dynamic friction coefficient, [11]. Certain values of friction coefficient were recommended as the slip-resistant standard for unloaded, normal walking conditions, [12, 13]. Relatively higher static and dynamic friction coefficient values may be required for safe walking when handling loads.

Researches revealed significant correlations between surface roughness of shoes and friction coefficient for a given floor surface, [14 - 18]. Abrasion of rubber soling in steps with increasingly coarse grit gradually raised the roughness in parallel with a rise in the friction coefficient on water wet surfaces. Dense rubbers never developed the same order of roughness, and they became smooth and polished when worn on ordinary floors or with mechanical polishing.

In the present work, it is aimed to investigate the frictional behaviour of the sliding of bare foot and different types of shoes against artificial grass.

EXPERIMENTAL

The test rig used in the present work was designed and manufactured to measure the friction coefficient displayed by the sliding of the tested shoes specimens against the artificial grass surface through measuring the friction force and applied normal force, Figs. 1, 2. The artificial grass surface in form of a tile is placed in a base supported by two load cells to measure both the horizontal force (friction force) and vertical force (applied load). Two digital screens were attached to the load cells to detect the friction and vertical forces. Friction coefficient is determined by the ratio between the friction force and the normal load. The artificial grass test specimens were prepared from four type of artificial grass. The types the of artificial grass are shown in Table 1.

Fig. 1 Test rig used.

Fig. 2 Load cells.

Table 1 The types the of artificial grass.

	
Specimen A **No. of fibres = 30** **Mesh size = 7.5 mm** **Fibre length = 30 mm** **Fibre width = 0.7 mm** **Fibre thikness = 0.13 mm**	**Specimen B Specimen B** **No. of fibres = 34** **Mesh size = 7.5 mm** **Fibre length = 30 mm** **Fibre width = 0.7 mm** **Fibre thikness = 0.13 mm**

	
Specimen C **No. of fiber = 32** **Mesh size = 7.5** **Fiber length = 30 mm** **Fiber width = 0.7 mm** **Fiber thikness = 0.13 mm**	**Specimen D** **No. of fiber = 12** **Mesh size = 7.5** **Fiber length = 60 mm** **Fiber width = 1.4 mm** **Fiber thikness = 0.22 mm**

Friction test were carried out at different forces (loads) ranging from 50 -350 N. Test specimens (bare foot and shoes) were loaded against counterface (artificial grass) at dry and water wetted sliding conditions. Four types of shoes, smooth shoe (I), sport shoe (II), football shoe (III) and rubber shoe (VI), Table 2.

Table 2 The types the of the tested shoes.

	
Flat Polyurethane Sole, (I)	**Sport Sole, (II)**
	
Sport Sole, (III)	**Football Sole, (IV)**

RESULTS AND DISCUSSION:

Bare foot walking on indoor flooring is a usual custom. Artificial grass can be used indoor near swimming pools and corridors. Dry sliding of barefoot against artificial grass displayed friction coefficient which slightly decreased with increasing normal load. The maximum value of friction coefficient (1.05) was observed at 100 N normal load for specimen (C), while minimum value (0.59) was observed at 600 N normal load for specimen (A), Fig. 3. Artificial grass (C) can be recommended to be used in indoor near the swimming pool due to the relatively high value of friction coefficient. Behaviour of specimen (D) reflected the sensitivity of bar foot to the thickness of the fibres of the grass.

For smooth polyurethane sole (I), friction coefficient slightly decreased with increasing normal load, Fig. 4. At all specimen, a very low friction coefficient, which leads to slipping for the user was observed. (D) is the worst specimen. Values of friction coefficient for smooth sole were lower than that displayed by bare foot. Polyurethane flat sole was influenced by the number of fibres, where friction coefficient decreased with decreasing number of fibres. This fact is confirmed by the highest friction coefficient by fibres, where friction coefficient decreased with decreasing number of fibres. This fact is confirmed by the highest friction coefficient displayed by fibres (B) of the highest fibre number folloed by fibres (C) and (A).

For sole (II) sliding against dry artificial grass, friction coefficient slightly decreased with increasing normal load, Fig. 5. The maximum value of friction coefficient (1.2) was observed at 100 N normal load for specimen (C), while minimum value (0.41) was observed at 600 N normal load for specimen (A), which confirmed the increase of slip risk. Fibres (D) showed higher friction coefficient than fibres (A) due to the higher fibre length and the increase of the fibre thickness.

