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Wind Tunnel Testing of Crossgrip TPO Roof Walkway Matting

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Introduction
The aim of this test program is to ascertain the effects of high wind speeds on Plastex Crossgrip TPO roof walkway mats; in particular to establish at what wind speed they are likely to lift away from the roof surface. These lift off speeds can then be compared with the wind conditions that could be experienced at potential installation sites.

The Beaufort Wind Scale
In 1805 Admiral Sir Francis Beaufort developed a scale to help sailors estimate the winds via visual observations. The Beaufort Scale extends from force 0 to force 12 and still used today to estimate wind strengths on land and at sea.

Force	Wind Speed (mph)	Description	Land Observations
0	0 - 1	Calm	Calm; smoke rises vertically.
1	1 - 3	Light air	Direction of wind shown by smoke drift, but not by wind vanes.
2	4 - 7	Light Breeze	Wind felt on face; leaves rustle; weather vanes moved by wind.
3	8 - 12	Gentle Breeze	Leaves and small twigs in constant motion; wind extends light flag
4	13 - 18	Moderate Breeze	Raises dust and loose paper; small branches are moved.
5	19 - 24	Fresh Breeze	Small trees in leaf begin to sway; crested wavelets form on inland waters.
6	25 - 31	Strong Breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
7	32 - 38	Near Gale	Whole trees in motion; inconvenience felt when walking against the wind
8	39 - 46	Gale	Breaks twigs off trees; difficult to walk against wind.
9	47 - 54	Severe Gale	Slight structural damage occurs (chimney-pots and tiles removed).
10	55 - 63	Storm	Seldom experienced inland; trees uprooted; considerable structural damage occurs.
11	64 - 72	Violent Storm	Very rarely experienced; accompanied by wide-spread damage.
12	73 - 83	Hurricane	Severe structural damage to buildings; widespread devastation.

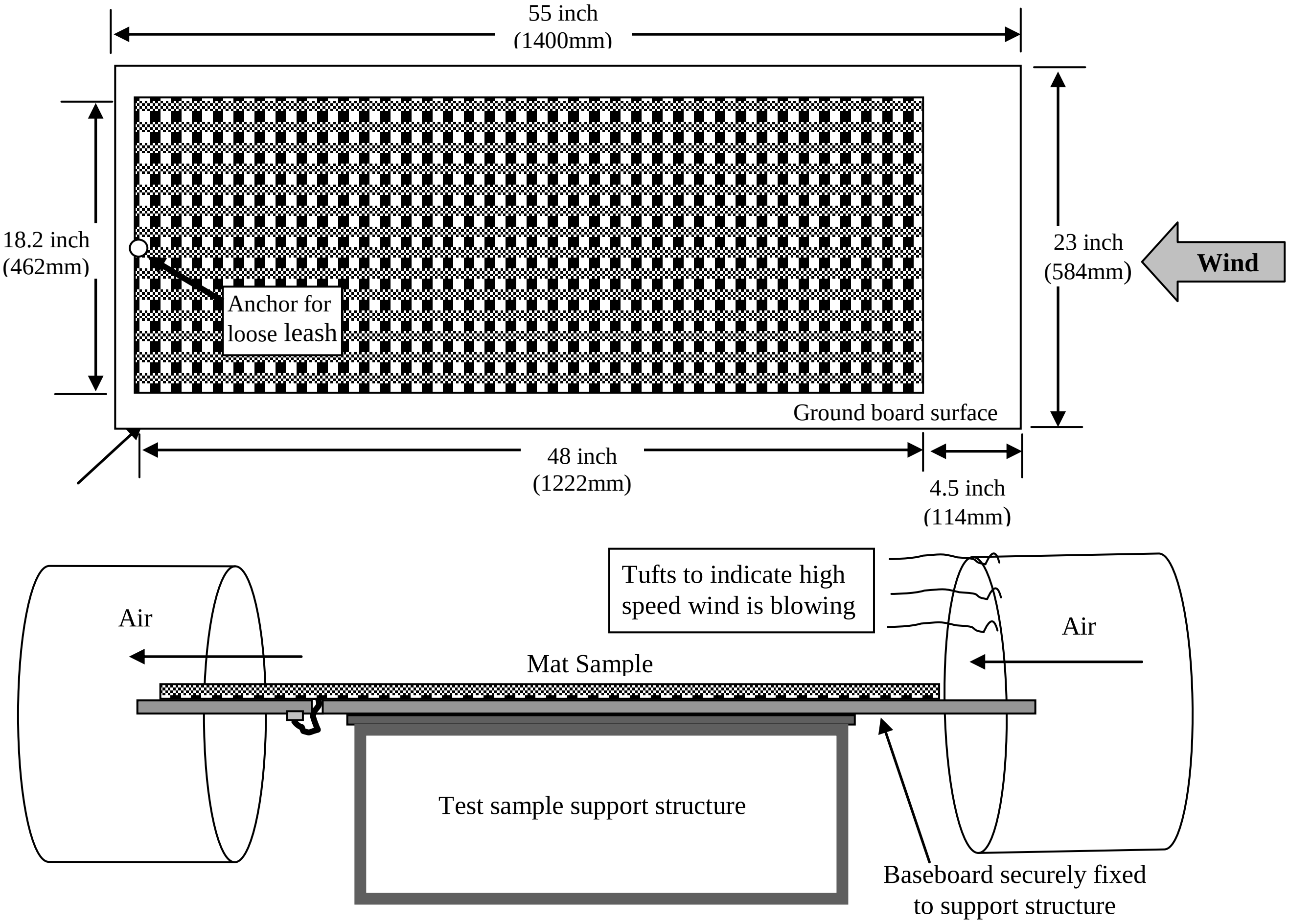
The inclusion of the Beaufort Wind Scale information in this report helps to relate the wind speeds at which the mats were tested to real weather conditions. However, it should be noted that, due to surface friction, there is a general tendency for the mean wind velocity closer to the ground to be lower than that at higher altitudes. The reduction in velocity near the ground is a function of surface roughness and hence will be more significant in built-up areas than over open ground or sea. The amount of turbulence and local wind variation will also increase at ground level in built-up areas due to a downward deflection of wind behind buildings and channelling in passages between buildings.

