RESULTS OF PHYSICAL WORKSHOP

1st Australian Runway and Roads Friction Testing Workshop

By :

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1.0 INTRODUCTION

In the week of the 5 August 2003, Sydney Airport Corporation held a workshop on friction or "skid" testing for both airports and roads authorities.

The workshop had two components, a day of presentations and a two day physical workshop.

The following is a record of the results of the physical workshop.

2.0 FRICTION/TEXTURE EQUIPMENT USED AT WORKSHOP

The list of equipment used at the Workshop was extensive. It included three types of Continuous Friction Measurement Equipment (CFME), a Laser texture profilometer and the static testers, the CT Meter and DF Tester.

Below is a list of equipment and owners ;

Table 1

No.	Owner	Equipment Type
1	NSW RTA	SCRIM
2	GeoPave	SCRIM
3	Emoleum Road Services	GripTester
4	Sydney Airport	GripTester
5	Fulton Hogan (NZ)	GripTester
6	Auckland University (NZ)	GripTester
7	Transport SA	GripTester
8	ARRB	ROAR
9	Main Roads Qld	ROAR
10	PMS	ROAR
11	PMS	Laser Texture Profilometer
12	Nippo Sangyo (Japan)	CT Meter
13	Nippo Sangyo (Japan)	DF Tester

To ensure privacy for testers at the workshop, the results of any machine used at this workshop will only be published by generic number and will not identify the owner.

3.0 OBJECTIVES OF THE WORKSHOP

The objectives of the workshop included;

1. Obtain better understanding of different friction measurement procedures

2. Obtain better understanding of factors influencing tire/runway friction performance.

3. Provide opportunity for those unfamiliar with friction testing to observe testing and obtain background information

4. Perform parallel friction testing along SACL’s Calibration Strip with a number of different devices

4.0 SACL TEST PAVEMENTS

To facilitate this workshop, and future workshops, Sydney Airport has constructed a series of test pavements.

Each test pavement is one hundred metres long and each surface was constructed to be as homogeneous as possible.

A list of the test pavements are shown below in Table 2;

Table 2

CODE	SITE	LOCATION	WIDTH (M)	SURFACE DESCRIPTION
A-1	A	Rwy 0725	3.75	Stone Mastic Asphalt - 7 mm
A-2	A	Rwy 0725	3.75	Stone Mastic Asphalt – 10 mm
A-3	A	Rwy 0725	3.75	Dense Grade Asphalt – 10 mm
A-4	A	Rwy 0725	3.75	Dense Grade Asphalt – 10 mm grooved 38 x 6 x 6
R-1	A	Rwy 0725	3.75	ASPEN sealer
R-2	A	Rwy 0725	3.75	CARBONYTE sealer
R-3	A	Rwy 0725	3.75	Emulsion with Sand
R-4	A	Rwy 0725	3.75	Dense Grade Asphalt – 10 mm, no rejuvenation
MS-1	A	Rwy 0725	3.75	Cold Overlay 0-7 mm
MS-2	A	Rwy 0725	3.75	Cold Overlay 0-4 mm
C-1	B	Twy Hotel	3	Polished Concrete
C-2	B	Twy Hotel	3	Polished Concrete, grooved 38 x 6 x 6
C-3	B	Twy Hotel	3	Broomed Concrete
C-4	B	Twy Hotel	3	Broomed Concrete, grooved 38 x 6 x 6

A total of 14 test pavements have been constructed. These pavements were designed to represent the full spectrum of frictional surfaces ranging from low friction (polished concrete) to high friction (grooved/broomed concrete). The majority of the test pavements (10) are flexible pavement construction with the remaining located on concrete pavement.

Of particular interest are the concrete pavements, which are highly stable and are not expected to deteriorate or vary from year to year. These four pavements will provide a baseline for testers who return in subsequent years.

5.0 RESULTS OF FRICTION WORKSHOP

The following is a summary of the results for each device that tested at the workshop.

5.1 CT Meter Results

The CT Meter is used to calculate the Mean Profile Depth (MPD). Following works at NASA's Wallops Island test facility between 1998 and 2002, an equation has been developed to translate MPD into Mean Texture Depth (MTD).

Thus, it is possible to calculate the Speed Constant Sp, for a pavement, which is required to determine the IFI value (F60).

Provided below in Table 3 is a summary of the results for the CT Meter;

Table 3

Surface	Chainage	MPD (mm)	RMS (mm)	ETD (mm)	Sp (km/h)
Asphalt Pavements					
A-1	300-400	0.87	0.70	0.893	89.9
A-2	500-600	0.79	0.74	0.817	81.2
A-3	600-700	0.38	0.34	0.429	37.1
A-4	700-800	2.21	1.98	2.162	234.0
R-1	300-400	0.22	0.18	0.277	19.9
R-2	400-500	0.46	0.20	0.505	45.7
R-3	400-500	0.18	0.08	0.239	15.6
R-4	700-800	0.47	0.31	0.514	46.8
MS/1	500-600	1.36	0.65	1.357	142.6
MS/2	600-700	1.14	0.51	1.149	118.9
Concrete Pavements					
C-1	300-400	0.04	0.03	0.107	0.5
C-2	400-500	2.31	1.99	2.257	244.8
C-3	300-400	0.51	0.26	0.552	51.1
C-4	400-500	1.88	1.66	1.849	198.5

NOTES:

ETD = 0.947 MPD + 0.069 (Predicted MTD)
Sp = 107.6 MPD - 3.76 (Predicted Speed Constant)

Of interest from these results is that ;

A. The polished concrete test surface, C-1, has a Mean Profile Depth (MPD) of only 0.04 mm. Whilst, the polished surface but grooved, C-2, had a high texture depth (2.31 mm).