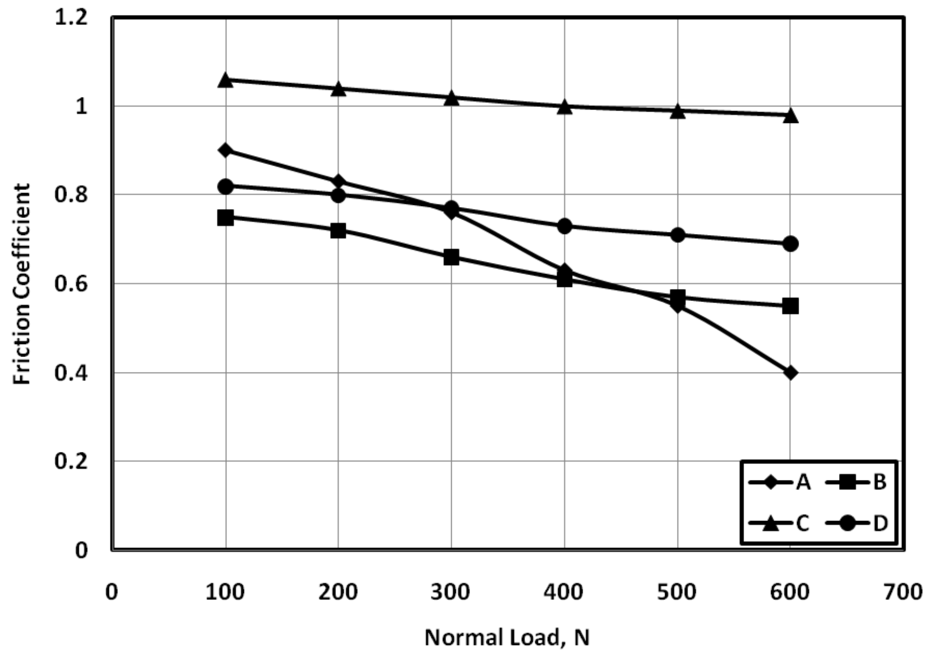

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Fig. 3 Friction coefficient of bare foot sliding against dry artificial grass.

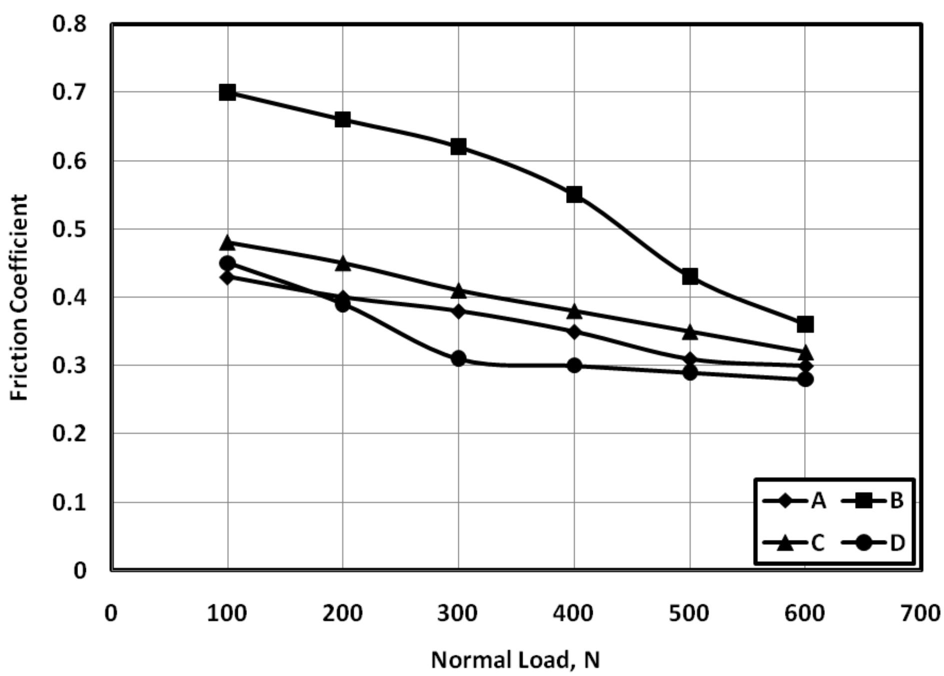

Fig. 4 Friction coefficient of sole (I) sliding against dry artificial grass.