The wind conditions applied to the mat test samples represent an extreme case of the full wind horizontal velocity acting directly onto the interface between the edge of the mat and its supporting surface.

Test Equipment
The testing was carried out using the open section, closed return wind tunnel in the aerodynamics laboratory of the School of Engineering and Technology at the University of Hertfordshire. This tunnel has a working section of 480 mm diameter. A fan driven by an electric motor provides close control of air velocity up to a maximum of approximately (90-100) mph (40-45 m/s).

Instrumentation
The average air velocity was obtained from calibrated pressure measurements built into the tunnel. An independent check of the air velocity local to the test region was made using a hand held pitot-static tube and an Airflow PVM100 micro-manometer. The results of this velocity check showed a variation between the two measured wind speeds of less than 5% for the full range of airspeeds up to the current maximum tunnel capability of 90mph.

Test Layout.



Mat Test Sample Size

In order to fit within the tunnel working section the mats were cut to a length of 1222mm (4 feet). The mat test sample width was 462mm.

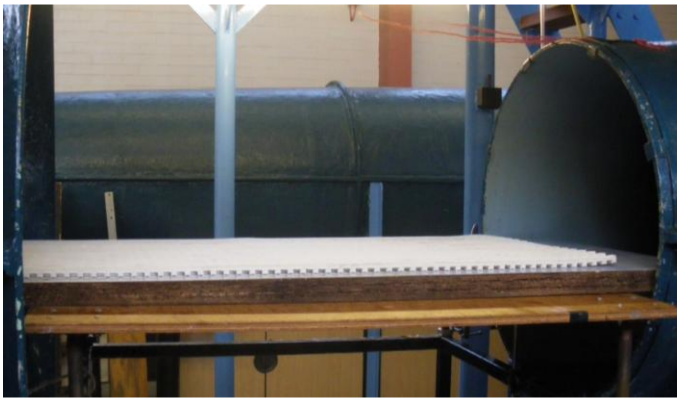
Roof Surface

In previous testing (2004), the mats were supported on either a smooth ground-board or on a ground-board covered with roofing felt. No sliding movement of the mats was observed on any surface and there was no apparent relationship between the surface finish of the ground-board and mat lift-off wind-speed.

Unless the roofing felt is fully bonded to the ground-board then wind penetrating the ground-board to roofing felt interface can itself set up lifting forces on the mat. Hence for this series of testing, a smooth surface wooden ground-board was used. There was no observed sliding movement of the mats relative to the ground-board during these tests.

Test Procedure

The mat was placed in the tunnel in two orientations; with the support bars running parallel and perpendicular to the air flow.



