Loughborough University Enterprises Limited

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Project **Laboratory Experimental Investigation of "Sport Surfaces Wear" from Mechanical Brushing**

FINAL REPORT OF FINDINGS

Project No **5940/CV/TSL**

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Client **Technical Surfaces Limited**

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1.0 Introduction

This report details the findings and measurements of the research consultancy work carried out for Technical Surfaces, by Loughborough University at the Sports Technology Institute, during the period April to June 2009. The consultant was Dr Paul Fleming. The work was carried out in accordance with the agreed brief,

The brief was:

Aim: To assess the effect of brushing on the wear of synthetic sport carpet systems

Objectives and Tasks

1. To develop a test method to replicate the mechanical rotating brushes used on site, in a laboratory environment
2. To utilise the test method to carry out a programme of tests on a series of carpet systems and with different brushes
3. To measure the wear over a number of cycles of application of the brush
4. To report the findings in a short summary report form

The preliminary meetings identified three brush types for testing, and three types of carpet. The specifications for the test procedure (including rotation speed, brush head ground speed, depth of brush embedment into the surface under test, direction of rotation, brush size – diameter and application width.) were also agreed during initial trials.

This set of three carpets three brush types have been termed Phase 1, in accordance with the agreed contract brief. It is believed that further testing in future may be required by the Client to investigate the range of carpet systems and brushes (Phase II). Future testing will benefit from the completed manufacture of the laboratory mechanical test method mounted onto the Fanuc robot in the Sports Technology Institute.

Note: The contract stated that the Client is willing to grant permission to publish the findings, with permission regarding the use of trade names etc.

In addition, the contract also stated that the rig was developed and is owned by Loughborough University, but will be readily available for future testing for the Client for a period of 6 months after completion of this programme of work. If no further testing is commissioned the University reserve the right to reuse any parts.

Section 2 provides the programme of testing and methods utilised. Section 3 presents the results in summary form, with conclusions.

2.0 Programme of Testing Carried Out

The programme of testing incorporated the following tasks

1. Develop suitable motorised unit to affix brush attachment – this to be suspended from the Fanuc robot arm in the STI. (Design and construction carried out by the client)
2. Make up sport surface system samples, adjacent to the robot unit, for testing (Client supplied all raw materials including carpet samples and infill. The Consultant resourced the filling of the systems ready for testing).
3. Cary out initial tests on pile length and infill height, as starting benchmark
4. Carry out the appropriate number of cycles of brush application to the carpet sample – to promote mechanical wear of the system.
5. During the cycles, the test was stopped periodically and the wear induced by the brushing was measured.
6. At the end of the test more detailed measurements of carpet pile length and infill height, and any change of state (e.g. splitting, fracture, loss etc) was assessed.

It should be noted that the carpet sample size was 1m long and 1m wide. However the test zone was the width of brushing, 450mm (brushes were cut to size by the Consultant), and approximately 900m length.

The visual assessment used comprised dividing the central part of the carpet into a 4 quadrant grid, and counting the number of fibres that either were curled over, (i.e. more so than in their initial untested state), fractured or split.
At end do final evaluation, photos etc

Each system test with each brush took between 1-2 days per test.

Samples were stored in their final state for the Client to view, and then removed by the Client.

The infill was installed dry, as close the manufacturers recommended weight per unit area as possible.

The infill moved during brushing, as expected, and some was returned to the sample to 'top up' similar to the field maintenance regime.

Photos were taken, where practicable, to provide supporting evidence of wear or lack of wear. See Appendix B. This included both the general surface and examples of worn/damaged fibres extracted. The photography technique comprised both general use of a 5 megapixel digital camera and also specialist macro-photography for close ups of the surfaces and damaged fibres (sub-contracted).

The Client attended the early test set up to confirm procedures, comment and observe the test running.

Table 1 below shows the summary of testing carried out, with specific details of the test set up for each system and brush.