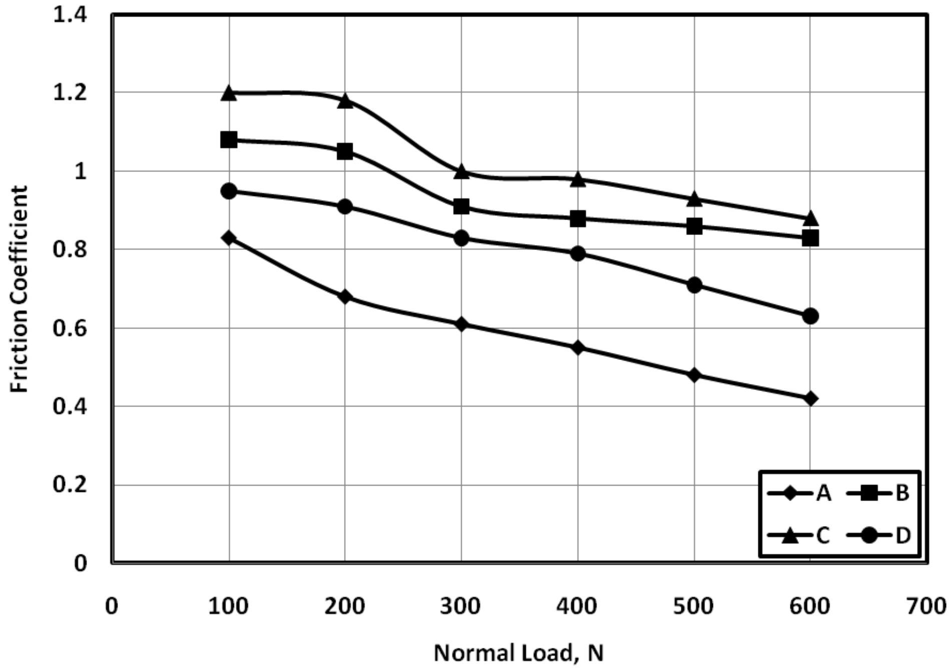

Fig. 5 Friction coefficient of sole (II) sliding against dry artificial grass.

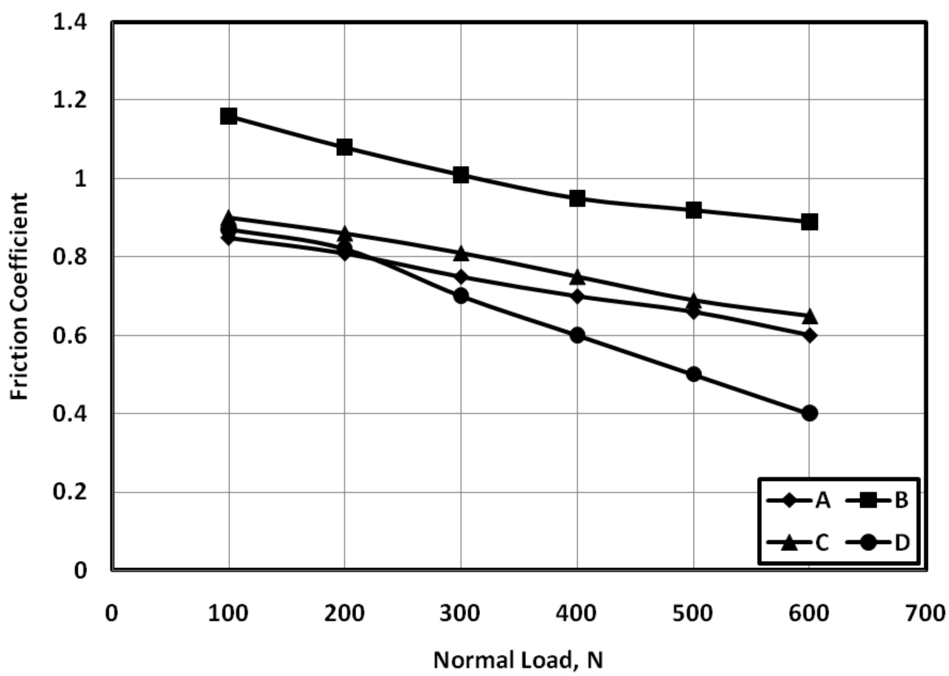

Fig. 7 Friction coefficient of sole (III) sliding against dry artificial grass.

