Slips and Falls – Risks for Pedestrians

Abstract

Pendulum slip resistance tests were conducted on 12 sites covering ceramic tiles, pebbles, and features such as tactile indicators, and manhole covers. The results show that the reduction of frictional resistance can be reduced up to 3 times when tested wet. The slip can be exacerbated when it is on a slope.

Keywords: slip, fall, pedestrian, slipperiness, tactile pavement, slope, wet floor, frictional resistance

Introduction

Slips and falls are a leading cause of injuries globally and its prevention remains a pressing public safety and health challenge. While studies on hazards and risk control measures of slips and falls due to environmental and human factors have been widely conducted [1], little has been reported on the risk for pedestrians when stepping over coatings and features such as tactile, manhole covers, etc. (Figure 1) during wet days.

This paper discusses the results of a study to evaluate the reduction in frictional resistance of some common features when wet. Also discussed is pedestrians' risk on slopes during rainy days.

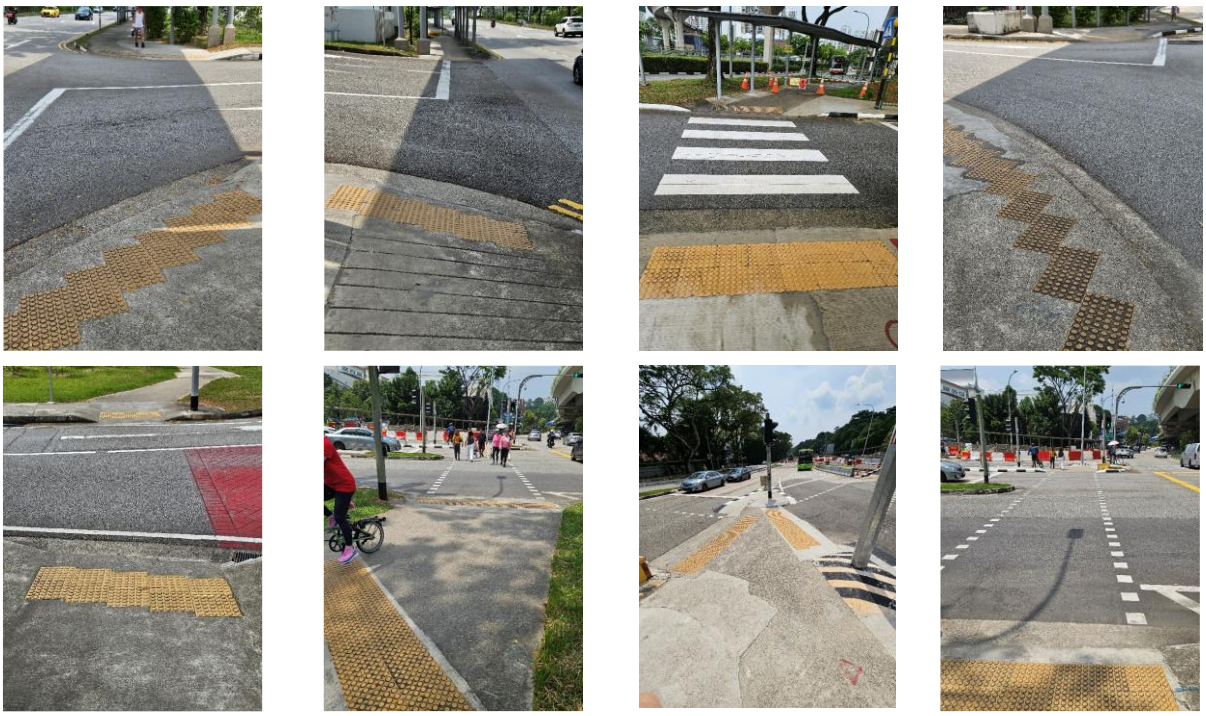


Figure 1 Some common coatings and features such as tactile and steel covering on pavements

Surface Roughness

Figure 2 describes the impact of the surface roughness of a pavement material on frictional resistance [2].