B. Thus, it is interesting that by grooving even the smoothest surface a texture in excess of 1 mm, which is required by the aviation regulations, can be achieved.

C. It was noted though, that the MPD result for C-2 is higher than C-4, which is a broomed concrete surface that was grooved to the same pitch and depth and should have returned a higher result.

D. The rejuvenation of the test pavements has significantly reduced the texture. Pavement R-3 shows a 62% reduction in MPD from R-4 which is the same pavement with no rejuvenation applied. Whilst Pavement R-1 shows a 42% reduction. Pavement, R-2, which was a rejuvenation agent with a sand applied, showed a 21% increase in MPD.

5.2 Laser Texture Profilometer Results

Unfortunately, the Laser Texture Profilometer was not used on the second day of testing on the Concrete Pavements. However, good results were collected of Site A: Asphalt Pavements.

Provided below in Table 4 is a summary of the results for the laser texture profilometer;

Table 4

Surface	Run 1	Run 2	Run 3	Run 4	MPD
					(mm)
A-1	1.140	1.046	1.120	1.035	1.085
A-2	0.849	0.804			0.826
A-3	0.496	0.489			0.492
A-4	1.704	1.661			1.682
R-1	0.287	0.291			0.289
R-2	0.423	0.444			0.434
R-3	0.645	0.734	0.665	0.701	0.686
R-4	0.516	0.595	0.567		0.559
MS/1	1.471	1.479	1.382	1.394	1.432
MS/2	1.214	1.118	1.179	1.182	1.173

Of interest from these results is that ;

A. All rejuvenated surfaces had less than 1 mm of texture. But R-4 was an old 10 mm dense grade asphalt (ungrooved)

B. Grooving of surface A-4 increase the MPD by 1.190 mm.

C. A-2 (Stone mastic 10 mm asphalt) had 68% more texture than A-3 (dense grade 10 mm asphalt). But less than half the texture of the A-4 (grooved surface)

D. The microsurface pavements had greater than 1 mm of texture.

5.3 DF TESTER RESULTS

The Dynamic Friction Tester is a static device which can be used to calculate F60. This requires the calculation of the speed constant, Sp, which was calculated by the CT Meter.

The results of the testing are listed below in Table 5;

Table 5

Surface	Chainage	DFT20	DFT40	DFT60	DFT70	F60
		20 km/h	40 km/h	60 km/h	70 km/h	
Asphalt Pavements						
A-1	300-400	0.960	0.902	0.834	0.809	0.531
A-2	500-600	0.817	0.730	0.666	0.658	0.447
A-3	600-700	0.864	0.815	0.786	0.777	0.296
A-4	700-800	0.982	0.919	0.863	0.835	0.687
R-1	300-400	0.327	0.232	0.218	0.218	0.113
R-2	400-500	0.814	0.676	0.608	0.605	0.329
R-3	400-500	0.224	0.139	0.139	0.139	0.094
R-4	700-800	0.850				0.346
MS/1	500-600	1.056	0.968	0.919	0.880	0.665
MS/2	600-700	0.999	0.876	0.824	0.792	0.603
Concrete Pavements						
C-1	300-400	0.402	0.348	0.363	0.408	0.081
C-2	400-500	0.534	0.481	0.462	0.449	0.413
C-3	300-400	0.969	0.943	0.922	0.899	0.405
C-4	400-500	0.937	0.928	0.921	0.912	0.642

NOTE :

F60 = 0.081 + 0.732*DFT20*exp(-40/Sp)

Of interest from these results is that ;

A. The polished concrete test surface, C-1, has an F60 value of only 0.081 and surface C-2 has a result of 0.413. Thus grooving provided not only adequate texture but also a 410% increase in friction.

   By comparison, the difference between surfaces C-3 and C-4 indicates that the grooving provided a 58% increase.

B. The CT Meter results indicated that rejuvenation without applying a sand treatment dramatically reduced texture. This was also illustrated in the F60 results. However, R-2 which should have an increase in texture (MPD) showed a reduction in friction (F60).

5.4 CFME RESULTS

Testing with CFME’s began on the 6th and 7th August 2003.

Each CFME completed multiple runs on both days. The average result recorded by each CFME on each test pavement is provided in table 6 below.