Table 1. Summary of Phase I Testing Programme

Sample type/name	**Brush type**	**Speed/Depth of penetration (mm) – fixed**	**No. cycles* and intervals of measurement.**
Sand Dressed (Evolution)	Regular (Hard)	944 revs 4mph 2mm	0, 10, 50, 150, 250, 500, 1000
Sand Filled (Multiplay)	Regular (Hard)	944 revs 4mph 2mm	0, 10, 50, 150, 250, 500, 1000
Rubber Filled (Soccer 65mm)	Regular (Hard)	944 revs 4mph 2mm	0, 10, 50, 150, 250, 500, 1000
Sand Dressed (Evolution)	Regular (Soft)	944 revs 4mph 2mm	0, 10, 50, 150, 250, 500, 1000
Sand Filled (Multiplay)	Regular (Soft)	944 revs 4mph 2mm	0, 10, 50, 150, 250, 500, 1000
Rubber Filled (Soccer 65mm)	Regular (Soft)	944 revs 4mph 2mm	0, 10, 50, 150, 250, 500, 1000
Sand Dressed (Evolution)	Revite ®	708 revs 2mph 7mm	0, 9, 18, 36, 72, 144, 180
Sand Filled (Multiplay)	Revite ®	708 revs 2mph 7mm	0, 9, 18, 36, 72, 144, 180
Rubber filled (Soccer 65mm)	Revite ®	708 revs 2mph 7mm	0, 9, 18, 36, 72, 135, 180

Notes

* 1 Cycle = 2 passes of the brush in opposite directions of travel.

The cycles are equated to 'life' as follows.

Regular brushes- done weekly at 2 passes (maximum), so 0, 10, 50, 150, 250, 500, and 1000 cycles is equated to 0, 10, 50, weeks: 3, 5, 10, and 20 years approximately.

Revite ® brush - done approximately annually (1 visit, 18 passes at each visit), so 0, 9, 18, 36, 72, 135 and 180 cycles is equated to 0, 1, 2, 4, 8, 15, and 20 years

3. Summary Results and Conclusions

Appendix 1 presents the detailed measurements made on each system, including the observed wear/damage at each interval of cycles. It should be noted that these data are cumulative, so that the numbers are the total number of fibres identified as worn/damaged at each cycle interval.

The data have been simply summarised in Table 2 below, that shows the cumulative total of 'damage' by summing the splits and breaks (bends are not included).

To assist in assessing the extent of the wear, the number of fibres within the measurement zone has been estimated based on the carpet manufacturers detailed specification for each system.

The summary results clearly show the low level of wear that was observed to be caused by the brushing alone. The life of 20 years was used to represent a period of time longer than most artificial pitches surfaces survive in practice. In reality, the effects of surface usage for playing the sport or training (at Loughborough University for example the total usage is around 50-65 per week on the soccer/rugby surfaces), and environmental effects (sun, rain, ice etc) are considered to be the main contributors to wear. A 3G soccer pitch may last only 3-7 years at this high level of use, for example.

It is thus considered that this study has shown that the contribution of maintenance brushing related wear is insignificant in comparison to the wear expected from the surface use and the exposure to the environment.

Table 2 – Summary results

CARPET	BRUSH	Passes	Life (est. YRS)	No. Fibres Affected By wear (total)	No. Fibres per measured area	Wear Extent As a %	Wear Extent Ratio
SOCCER 65	REGULAR S	2000	20	103	9253	1.11	1 in 100
EVOLUTION	REGULAR S	2000	20	46	44906	0.10	1 in 1000
MULTIPLAY	REGULAR S	2000	20	49	8573	0.29	3 in 1000
SOCCER 65	REGULAR H	2000	20	115	9253	1.24	1 in 100
EVOLUTION	REGULAR H	2000	20	118	44906	0.26	3 in 1000
MULTIPLAY	REGULAR H	2000	20	135	8573	0.79	8 in 1000
SOCCER 65	REVITE ®	720	20	145	9253	1.57	2 in 100
EVOLUTION	REVITE ®	720	20	195	44906	0.43	4 in 1000
MULTIPLAY	REVITE ®	720	20	98	8573	0.57	6 in 1000

Note: The calculation of the number of fibres per measured area is detailed in Appendix 3. H = Hard, S = soft.

In conclusion:

The brush testing programme permitted the control of variables such that the wear caused by brushing alone, over a 20 year life simulation, was successfully achieved.

The detailed data, measured at intervals of cycles, permits the monitoring of the progressive accumulation of wear.

The level of wear caused by the brushes is considered to be very low (relative to other wear factors such as usage).

