University of Hertfordshire

School of Aerospace, Automotive & Design Engineering

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Wind Tunnel Testing of Crossgrip Roof Walkway Matting

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For: Plastic Extruders Ltd
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Wind Tunnel Testing of Roof Walkway Mats

Introduction

The aim of this test program is to ascertain the effects of high wind speeds on Plastex Crossgrip roof walkway mats; in particular to establish at what 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. The inclusion of this information in this report helps to relate the wind speeds at which the mats were tested to real weather conditions.

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.

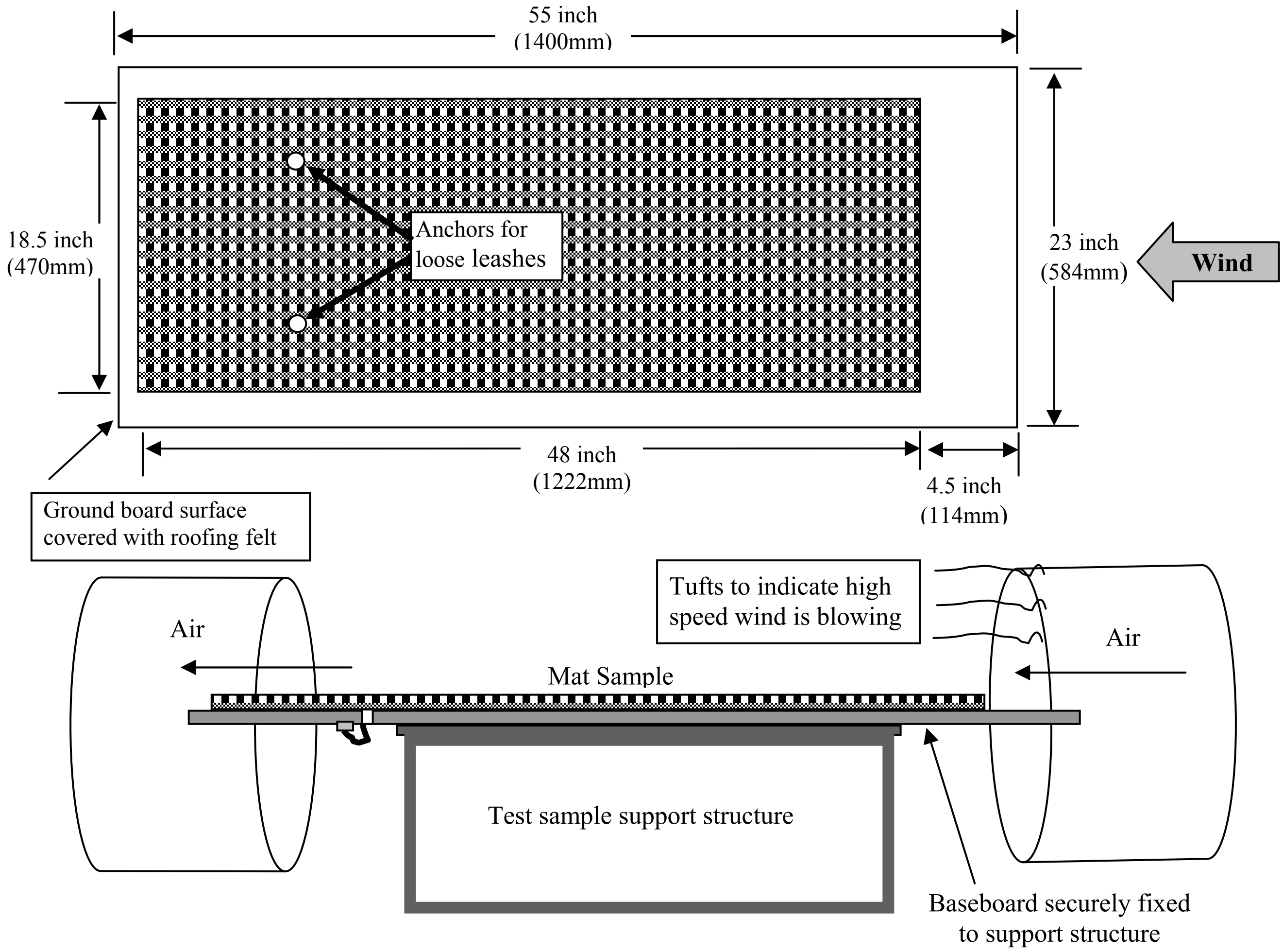
Test Equipment

The testing was carried out using the open return wind tunnel in the aerodynamics laboratory of the School of Aerospace Automotive and Design Engineering 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 100 mph (45 m/s).