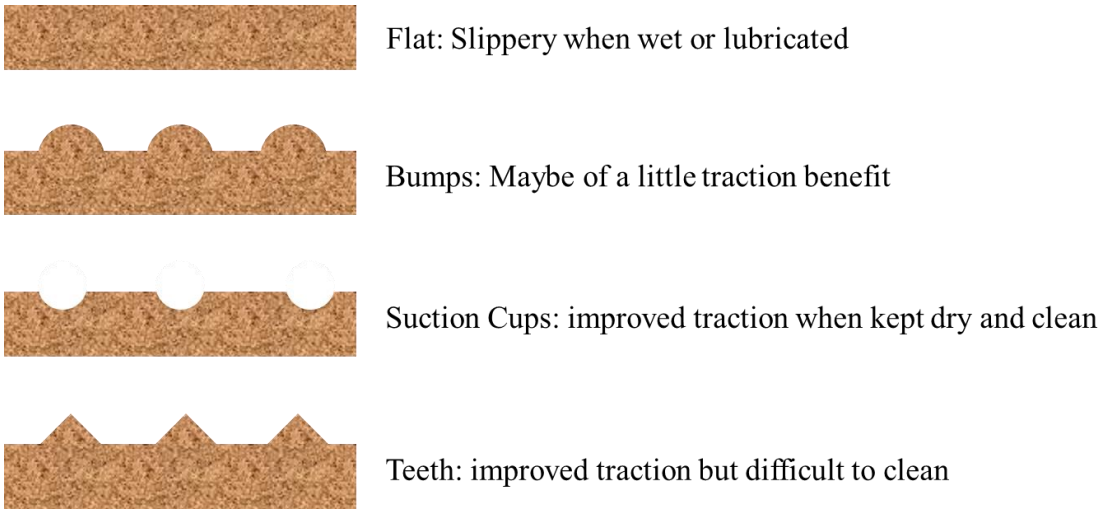


Figure 2 Impact of surface roughness to frictional resistance

Anti-slip treatment, a process which removes soft particles and exposes hard particles on the flooring surface, may be used to alter the mineral structure of the floor surface which in turn increases the slip resistance properties and makes the floor safer when wet or lubricated.

Hydroplaning

An approved pavement material is usually safe from skid and fall when it is in a dry and clean condition. However, when it is wet or lubricated, the effect of hydroplaning or aquaplaning (loss of traction when a layer of water builds up between the sole of the footwear and the surface of the pavement) may take place.

The friction between the sole of footwear and the pavement surface depends on the grooves of the sole to disperse water beneath. Hydroplaning or aquaplaning occurs when the sole of footwear encounters more water than it can dissipate. In extreme cases, like a vehicle going through a large puddle of water on a road, the water pressure in front of the wheel may force a wedge of water under the leading edge of the tyre, causing it to lift from the road and skates on a sheet of water with little, if any, direct road contact.

Methodology

Pendulum slip tests according to SS485 were conducted on various floor surfaces (Figure 4).