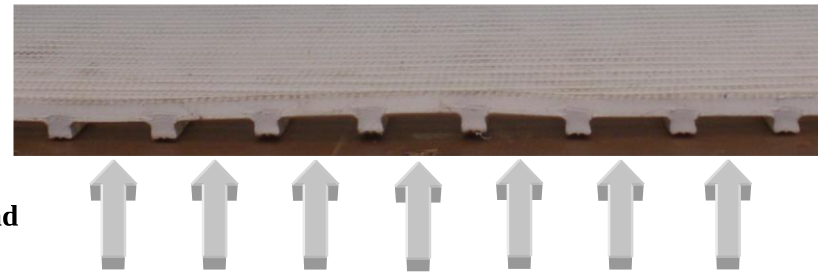
The wind speed was gradually increased until the mat lifted from the surface. This speed was recorded and video pictures taken of the event.

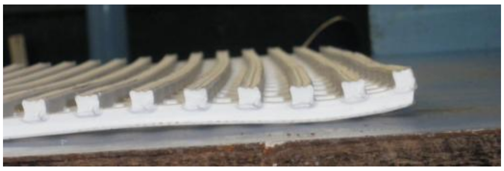
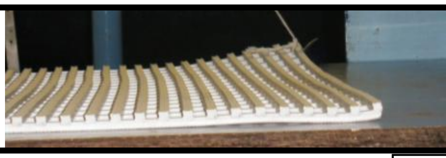
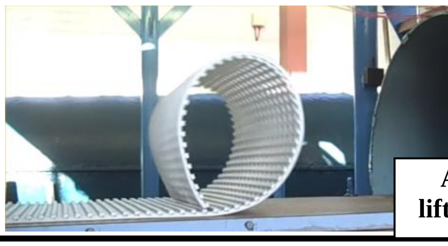
Testing was also performed with the leading edge of the mat raised slightly from the ground board, by soft attachment to the upper frame of the tunnel, to simulate possible installation scenarios. The mat was also tested in a partly rolled back arrangement.

Some of the test arrangements were repeated to confirm the mat lift-off wind-speeds.

Results 1

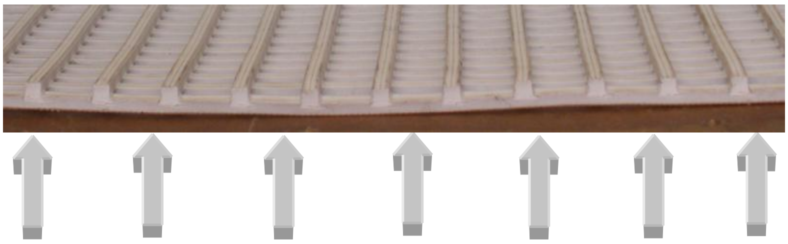
Mat orientated such that the transverse bars are on top and the channels between the longitudinal support bars are exposed to the wind

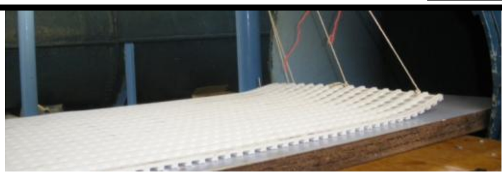
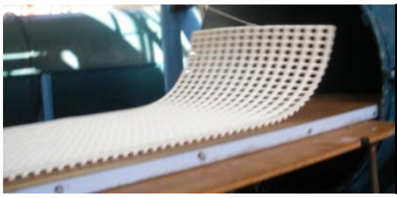
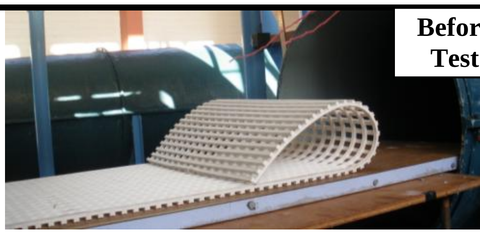
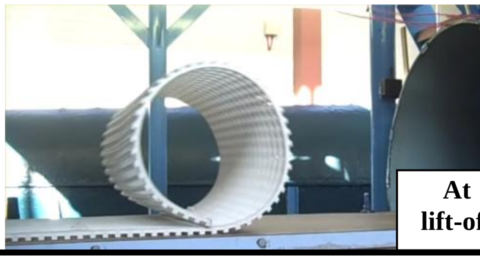