Instrumentation

The air velocity was measured using calibrated pressure tappings built into the tunnel. An independent check of the velocity measurement was made using a hand held pitot-static tube and an Airflow PVM100 micromanometer. The results of this velocity check showed a variation between the two measured wind speeds of less than 2% over the range 25mph – 100mph.

Test Layout.



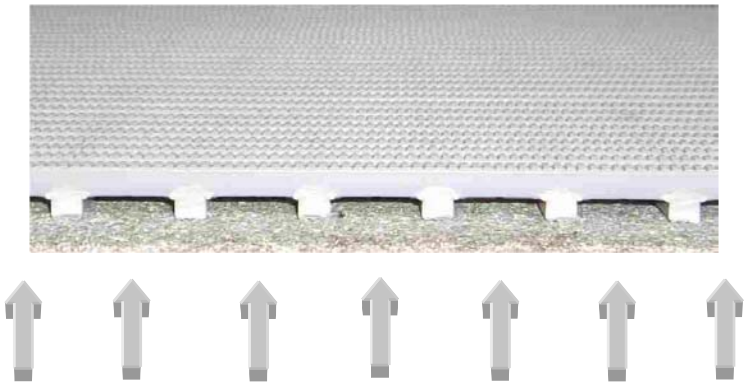
Mat Test Sample Size
In order to fit within the tunnel working section the mats were cut to a length of 1222mm (4 feet). For the testing of mats supported by the bars running parallel to the air flow the test sample width was 475mm. For the testing of mats supported by the bars running perpendicular to the air flow the test sample width was 470mm. This small difference is due to the mats being cut adjacent to a bar.

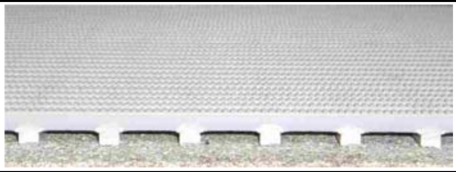
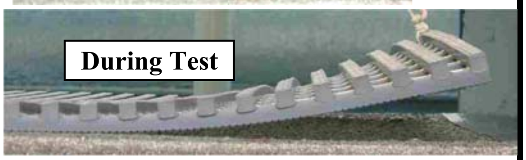
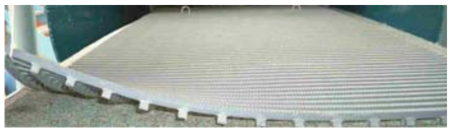
Roof Surface
The ground board supporting the mats was covered with standard roofing felt. However, to ascertain if surface finish was significant, some testing was performed on a smooth-surfaced plywood ground board.

Test Procedure
The mat was placed in the tunnel in two orientations; with the support bars running parallel and perpendicular to the air flow. Testing was also performed with the leading edge of the mat raised slightly from the ground board, by wire support from the upper frame of the tunnel, to simulate possible installation scenarios. The mat was also tested in a partly rolled back arrangement. The wind speed was gradually increased until the mat lifted from the surface. This speed was recorded and some video footage was taken of the event. A selection of the test arrangements were repeated to confirm the values for the mat lift-off speeds.