Sole (III) sliding against dry artificial grass displayed relatively lower values of friction coefficient, Fig. 7. Those values can leads to slipping, where specimen (D) represented the worst performance. It seems that the as the number of fibres in the bundle

decraesed, friction coefficient decreased. Fibres (B) showed the highest friction values followed by fibres (C) and (A).

For sole (IV) sliding against dry artificial grass, friction coefficient slightly decreased with increasing normal load, Fig. 6. The maximum value of friction coefficient (1.05) was observed at 100 N normal load for specimen (B), while minimum value (0.33) was observed at 600 N normal load for specimen (D). Although the sole (IV) was fitted by six polyamide studs and five polyethylene studs, friction values were lower than that observed for soles (II) and (III) due to decrease in the contact area, where the contact in this condition was between the grass and the studs. This observation should be considered in further investigations to select the proper materials used in manufacturing of the foot ball studs.

For bare foot sliding against water wetted artificial grass, friction coefficient slightly decreased with increasing normal load, Fig. 8. The maximum value of friction coefficient (1.05) was observed at 100 N normal load for specimen (B), while minimum value (0.68) was observed at 600 N normal load for specimen (A). Comparing that behaviour to that shown for dry sliding, insignificant change was observed. The thickness of the fibres showed significant effect on friction coefficient. It seems that the deflection of the fibres subjected to the contact area was affected by the fibre thickness. It can be recommended to extend this investigation to test the effect of the fibre thickness on friction coefficient.

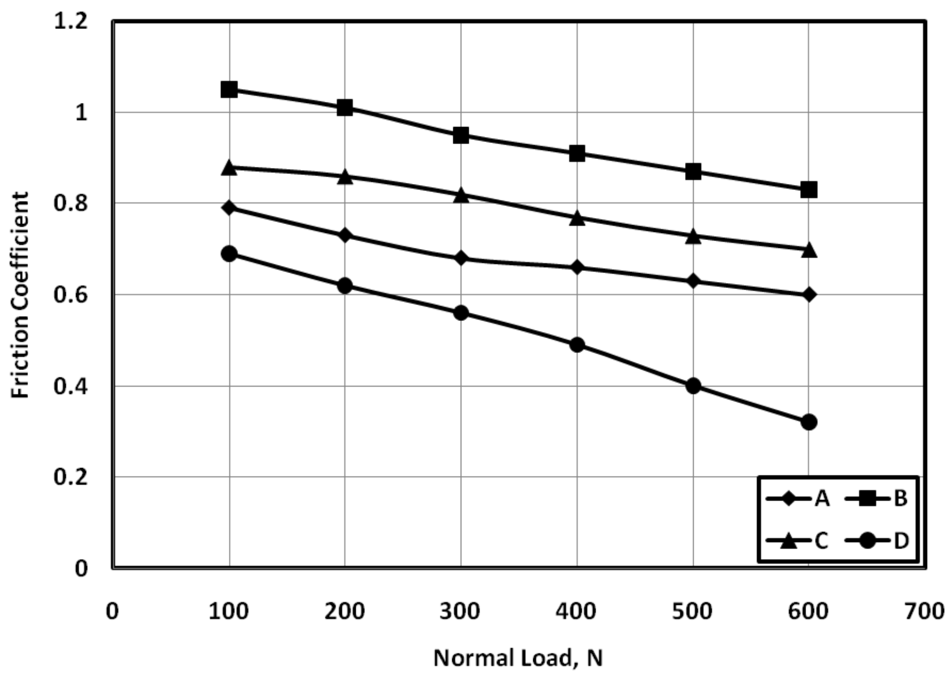

Fig. 6 Friction coefficient of sole (IV) sliding against dry artificial grass.