The longer pile carpet, Soccer 65, was the most affected of the carpet systems by the brushing.

The 'Revite ®' brush caused the most wear – despite the fewer cycles applied. This is considered as a result of the combined effects of the brush bristle stiffness and the higher depth of penetration relative to the other brushes.
The 'Regular' Hard brush caused slightly more wear than the 'soft' brush.

In regard to fibre wear, this was measured as breaks and splits in particular, although 'bends' were also measured.

No evidence of fibre shortening was apparent from the testing programme.

The photos provide supporting evidence of the nature of the 'wear' observed.

APPENDIX 1 – Detailed Data Tables of all carpet samples and brushes

Thursday 30th April
Soccer 65
Regular Soft

Initial Measurements

Soccer 65 – 1							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
66	66	66	67	64	64	63	63
67	66	67	67	63	64	63	64
67	66	67	67	65	65	64	65

Name	Cycle	Total Cycle	Description	Quadrant			
				1	2	3	4
Soccer 65	0	0	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	10	10	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	40	50	Breaks	1	1	1	2
			Splits	1	0	3	1
			Bends	0	1	1	2
	100	150	Breaks	2	4	4	5
			Splits	3	1	7	3
			Bends	0	2	2	5
	100	250	Breaks	3	7	8	9
			Splits	4	2	11	5
			Bends	3	3	3	10
	250	500	Breaks	4	10	12	13
			Splits	6	3	16	8
			Bends	7	5	4	15
	500	1000	Breaks	6	15	17	18
			Splits	8	4	21	14
			Bends	10	7	5	20

Final Measurements

Soccer 65-1							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
66	65	65	65	62	62	61	62
65	66	65	66	62	62	63	62
65	65	64	65	61	62	62	63

Tuesday 5th th May
Multi play 24
Regular Soft

Initial Measurements

Multi Play 24 - 1							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
26	25	26	25	24	23	24	23
25	25	26	25	24	23	23	23
25	25	26	25	24	24	24	23

Name	Cycle	Total Cycle	Description	Quadrant			
				1	2	3	4
Multi Play 24	0	0	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	10	10	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	40	50	Breaks	0	0	1	0
			Splits	2	2	1	1
			Bends	1	1	2	0
	100	150	Breaks	0	0	2	0
			Splits	4	3	3	4
			Bends	1	2	3	2
	100	250	Breaks	0	0	3	1
			Splits	6	6	5	7
			Bends	3	3	3	3
	250	500	Breaks	2	0	3	1
			Splits	8	9	6	9
			Bends	4	4	5	6
	500	1000	Breaks	3	0	3	2
			Splits	10	12	7	12
			Bends	5	5	6	8

Final Measurements

Multi Play 24 - 1							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
26	24	24	26	20	21	20	20
25	26	25	25	19	20	21	20
25	26	25	25	20	20	21	20

Thursday 7th May
Evolution
Regular Soft

Initial Measurements

Evolution - 1							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
20	20	19	20	17	18	18	18
20	20	19	20	17	17	18	18
20	20	20	20	18	18	18	18

Name	Cycle	Total Cycle	Description	Quadrant			
				1	2	3	4
Evolution	0	0	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	10	10	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	40	50	Breaks	0	0	0	1
			Splits	0	0	1	1
			Bends	0	0	0	0
	100	150	Breaks	2	4	1	2
			Splits	1	1	4	2
			Bends	0	1	0	1
	100	250	Breaks	3	7	3	4
			Splits	2	3	4	3
			Bends	0	1	0	1
	250	500	Breaks	4	9	5	6
			Splits	2	4	4	3
			Bends	0	1	0	1
	500	1000	Breaks	5	12	6	7
			Splits	2	6	5	3
			Bends	0	1	0	1

Final Measurements

Evolution - 1							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
20	19	20	20	15	14	15	14
20	19	19	20	14	13	15	15
20	20	20	18	14	15	15	14

Tuesday 12th May
Soccer 65
Regular Hard

Initial Measurements

Soccer 65 - 2							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
67	66	67	67	65	65	65	65
67	67	66	67	65	64	65	64
67	67	67	67	65	64	65	65