Results 1

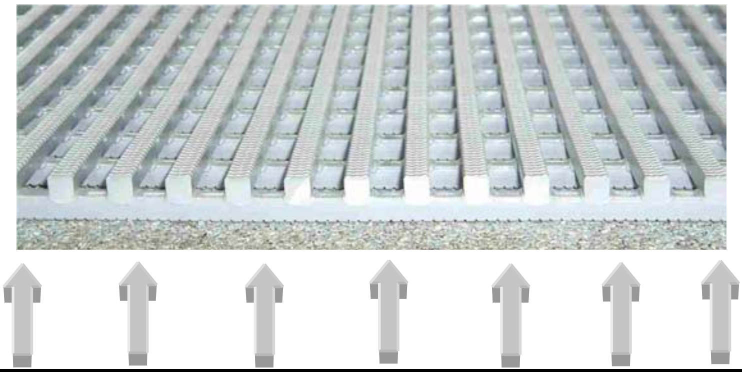
Mat orientated such that channels between support bars are exposed to the wind

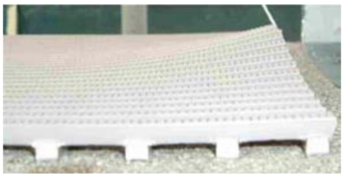
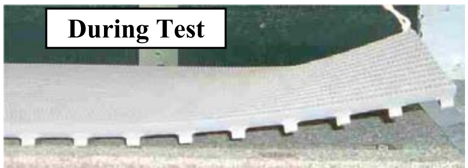


	Arrangement	**Wind Speed at mat lift**		**Photo of Test Arrangement**
		m/s	**mph**	
1.0	Flat	41 42.7		
	Average	**41.9**	**93.6**	
1.1	Leading edge of mat raised by ~25mm (~1 inch) from ground board at a single local central position	25.9 26.0		
		26.0	**58.1**	
1.2	Leading edge of mat raised by ~25mm (~1 inch) from ground board at a single local central position Simulated gust 20-55 mph in 5 seconds	**26.0**	**58.1**	 **Before Test**
1.3	Leading edge of mat raised by ~51mm (~2 inch) from ground board at a single local central position	**20.5**	**45.9**	
1.4	Leading edge of mat raised by ~76mm (~3 inch) from ground board at a single local central position	**18.9**	**42.2**	
1.5	Whole of mat leading edge raised by ~25mm (~1 inch) from ground board	**22.8**	**51.1**	
1.6	Whole of mat leading edge raised by ~51mm (~2 inch) from ground board	**20.5**	**45.9**	
1.7	Corner of mat leading edge raised by ~64mm (~2.5 inch) from ground board	**26.3**	**58.7**	
1.8	Mat partially rolled back	**19.8**	**44.2**	
1.9	Flat on a smooth surface ground board	**> 45**	**> 100**	

Results 2

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



	Arrangement	Wind Speed at mat lift		Photo of Test Arrangement
		m/s	**mph**	
2.0	Flat	> 45 > 45		
	Average	**> 45**	**> 100**	
2.1	Leading edge of mat raised by ~25mm (~1 inch) from ground board at a single local central position	36.2 36.2	81.0	
		36.2	**81.0**	
2.2	Leading edge of mat raised by ~51mm (~2 inch) from ground board at a single local central position	**29.9**	**66.8**	 **Before Test**
2.3	Leading edge of mat raised by ~76mm (~3 inch) from ground board at a single local central position	**24.3**	**54.2**	
2.4	Whole of mat leading edge raised by ~25mm (~1 inch) from ground board	**33.0**	**73.9**	
2.7	Corner of mat leading edge raised by ~64mm (~2.5 inch) from ground board	**36.2**	**81.0**	
2.8	Mat partially rolled back	15.4 18.4		
	Average	**16.9**	**37.8**	
2.9	Flat on a smooth surface ground board	**> 45**	**> 100**	

Discussion of Results

The results showed a consistent trend with good repeatability.

For the mat placed on either a flat standard roofing felt surface, with a natural roughness or a flat smooth surface, with the solid surface of the support bars exposed to the wind direction the mat did not slide or lift for the full wind speed range of the tunnel, which was just in excess of 100mph. However, at 100 mph the leading edge of the mat exhibited some small, (a few mm) vertical oscillations.

For the mat placed on a flat smooth surface with the channels formed by the support bars parallel to the wind direction the mat did not slide or lift for the full wind speed range of the tunnel which was just in excess of 100mph.