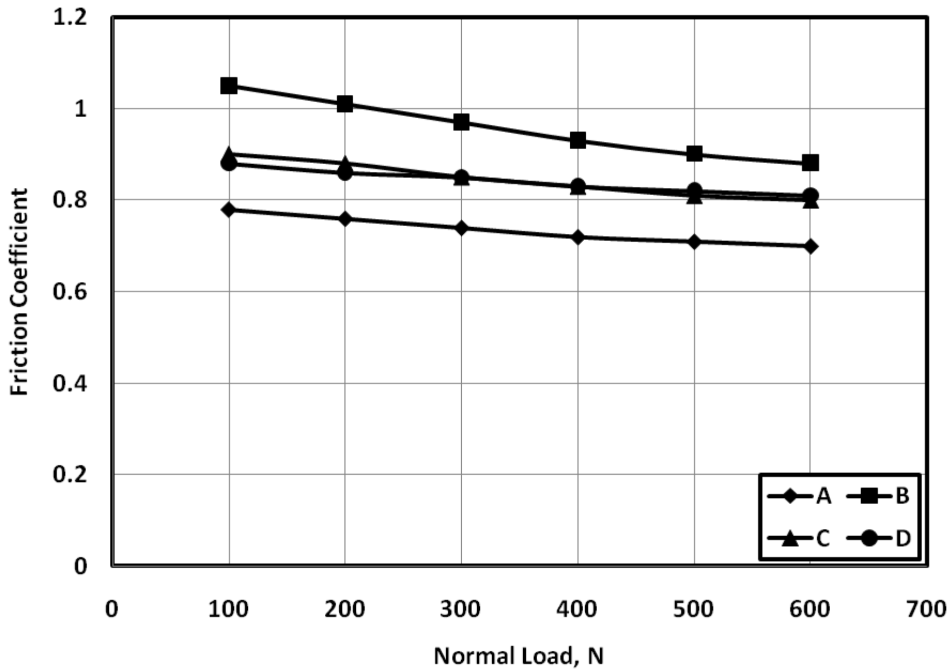

Fig. 8 Friction coefficient of bare foot sliding against water wetted artificial grass.

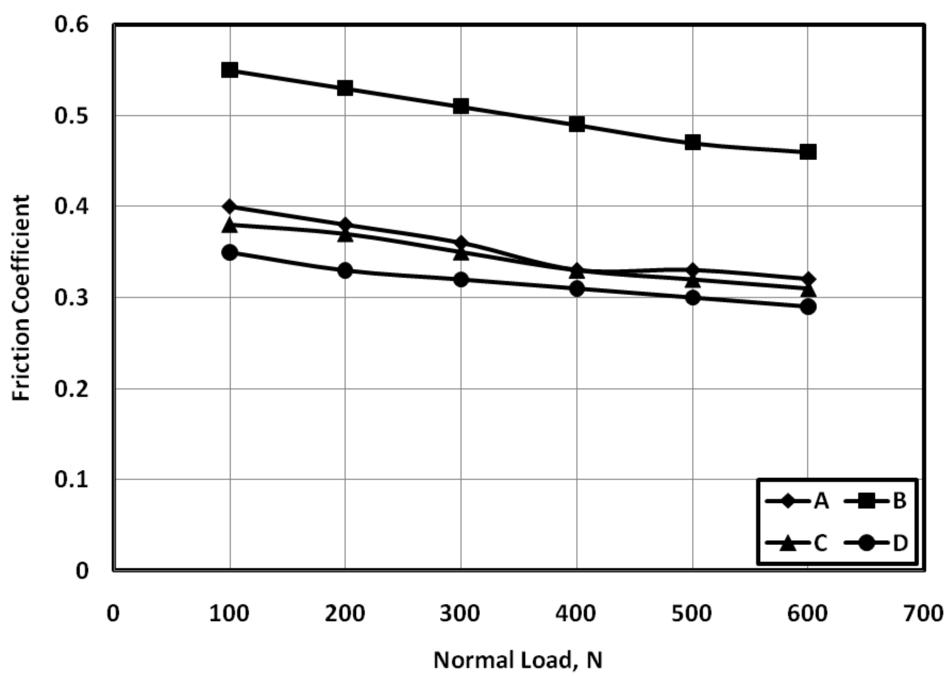

Fig. 9 Friction coefficient of sole (I) sliding against water wetted artificial grass.