Name	Cycle	Total Cycle	Description	Quadrant			
				1	2	3	4
Soccer 65	0	0	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	10	10	Breaks	2	0	1	1
			Splits	2	3	1	1
			Bends	0	0	1	0
	40	50	Breaks	3	2	2	3
			Splits	4	4	2	3
			Bends	0	0	2	1
	100	150	Breaks	4	3	5	5
			Splits	11	9	5	7
			Bends	1	2	4	3
	100	250	Breaks	6	4	5	7
			Splits	5	14	8	10
			Bends	2	3	6	3
	250	500	Breaks	8	6	8	10
			Splits	8	18	12	15
			Bends	3	3	7	5
	500	1000	Breaks	10	9	11	12
			Splits	12	21	18	22
			Bends	4	4	9	8

Final Measurements

Soccer 65 - 2							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
66	66	67	67	62	63	62	61
66	66	67	67	61	62	63	62
67	67	66	67	62	62	62	62

Friday 15th May
Multi Play 24
Regular Hard

Initial Measurements

Multiplay 24 – 2							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
26	25	26	26	24	24	24	24
26	26	25	26	23	24	24	24
26	26	25	26	24	24	23	24

Name	Cycle	Total Cycle	Description	Quadrant			
				1	2	3	4
Multiplay 24	0	0	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	10	10	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	40	50	Breaks	1	2	2	1
			Splits	3	5	3	5
			Bends	1	1	0	0
	100	150	Breaks	2	5	6	6
			Splits	6	6	7	11
			Bends	4	3	2	1
	100	250	Breaks	5	9	8	11
			Splits	11	9	13	18
			Bends	6	4	4	3
	250	500	Breaks	9	12	10	13
			Splits	14	11	17	21
			Bends	9	6	6	6
	500	1000	Breaks	11	15	13	18
			Splits	18	15	22	23
			Bends	11	9	7	7

Final Measurements

Multi Play 24 - 2							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
25	26	25	26	21	21	19	21
25	25	26	26	22	20	22	22
24	26	26	26	20	20	22	21

Wednesday 20th May
Evolution
Regular Hard

Initial Measurements

Evolution - 2							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
20	20	20	20	18	18	17	18
21	20	20	20	16	18	18	18
20	20	20	21	16	18	18	18

Name	Cycle	Total Cycle	Description	Quadrant			
				1	2	3	4
Evolution	0	0	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	10	10	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	40	50	Breaks	2	2	1	3
			Splits	2	3	3	3
			Bends	0	0	1	1
	100	150	Breaks	5	5	4	5
			Splits	5	7	7	5
			Bends	1	0	2	1
	100	250	Breaks	8	7	6	8
			Splits	8	11	9	8
			Bends	3	1	4	3
	250	500	Breaks	11	9	9	10
			Splits	12	14	11	10
			Bends	4	4	5	5
	500	1000	Breaks	15	12	13	15
			Splits	16	18	14	15
			Bends	5	4	7	5

Final Measurements

Evolution - 2							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
20	19	20	19	14	13	15	14
19	19	20	20	15	15	15	15
20	20	20	20	15	15	13	14

Friday 22nd May
Soccer 65
Revite ®

Initial Measurements

Soccer 65 - 3							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
67	67	66	66	65	65	64	65
67	67	67	67	65	64	64	65
67	67	66	66	65	64	64	65

Name	Cycle	Total Cycle	Description	Quadrant			
				1	2	3	4
Soccer 65	0	0	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	9	9	Breaks	2	1	4	4
			Splits	3	3	3	4
			Bends	1	2	1	1
	9	18	Breaks	4	4	8	7
			Splits	5	5	7	6
			Bends	1	4	3	4
	18	36	Breaks	7	6	12	11
			Splits	10	10	10	8
			Bends	3	7	6	6
	36	72	Breaks	9	7	16	13
			Splits	13	13	12	10
			Bends	5	10	18	15
	63	135	Breaks	12	9	19	17
			Splits	18	17	16	13
			Bends	7	11	19	16
	45	180	Breaks	15	11	21	21
			Splits	21	21	19	16
			Bends	8	13	21	17

Final Measurements

Soccer 65 - 3							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
67	65	67	66	61	62	60	60
64	67	67	65	60	61	61	60
64	64	65	66	60	61	62	60