Table 6

Surf	*Chainage*	*GT1*	*GT2*	*GT3*	*GT4*	*GT5*	*SCRIM 1*	*SCRIM 2*	*ROAR1*	*ROAR2*
Asphalt Pavements										
A-1	300-400	0.72	0.93	0.98	0.91	0.98	91.33	94.73	0.86	1.07
A-2	500-600	0.70	0.80	0.86	0.81	0.91	87.33	86.20	0.78	0.94
A-3	600-700	0.69	0.79	0.87	0.78	0.93	90.00	93.97	0.69	0.88
A-4	700-800	0.73	0.87	0.95	0.89	1.00	101.00	102.78	0.88	1.13
R-1	300-400	0.54	0.42	0.49	0.37	0.51	42.67	52.48	0.32	0.58
R-2	400-500	0.66	0.67	0.78	0.70	0.87	67.00	81.28	0.53	0.72
R-3	400-500	0.44	0.35	0.34	0.23	0.38	12.00	19.93	0.13	0.26
R-4	700-800	0.69	0.85	0.94	0.86	0.98	94.00	104.57	0.81	1.08
MS/1	500-600	0.75	0.80	0.88	0.91	0.98	88.67	99.00	0.86	1.11
MS/2	600-700	0.72	0.90	0.91	0.91	1.00	87.67	102.22	0.84	1.02
Concrete Pavements										
C-1	300-400	0.38	0.22	0.25	0.15	0.34	26.40	30.49	0.19	0.31
C-2	400-500	0.50	0.35	0.47	0.33	0.47	47.80	49.68	0.49	0.92
C-3	300-400	0.72	0.80	0.98	0.90	1.03	97.00	91.27	0.78	1.29
C-4	400-500	0.72	0.89	1.03	0.93	1.06	91.00	92.97	0.83	1.19

There are several factors that need to be considered when interpreting this data ;

A. **Amount of water on test surface.** The SCRIMs dumped a lot of water on the test surfaces after each of their passes which may have affected some of the results. On the second day of testing, the SCRIMs were required to hold back and not test until later in the session to allow the ROARs and GripTester to test a drier surface. Still, it did not take long for water to build up on the surface.

B. **Temperature Variability.** Testing was conducted over 2 days and the temperature during that period varied from 15 to 22 degrees Celsius. This could have results in a small variation in the results over the two days.

C. **Tyre Variability.** This workshop was not set up as a correlation trial and as such not all of the GripTester were using calibration tyres. With variety of wear comes variability of the results.

5.5 SCRIM Result Comparison

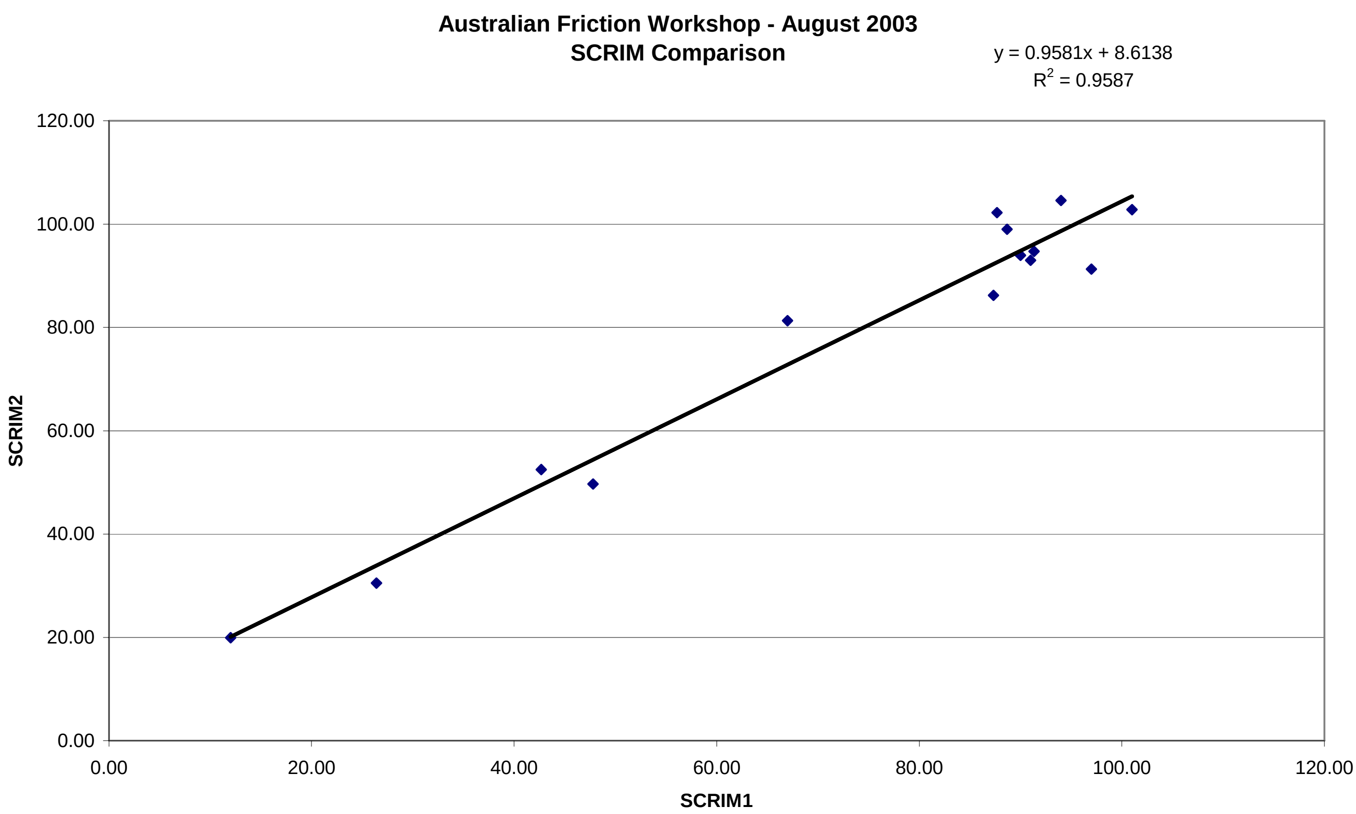
The SCRIMs displayed very good consistent results over the two days of testing at Sydney Airport.