For the mat placed on a flat standard roofing felt surface, with a natural roughness, with the channels formed by the support bars parallel to the wind direction the lift-off point was very sudden and preceded only by a slight twitching and lifting of the mat leading edge. This result was confirmed by repeat testing. It is likely that small flow perturbations and boundary layer development caused by the surface roughness of the ground board are sufficient to cause small amounts of lifting of the mat leading edge into the incident airflow which then lead very rapidly to lift-off of the whole mat.

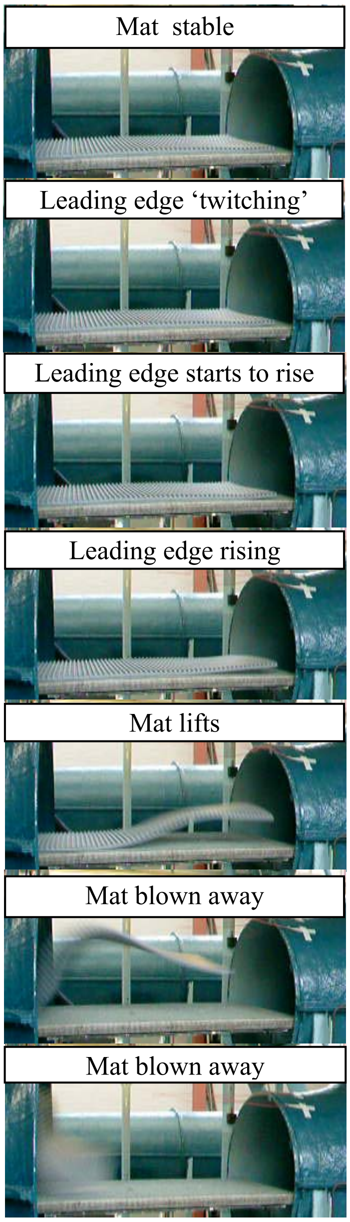
For all arrangements where any part of the leading edge of the mat was lifted then the speed at which total lift-off of the mat occurred was generally a function of the amount of initial leading edge distortion away from the ground board.

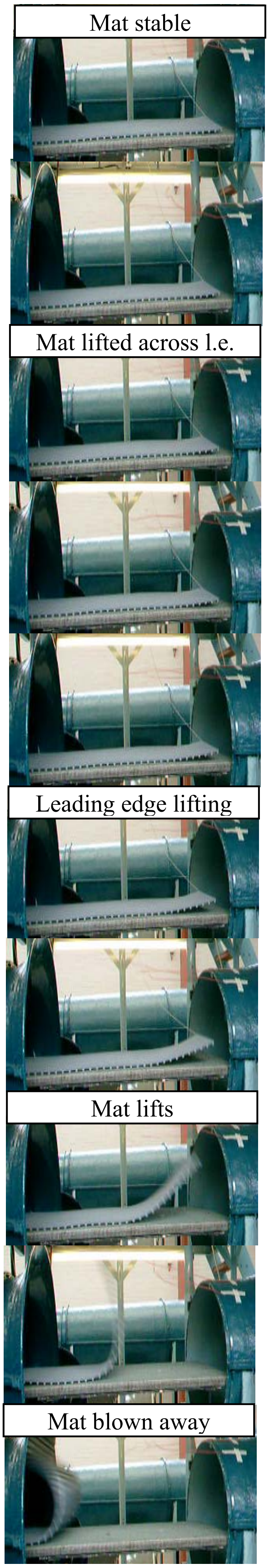
For the arrangement where the leading edge of the mat was lifted locally, the whole of the leading edge lifted with increasing wind speed and attained a state of lift – weight balance prior to complete mat lift-off. The lift off speed was similar for both the roofing felt and smooth ground board surfaces.