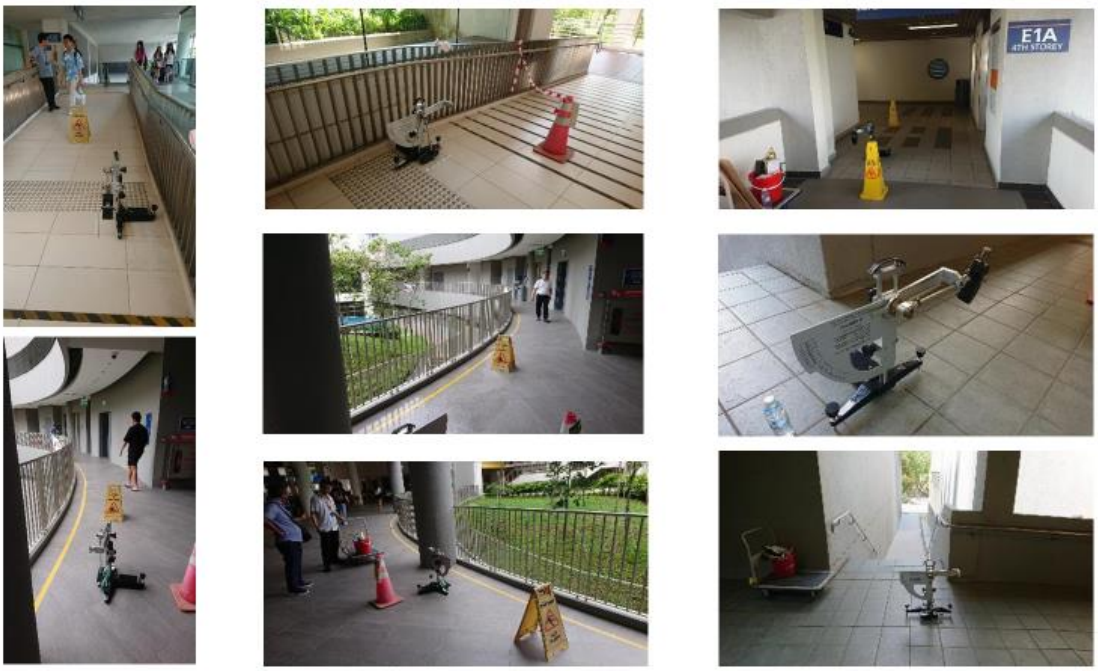


Figure 4 Examples of pendulum slip tests conducted on various sites

Tests were conducted under the following conditions:

1. **As Is** – Original state with no intervention.
2. **Dry(Clean)** – A simple cleaning of the surface with a wet towel, dry before testing.
3. **ASTM E303 –**ASTM standard condition.

4. **Flow -** With a flow of streaming water from a bottle.

Results

Case 1 – Bridge pathway – Ceramic Tile

Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	30.5	125	58	58	57	58	58	58
Dry (Clean)	30.7	125	50	50	50	50	50	50
ASTM E303	29.8	125	28	27	26	25	25	26
Flow	29.6	125	26	24	23	23	23	23

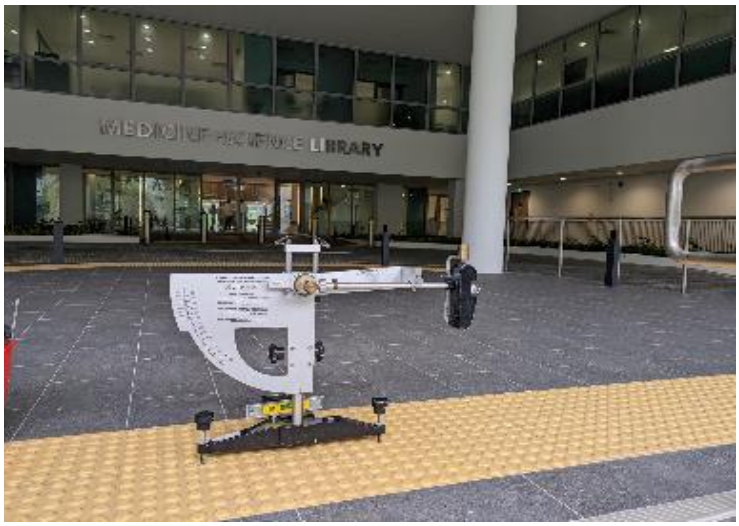
Case 2 – Link pathway – Ceramic Tile

Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	32.4	127	52	55	53	58	58	56
Dry (Clean)	32.3	127	57	53	55	57	57	56
ASTM E303	31.6	127	32	33	31	31	31	32
Flow	30.5	127	30	28	28	25	28	27

Case 3 – Washroom – Ceramic Tile

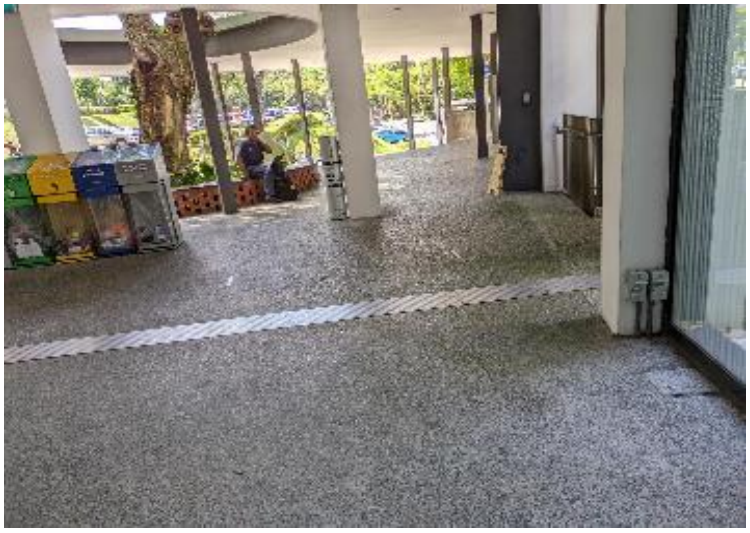
Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	29.7	127	71	73	76	77	79	76
Dry (Clean)	29.7	127	72	72	77	78	81	77
ASTM E303	29.5	127	29	27	26	24	26	26
Flow	29	127	22	24	24	26	25	25