Some of the more interesting observations included ;

A. Whilst both SCRIMs showed an increase in recorded friction from the smooth concrete test surface (C-1) to the grooved smooth concrete test surface (C-2), neither SCRIM showed much of a change between the broom grooved and un-grooved concrete surfaces.

B. Both SCRIMS showed a reduction in friction values for all of the rejuvenation surface treatments, R-1, R-2 and R-3.

C. There was significant variability on the slurry seal surfaces. However, this is in line with the visual inspections, which indicated that the surfaces were not homogeneous.



Comparing the two SCRIMs through a harmonisation analysis, the correlation co-efficient (R^2) is 0.96. This indicates that the two SCRIMs correlate quite well.

However, what can not be stated is whether the differences between the two machines was due to variability of testing or whether one of the devices was slightly out of calibration.

5.6 ROAR Result Comparison

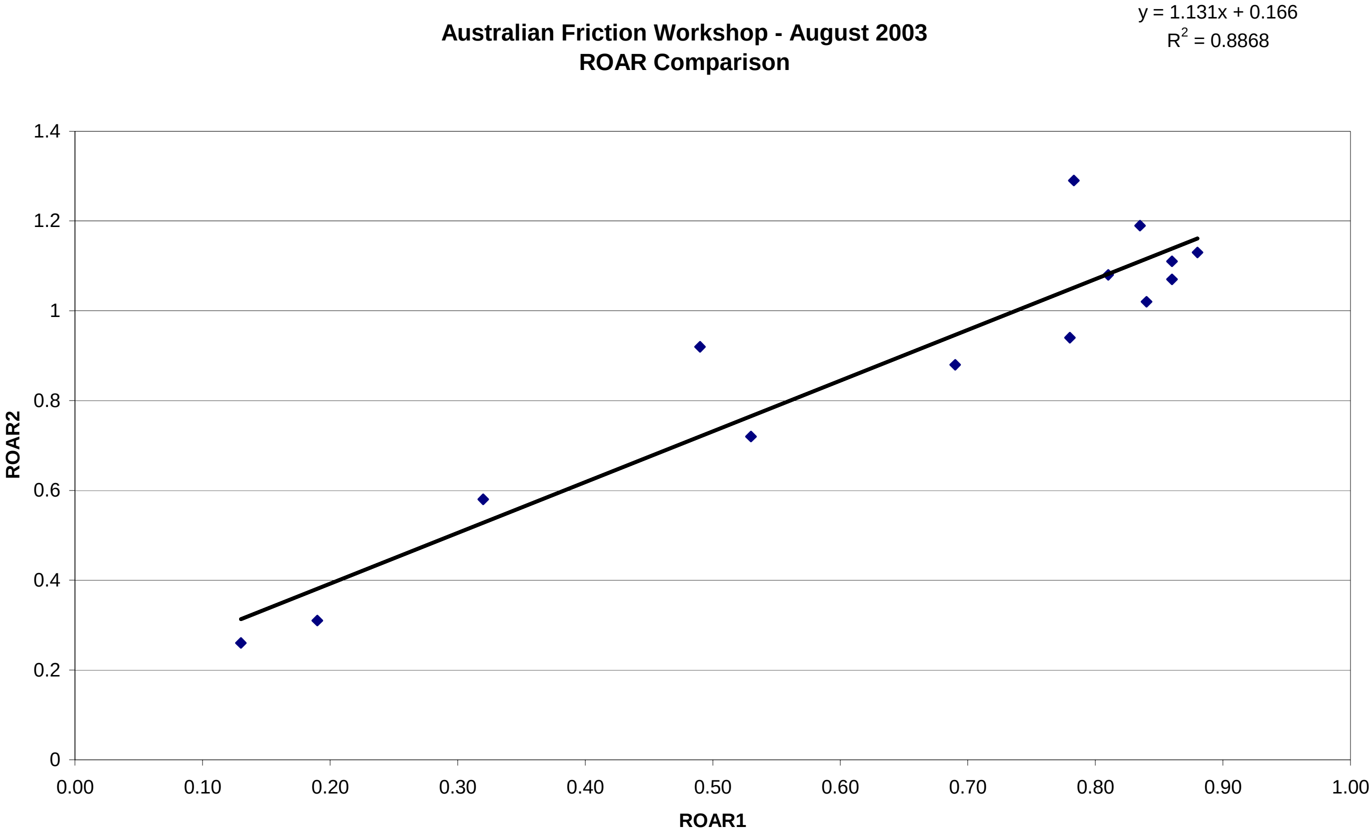
The ROARs displayed a high degree of variability between each machine and between the various repeated runs. Also, only two of the ROARs provided data as the third ROAR experienced technical problems and could not complete testing.