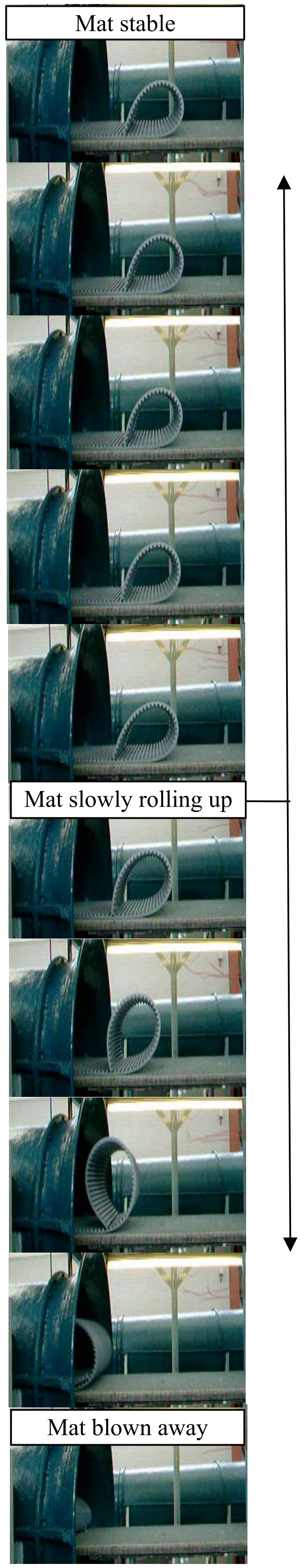
For the partially rolled up mat arrangement the lift-off speed was relatively low with the gradual lift process preceded by a rocking of the rolled mat.

The following table shows some still frames from the videos of the mat lifting away from the ground board.

Video Sequence for Mat Lifting. Frame duration = 100ms. (Every 2nd frame shown for rolled up mat)		
Flat mat on rough surface	**Mat lifted locally at leading edge**	**Partially rolled up mat**
Time from stable to total lift-off ~ 7 frames = 0.7 seconds.	Time from stable to total lift-off ~ 10 frames = 1 second.	Time from stable to total lift-off ~ 20 frames = 2 seconds.







Conclusions

Wind Speed Range	Lift mph	Mat Behaviour
	>100	Mat with support bar facing into flow did not slide or lift when placed flat on smooth or rough surfaces *
		Mat with support bar channels facing into flow did not slide or lift when placed flat on a smooth surface
	94	Lifting of flat mat placed on rough roofing felt surface with support bar channels facing into flow
Force 12 Hurricane 73 – 83 mph	81	Lifting of mat with support bar facing into flow with leading edge corner raised locally by 64mm
	81	Lifting of mat with support bar facing into flow, with leading edge raised locally by 25mm, on smooth or rough surfaces.
	74	Lifting of mat with support bar facing into flow with whole leading edge raised by 25mm on smooth or rough surfaces.
Force 11 Violent Storm 64 – 72 mph	67	Lifting of mat with support bar facing into flow with leading edge raised locally by 51mm on smooth or rough surfaces
Force 10 Storm 55 – 63 mph	59	Lifting of mat with channels facing into flow with leading edge corner raised locally by 64mm.
	58	Lifting of mat with channels facing into flow, with leading edge raised locally by 25mm, on smooth or rough surfaces. Similar result with slow (5 second) gust from 20 mph.
Force 9 Severe Gale 47 – 54 mph	54	Lifting of mat with support bar facing into flow with leading edge raised locally by 76mm on smooth or rough surfaces.
	51	Lifting of mat with channels facing into flow with whole leading edge raised by 25mm on smooth or rough surfaces.
Force 8 Gale 39 – 46 mph	46	Lifting of mat with channels facing into flow with leading edge raised by 50mm, locally and across whole leading edge on smooth or rough surfaces
	44	Lifting of partially rolled mat with support bar facing into flow
	42	Lifting of mat with channels facing into flow with leading edge raised locally by 76mm on smooth or rough surfaces.
Force 7 Near Gale 32 – 38 mph	38	Lifting of partially rolled mat with channels facing into flow
Force 0 – 6 Calm to Strong Breeze 0 – 31 mph		All mat arrangements unaffected on smooth or rough surfaces.

** for all tests, rough surface = standard roofing felt.*