Case 4 – Lobby – Ceramic Tactile



Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	27.3	124	76	77	77	70	70	74
Dry (Clean)	27.1	124	65	61	69	72	68	68
ASTM E303	26.8	124	22	33	36	35	35	35
Flow	26.2	124	33	39	39	39	38	39

Case 5 – Lobby – Pebble



Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	27.7	127	72	77	77	85	76	79
Dry (Clean)	27.3	127	80	83	78	76	80	79
ASTM E303	27.2	127	39	36	37	37	39	37
Flow	27.2	127	37	35	34	33	32	34

Case 6 – Outdoor – Stainless Steel Manhole Cover

Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	27.5	124	51	54	54	56	55	55
Dry (Clean)	27.1	124	71	71	71	75	75	73
ASTM E303	27.3	124	32	26	30	30	33	30
Flow	26.9	124	36	35	32	34	36	34

Case 7 – Canteen– Ceramic Tile

Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	28.6	127	64	73	64	68	74	70
Dry (Clean)	28.4	127	65	68	70	68	68	69
ASTM E303	28.1	127	23	23	22	20	21	22
Flow	28	127	22	21	22	21	22	22

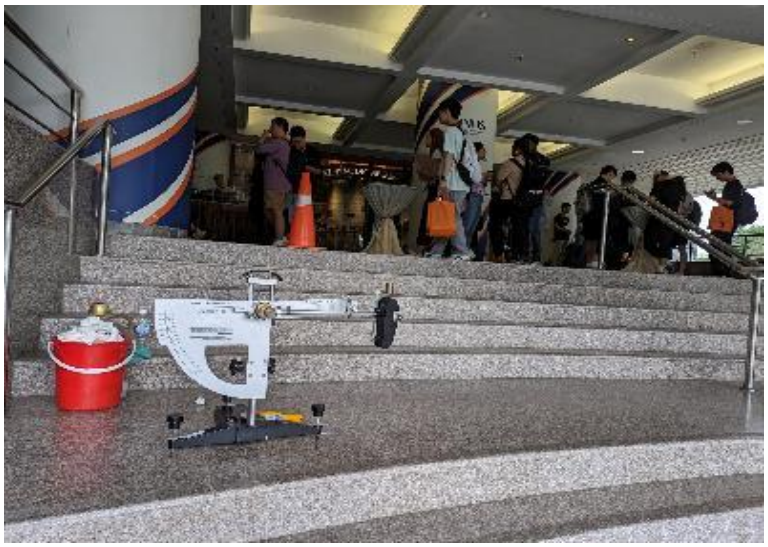
Case 8 – Pathway – Ceramic Tile

Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	30	125	70	69	63	66	62	65
Dry (Clean)	30.9	125	59	56	65	71	68	65
ASTM E303	30.5	125	26	20	20	21	23	21
Flow	30	125	21	22	20	21	22	21

Case 9 – Outdoor – Ceramic Tile

Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	30.7	124	58	54	60	60	61	59
Dry (Clean)	28.3	124	58	71	68	60	67	67
ASTM E303	-	124	31	28	27	27	26	27
Flow	-	124	24	25	27	26	24	26

Case 10 – Grand Stairs - Granite



Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	26.9	125	61	59	60	61	60	60
Dry (Clean)	26.8	125	54	52	53	55	56	54
ASTM E303	26.7	125	22	21	20	19	19	20
Flow	26.4	125	20	21	20	20	20	20

Case 11 – Outdoor pavement– Pebble

Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	26.3	127	70	75	75	75	80	76
Dry (Clean)	26.2	127	81	81	80	83	82	82
ASTM E303	26.2	127	31	29	30	30	30	30
Flow	26.1	127	27	27	28	28	29	28