Some of the more interesting observations included ;

A. The average variability between the two ROAR's was 30%.

B. Both ROARs showed a reduction in friction values for all of the rejuvenation surface treatments, R-1, R-2 and R-3.

C. Whilst both ROARs showed an increase in recorded friction from the smooth concrete test surface (C-1) to the grooved smooth concrete test surface (C-2), ROAR1 showed only a small change between the broom grooved and un-grooved concrete surfaces (C-3 and C-4), whilst ROAR2 showed grooving reduced the result.



Comparing the two ROARs through a harmonisation analysis, the correlation co-efficient (R^2) is 0.88. This indicates that the two ROARs did not correlate well. If you remove two surfaces from the analysis, C-2 and C-3, then the correlation co-efficient (R2) increases to 0.97 which is a high value.

However, C-2 or C-3 where not on the same track and where tested several times by both machines. As such, it would be difficult to question the result on these two stable surfaces.

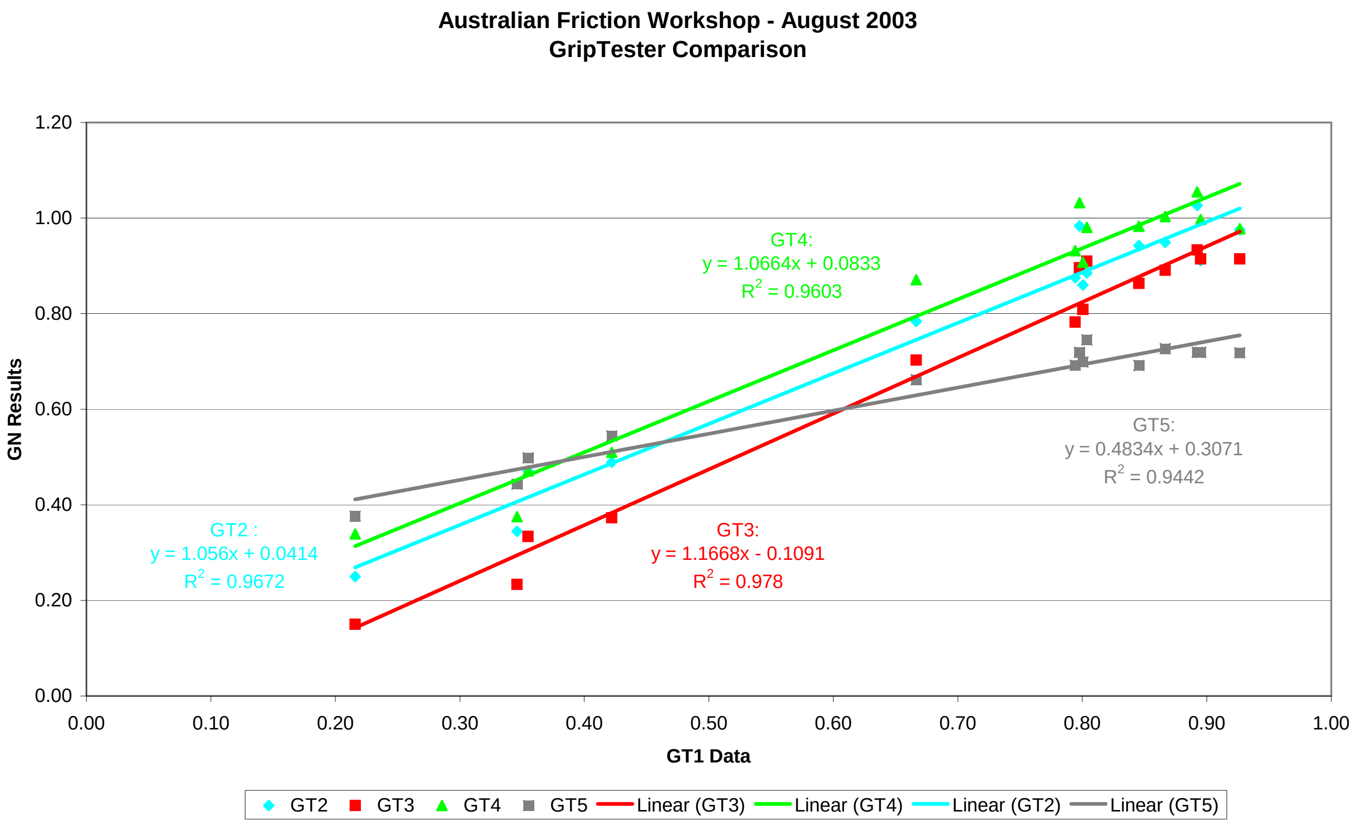
5.7 GripTester Result Comparison

The GripTesters displayed a high degree of variability between each machine but good repeatability between the various repeated runs. Also, the results of GT5 should be questioned as it appears that the device was experiencing technical problems.