	Arrangement	Wind-Speed at mat lift		Photo of Test Arrangement
		m/s	mph	
1.0	Flat	**Did not lift** up to max tunnel wind-speed		
		39.6 40.3 38.8 39.1		
	Average	**39.5**	**88.3**	
1.1	Full width of mat leading edge raised by ~25mm from ground board	**17.1**	**38.3**	 **Before Test**  **At lift-off**
1.2	Leading edge of mat raised by ~25mm from ground board at a single local central position.	**Did not lift** up to max tunnel wind-speed.		 **Before Test**
		38.6 38.7	86.4 86.6	
	Average	**38.65**	**86.5**	
1.3	Leading edge of mat raised by ~50mm from ground board at a single local central position	**18.4**	**41.2**	 **At lift-off**
1.4	Leading edge of mat raised by ~75mm from ground board at a single local central position	**13.5**	**30.2**	
1.5	Corner of mat leading edge raised by ~25mm from ground board.	22.7 22.4		
	Average	**22.5**	**50.4**	
1.6	Mat partially rolled back	**16.0**	**35.7**	 **Before Test**  **At lift-off**

Results 2

Mat orientated such that solid surface of the transverse support bar is exposed to the wind



	Arrangement	Wind Speed at mat lift (m/s)	Wind Speed at mat lift (mph)	Photo of Test Arrangement
2.0	Flat	**Did not lift** up to max tunnel wind-speed		 **No lift-off**
		39.4 39.2 39.8		
	Average	**39.5**	**88.3**	
	Flat with residual curl? Mats stored and tested 'flat' soon after being delivered in a rolled up condition.	23.4 22.6 24.7		 **At lift-off**
	Average	**23.6**	**52.8**	
2.1	Full width of mat leading edge raised by ~25mm from ground board.	14.5 14.4 14.6 14.3		
	Average	**14.5**	**32.3**	
2.2	Leading edge of mat raised by ~25mm from ground board at a single local central position	18.0 19.9	40.3	 **Before Test**
	Average	**18.9**	**42.4**	
2.3	Leading edge of mat raised by ~50mm from ground board at a single local central position	**15.2**	**34.1**	 **At lift-off**
2.4	Leading edge of mat raised by ~75mm from ground board at a single local central position	**13.4**	**30.0**	
2.5	Corner of mat leading edge raised by ~25mm from ground board	18.4 19.5 18.0		
	Average	**18.6**	**41.7**	
2.6	Mat partially rolled back	**13.0**	**29.0**	 **Before Test**  **At lift-off**

Conclusions from Testing of Crossgrip TPO Walkway Matting

Wind Speed Range	Lift mph	Mat Behaviour
Higher than 83 mph	NO	Mat placed flat on surface with transverse bars positioned downwards did not slide or lift when exposed to max tunnel wind speed of **88 mph**
	NO	Mat placed flat on surface with transverse bars positioned downwards did not slide or lift when exposed to max tunnel wind speed of **88 mph** (* below)
	NO	Mat with transverse bars positioned upwards and whole leading edge raised by 25mm above surface did not slide or lift when exposed to max tunnel wind speed of **86 mph.**
Hurricane: Force 12 73 – 83 mph		
Violent Storm: Force 11 64 – 72 mph		
Storm: Force 10 55 – 63 mph		
Severe Gale: Force 9 47 – 54 mph	53	* Lifting of flat mat placed flat on surface with transverse bars positioned downwards. (possible initial mat leading edge curvature)
	50	Lifting of mat with transverse bars positioned upwards and leading edge corner raised by 25mm above surface.
Gale: Force 8 39 – 46 mph	42	Lifting of mat with transverse bars positioned downwards and leading edge initially raised ~ 25mm above surface at a single central position.
		Lifting of mat with transverse bars positioned downwards and leading edge corner raised by 25mm above surface.
	41	Lifting of mat with transverse bars positioned upwards and leading edge initially raised ~ 50mm above surface at a single central position
Near Gale: Force 7 32 – 38 mph	38	Lifting of mat with transverse bars positioned upwards and whole leading edge raised by 25mm above surface.
	36	Lifting of partially rolled mat with transverse bars positioned upwards.
	34	Lifting of mat with transverse bars positioned downwards and leading edge initially raised ~ 50mm above surface at a single central position.
	32	Lifting of mat with transverse bars positioned downwards and whole leading edge raised by 25mm above surface.
Force 0 – 6 Calm to Strong Breeze 0 – 31 mph	30	Lifting of mat with transverse bars positioned downwards and leading edge initially raised ~ 75mm above surface at a single central position.
	29	Lifting of partially rolled mat with transverse bars positioned downwards.

Overall Conclusions

When positioned completely flat on a surface, the mat samples tested withstood a wind-speed of at least 88 mph without lifting completely from the surface.

Any distortion of the mat resulting in an initial raising of the leading edge (into the wind) resulted in a significant reduction in the wind-speed at which the mat lifted from the surface.