Case 12 – Outdoor – Ceramic Tactile

Condition	C°	Travel (mm)	1X	1	2	3	4	BPN Average
As Is	27.7	127	40	69	70	74	76	72
Dry (Clean)	28.2	127	65	64	80	84	78	77
ASTM E303	28.1	127	33	40	36	23	31	33
Flow	26.6	127	36	30	29	33	28	30

Discussion

The results show that, with a film of sprayed water, the frictional resistance of the wet surfaces for all cases was reduced 2 to 3 times compared to that of the corresponding dry surfaces. Similar results were obtained for features including tactile, manhole cover and pebbles. The study reinforces the need for awareness of pedestrians when walking over features installed on rough concrete pavements. Those features may appear as slip-resistant as the adjacent rough concrete pavement when dry, but may be up to 3 times more risky when wet.

The situation can be further exacerbated when a pedestrian is using a slope, in which case the force on the slope can be computed based on the forward force and the weight of the pedestrian (Figure 3).

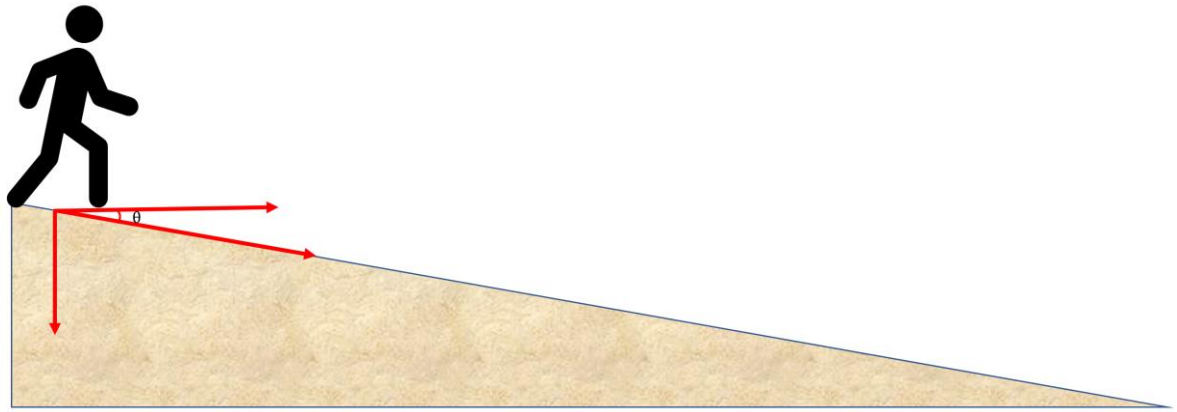


Figure 3 Higher slip resistance required on a slope

A higher 'Pendulum Test Value' (PTV) to prevent slips on slopes is required. Health and Safety Executive (HSE) recommends that for a horizontal floor where a Pendulum Test Value of 36 PTV on a WET or CONTAMINATED floor is required to ensure a 'Low Slip Potential', for every one degree of slope, the PTV value shall be increased by 1.75 PTV. It is suggested to use approximately 2 PTV per degree to allow for tolerancing and floor wear.

It should be noted that all such mentioned features e.g. tactile indicators should not be installed on a slope [4].

Conclusions

The results show that the reduction of frictional resistance can be reduced up to 3 times when tested wet for all cases. Pedestrians need to pay special attention when stepping over features including tactile, manhole covers, coating etc. when wet. The reduction in frictional resistance will be further exacerbated if the features are installed on a slope.

References

[1] Hippi, M.; Kangas, M., “Impact of Weather on Pedestrians’ Slip Risk”, International Journal of Environmental Research and Public Health, **2022**, 19, 3007. https://doi.org/10.3390/ijerph19053007

[2] John Scotter, “Floor Slip Resistance Explained”, Safety Direct America, 2014, https://www.youtube.com/watch?v=--h5PnR6h3g

[3] UK Slip Resistance Group, “The Assessment of Floor Slip Resistance”, The UK Slip Resistance Group Guidelines, Issue 6, 2024,

[4] Tokuda K., et al, “Guidebook for the Proper Installation of Tactile Ground Surface Indicators (Braille Blocks) : Common Installation Errors”, International Association of Traffic and Safety Sciences, 2008.