Some of the more interesting observations included ;

A. The average variability between all five GT's was 17%. If GT5 is excluded from the analysis this average variability is reduced to 9%

B. All GTs showed a reduction in friction values for the rejuvenation surface treatments, R-1 and R-3, but minimal reduction of R-2. This illustrates the sensitivity of the GripTester to microtexture.



Using GT1 as the reference device and comparing the GripTesters through a harmonisation analysis, the correlation co-efficient (R^2) for all devices was greater than 0.94. This indicates that all the GripTesters correlated well against the reference device.

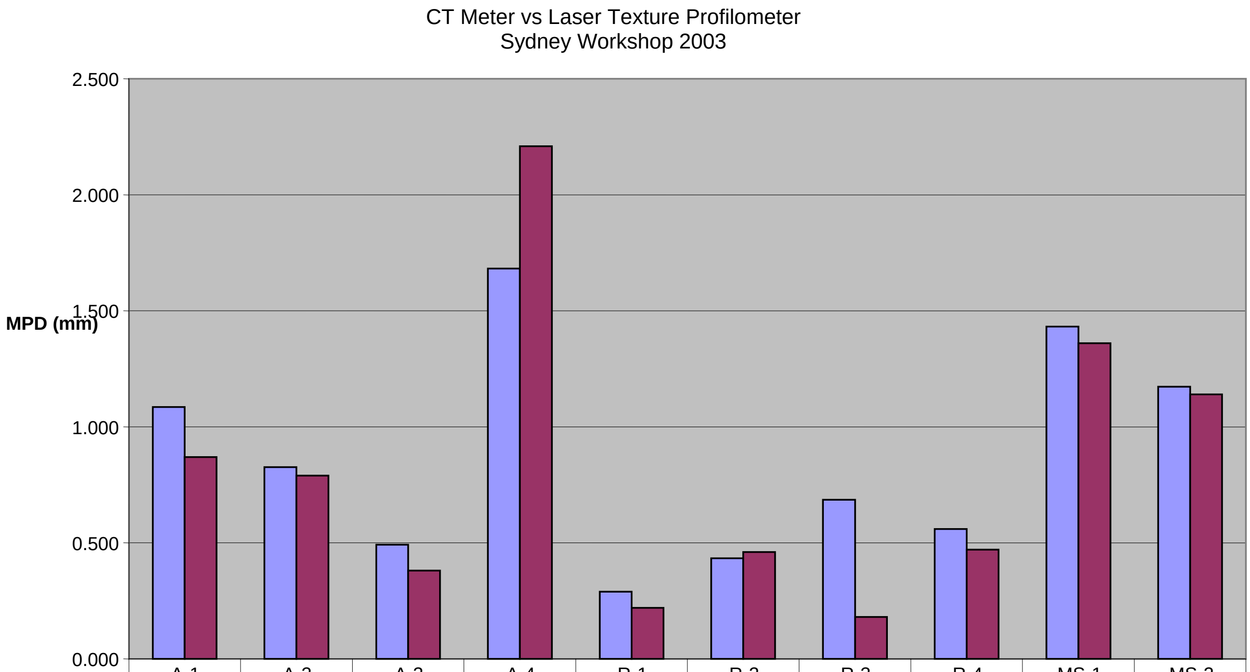
However, GT5 was obviously experiencing technical problems as the harmonisation constants are so large and the grade of the line varies significantly from the other devices.

6.0 COMPARISION OF RESULTS

The following is a comparison of the data collected.

6.1 CT Meter vs Laser Texture Profilometer

Both the CT Meter and the Laser Texture Profilometer calculate Mean Profile Depth (MPD). The results of each methodology are compared below.



	A-1	A-2	A-3	A-4	R-1	R-2	R-3	R-4	MS-1	MS-2
LTP	1.085	0.826	0.492	1.682	0.289	0.434	0.686	0.559	1.432	1.173
CTMeter	0.870	0.790	0.380	2.210	0.220	0.460	0.180	0.470	1.360	1.140

Of the ten test pavements, two surfaces (MS-1 and MS-2) showed high degree of variability. The Cold Overlay test pavements were constructed one month before the workshop and were unfortunately too “green”. Visual inspections confirmed that they were highly variable.

As such it would not be fair to compare the results of the CT Meter and the LTP on these pavements, even though the variance between the CT Meter and the LTP was only 4.1%.

What is not easily explainable are the differences between the two devices on the Asphalt and Rejuvenation surfaces, outlined in Table 7.

Table 7

Variance of CT Meter and Laser Texture Profilometer Results.	High	Low	Average
Asphalt “A” Series	29.6%	-23.9%	8.8%
Rejuvenation “R” Series	281.3%	-5.7%	81.5%

6.2 DF Tester vs CFME

The purpose of this section is to compare the effectiveness of these devices in calculating F60.

F60 data for the DF Tester was provided by the tester, as was the F60 data for the ROAR.

However, to calculate F60 for the GripTester and the SCRIM equations within ASTM 1960 were utilised.