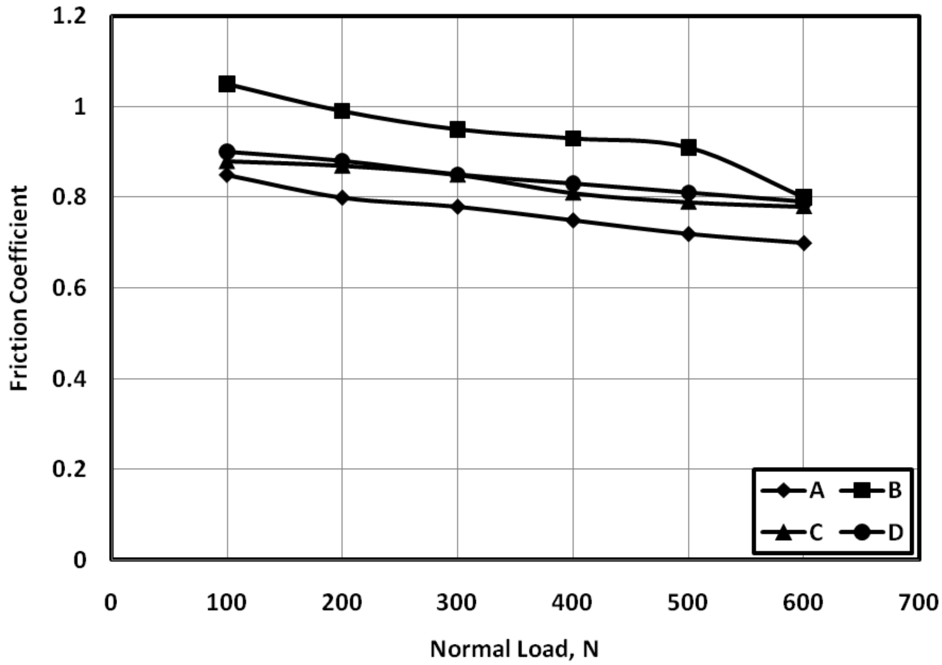

Fig. 10 Friction coefficient of sole (II) sliding against water wetted artificial grass.

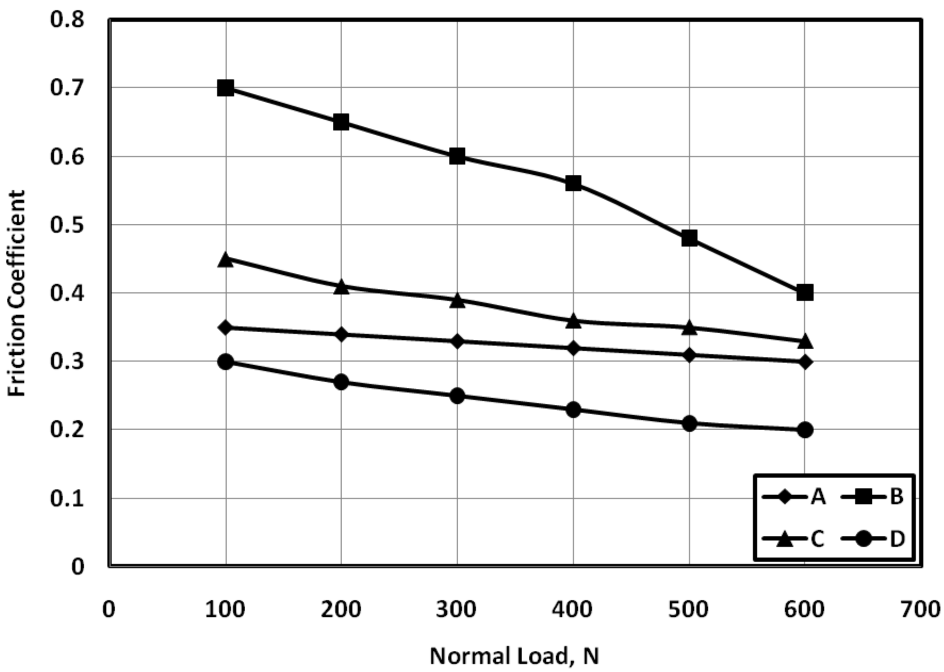

Fig. 11 Friction coefficient of sole (III) sliding against water wetted artificial grass.