Thursday 28th May
Multiplay 24
Revite ®

Initial Measurements

Multiplay 24 - 3							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
26	26	24	26	23	24	23	24
26	25	26	25	24	23	24	24
26	26	26	25	22	23	24	24

Name	Cycle	Total Cycle	Description	Quadrant			
				1	2	3	4
Multiplay 24	0	0	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	9	9	Breaks	1	2	1	1
			Splits	2	2	1	1
			Bends	0	0	0	0
	9	18	Breaks	3	3	3	2
			Splits	3	3	2	2
			Bends	0	1	0	1
	18	36	Breaks	5	4	4	2
			Splits	5	5	4	5
			Bends	1	2	0	2
	36	72	Breaks	7	5	5	4
			Splits	8	7	7	7
			Bends	2	2	1	3
	63	135	Breaks	10	8	7	7
			Splits	11	10	11	12
			Bends	3	3	3	4
	45	180	Breaks	13	10	8	10
			Splits	15	14	14	14
			Bends	4	4	4	5

Final Measurements

Multi Play 24 - 3							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
26	25	26	25	21	22	20	22
26	26	26	25	20	21	21	20
25	26	26	26	20	21	21	20

Thursday 28th May
Evolution
Revite ®

Initial Measurements

Evolution - 3							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
20	20	20	20	18	17	18	18
20	20	20	20	18	18	18	18
20	20	19	20	18	18	18	18

Name	Cycle	Total Cycle	Description	Quadrant			
				1	2	3	4
Evolution	0	0	Breaks	0	0	0	0
			Splits	0	0	0	0
			Bends	0	0	0	0
	9	9	Breaks	4	7	4	3
			Splits	5	6	4	5
			Bends	1	2	1	1
	9	18	Breaks	6	9	7	6
			Splits	9	9	7	10
			Bends	2	3	2	1
	18	36	Breaks	9	11	10	8
			Splits	14	13	10	16
			Bends	3	3	3	2
	36	72	Breaks	12	14	14	13
			Splits	21	21	16	25
			Bends	4	4	5	3
	63	135	Breaks	15	18	18	17
			Splits	25	25	21	31
			Bends	5	5	5	3
	45	180	Breaks	21	21	20	21
			Splits	27	28	23	34
			Bends	5	6	8	4

Final Measurements

Evolution - 3							
Measurement to Top of the Fibre				Measurement to Top of the Infill			
Quadrant				Quadrant			
1	2	3	4	1	2	3	4
19	18	18	20	15	15	16	15
18	18	19	18	16	16	16	15
20	19	18	20	16	16	16	16

APPENDIX 2 – Selected Photos of carpet 'wear' during brush testing

These comprise photos of set up and general state with a standard digital camera, and close up macro photography with a special lens and lighting

(more are provided on the memory stick)

Soccer 65 – Regular Soft Brush – 500 cycles. Note break in fibre top left

Soccer 65 – Revite ® Brush, 180 cycles. Note split.

Multiplay 24 – Regular soft brush 1000 cycles.

Evolution – Regular hard brush – 10 cycles. Note fibre pulling out.

APPENDIX 3 – Analysis of the number of fibres in the measurement area, for each carpet system

Table Appendix 3 – Analysis of Fibres in the measurement area

Carpet Type			per m	stitches	fibres	fibres total	Fibres In
	pile weight (g/m^2)	Tufts/ m^2	stitch rate	/ m^2	/tuft	/ m^2	4 quads
Multiplay 24	**1100**	**44100**	**210**	**22050**	**12**	**529200**	**17146**
Dtex 8800							
Evolution	**1650**	**115500**	**275**	**57750**	**12**	**1386000**	**44906**
Dtex 6600							
Soccer 65	**1700**	**17850**	**170**	**8925**	**16**	**285600**	**9253**
Dtex 13200							

Note: Multiplay is 2 wide tape fibres per tuft, however as it is fibrillated there is consistently slits made that result in 6 smaller width apparent fibres per wide tape, making 12 fibres per tuft.

Total number of fibres (per square metre) = fibres per tuft multiplied by tufts/m^2. The approximate area of the 4 quadrants together is 180mm by 180mm = 0.032 m^2. Thus the number of fibres within the measurement zone is the product of Tufts/ m^2 * fibres/tuft * 0.032.