The results are shown in Table 8 ;

Table 8

F60 Results	DF Tester	ROAR	GT	SCRIM
Surface				
A-1	0.53	0.71	0.55	0.52
A-2	0.45	0.61	0.46	0.48
A-3	0.30	0.61	0.26	0.27
A-4	0.69	0.79	0.71	0.76
R-1	0.11	0.29	0.11	0.07
R-2	0.33	0.44	0.28	0.26
R-3	0.09	0.15	0.09	0.04
R-4	0.35	0.70	0.33	0.35
MS/1	0.67	0.70	0.59	0.60
MS/2	0.60	0.69	0.61	0.56
C-1	0.08	0.11	0.08	0.03
C-2	0.41	0.60	0.34	0.38
C-3	0.41	0.77	0.34	0.39
C-4	0.64	0.68	0.70	0.67

Note:

For the GripTester A = 0.082 and B = 0.910
For the SCRIM A = 0.033 and B = 0.872 (based on SCRIMTEX)

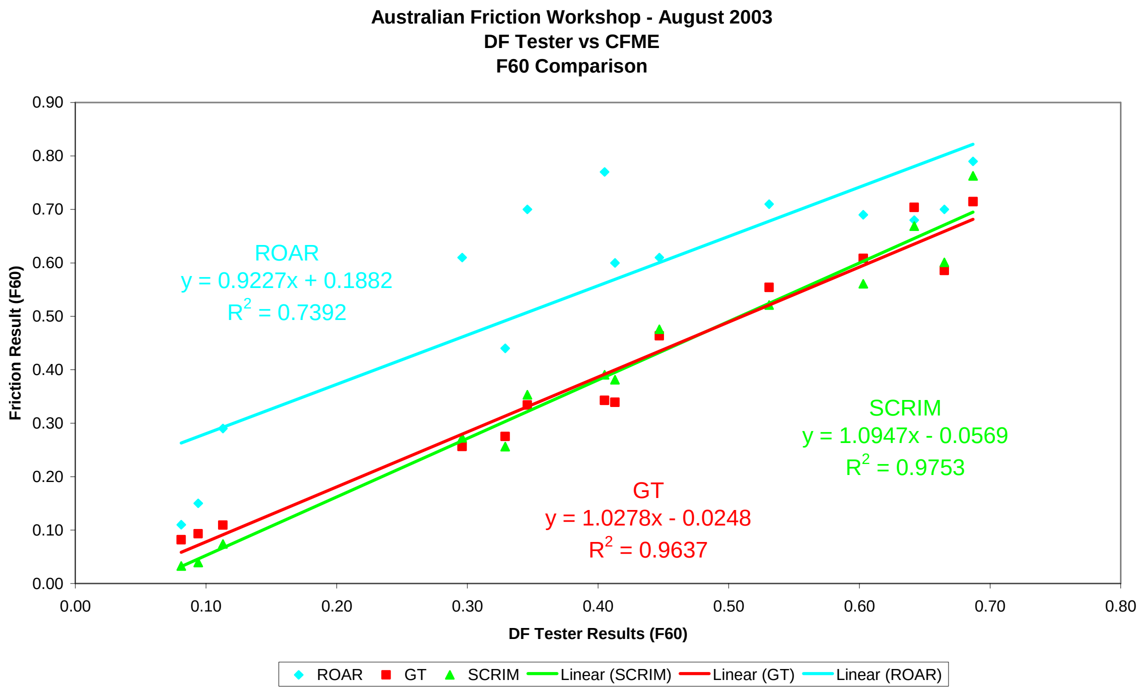
$$F60 = A + B \times FRS \times EXP\,[(S-60)/Sp]$$

Where;

A,B Harmonisation Constants for particular device listed in ASTM 1960
FRS the friction measured the equipment
Sp Speed Constant : determined by CT Meter
S Slip Speed of the Device

When comparing the data, the DF Tester, GripTester and the SCRIM all correlate extremely well.

However, the ROAR has an R^2 value of 0.74 which is low and does not appear to have good correlation. This can partially be explained in that the test pavements where short (100 metres) and the device was running in variable slip mode.



6.3 Texture vs Friction vs F60

In this section we shall compare the texture, friction and F60 results for the tests pavements. The CT Meter shall be utilised for texture, the GripTester for Friction and the DF Tester for F60.