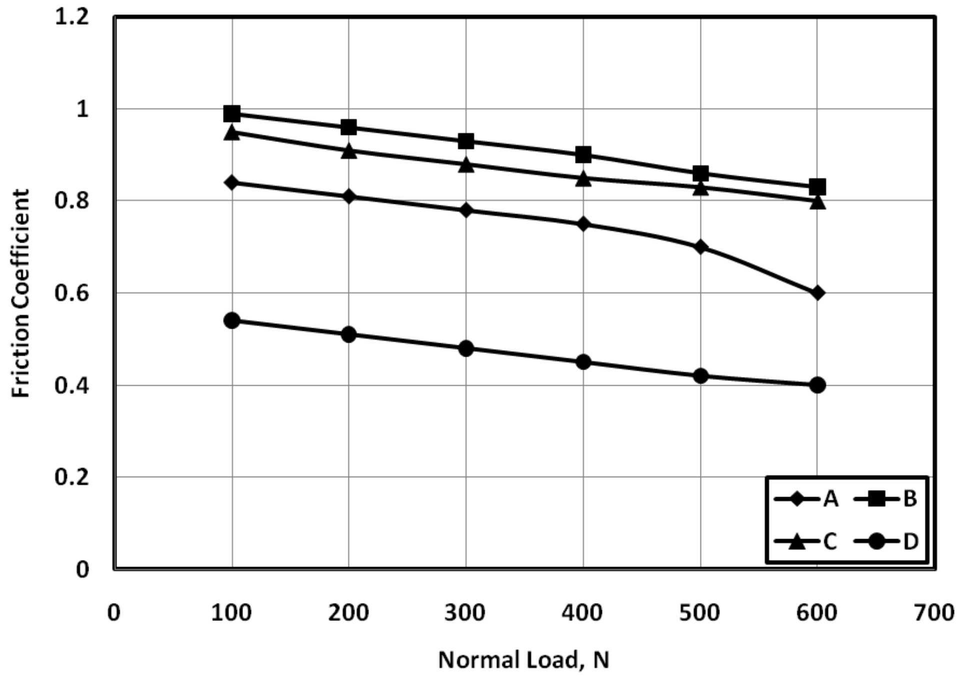

Fig.12 Friction coefficient of sole (IV) sliding against water wetted artificial grass.

For sole (I) sliding against water wetted artificial grass, friction coefficient showed drastic decrease compared to bare foot sliding. The highest friction values were displayed by specimen (B), Fig. 9. The maximum value of friction coefficient (0.56) was observed at 100 N normal load. A very low friction coefficient which can lead to slipping was displayed by specimen (A). The flat surface of sole (I) was responsible for that decrease due to formation of water film on the contact area.

For sole (II), friction coefficient slightly decreased with increasing normal load, Fig. 10, of values higher than that represented by sole (I). This behaviour can be attributed to the presence of protrusions in the sole surface which allowed the water leakage from the contact area. The height and width of the treads strongly depend on the water film thickness.

For sole (III) sliding against water wetted artificial grass, friction coefficient slightly decreased with increasing normal load, Fig. 11. For all test specimens, very low friction coefficient, which leads to slipping for the user, was observed. Fibres (D) displayed the lowest values of friction coefficient. This behaviour can be explained on the basis that the number of the fibres was very low as well as the tread groove did not allow the water to escape from the sliding surface.

Sole (IV) showed relatively higher friction values than soles (I) and (III), Fig. 11. Friction coefficient slightly decreased with increasing normal load. The maximum value of friction coefficient (0.99) was observed at 100 N normal load for specimen (B), while minimum value (0.40) was observed at 600 N normal load for specimen (D). The

difference in friction coefficient among the tested fibres confirmed the significant effect of the number of fibres.

CONCLUSIONS

1. Friction coefficient displayed by sliding against artificial grass decreased with increasing normal load.
2. Dry sliding of barefoot against artificial grass displayed relatively higher values of friction coefficient.
3. Values of friction coefficient for smooth sole were lower than that displayed by bare foot.
4. As the fibre length and thickness increased friction coefficient increased.
5. For sole (IV) that fitted by six polyamide studs, friction values were lower than that observed for soles (II) and (III) due to decrease in the contact area, where the contact in this condition was between the grass and the studs.
6. For bare foot sliding against water wetted artificial grass, thickness of the fibres showed significant effect on friction coefficient.
7. Smooth sole, sliding against water wetted artificial grass, showed drastic decrease compared to bare foot sliding.
8. Presence of protrusions in the sole surface increased friction coefficient due to their allowance the water leakage from the contact area. The height of the protrusions and width of the treads strongly depend on the water film thickness.

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