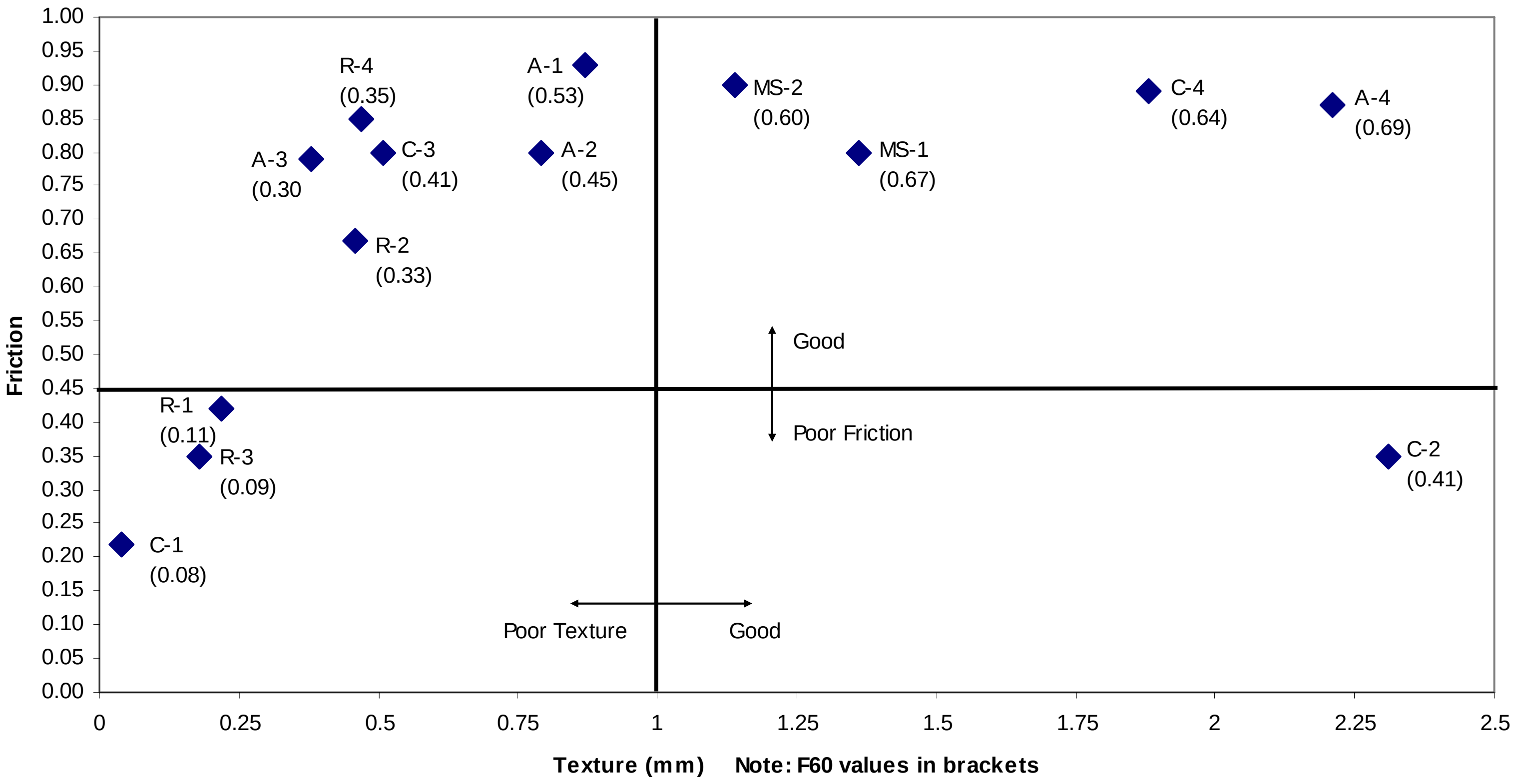
This results is shown in Table 9 below;

Table 9

Surface	Surface Type	Texture	Friction	F60
A-1	Stone Mastic Asphalt - 7 mm	0.87	0.93	0.53
A-2	Stone Mastic Asphalt – 10 mm	0.79	0.80	0.45
A-3	Dense Grade Asphalt – 10 mm	0.38	0.79	0.30
A-4	Dense Grade Asphalt – 10 mm (G)	2.21	0.87	0.69
R-1	ASPEN sealer	0.22	0.42	0.11
R-2	CARBONYTE sealer	0.46	0.67	0.33
R-3	Emulsion with Sand	0.18	0.35	0.09
R-4	Dense Grade Asphalt, no rejuv	0.47	0.85	0.35
MS/1	Cold Overlay 0-7 mm	1.36	0.80	0.67
MS/2	Cold Overlay 0-4 mm	1.14	0.90	0.60
C-1	Polished Concrete	0.04	0.22	0.08
C-2	Polished Concrete, grooved	2.31	0.35	0.41
C-3	Broomed Concrete	0.51	0.80	0.41
C-4	Broomed Concrete, grooved	1.88	0.89	0.64

The results are then graphically displayed below. The area of the graph is divided into good friction (>0.45) and poor friction and good texture (>1 mm) and poor texture.

Sydney Workshop - August 2003
Texture vs Friction vs F60



Based on these results;

- Test Pavement C-2 has good texture but poor friction. This is in line with expected results as the surface is polished.
- The grooved test pavements have the highest texture and friction and have good F60 results.
- The polished concrete has low texture and poor F60 in line with expected results.
- The stone mastic asphalts produced a poor texture and F60 result

7.0 CONCLUSIONS

The purpose of the Physical Workshop was to have all these machines test side by side and see what the result would be. The results have indicated that ;

A. There was a degree of variability between texture devices used, CT Meter and Laser Texture Profilometer. Future workshops should have sand or grease patch tests to calibrate against.

B. There was also a high degree of variability between the CFME’s. However, the machines did correlate quite well ($R^2 > 0.94$).

C. All devices experienced loss of friction and texture on rejuvenated surfaces that do not contain a grit or sand component.

D. When ASTM 1960 was used to convert CFME data to F60, the SCRIM, GripTester and DF Tester showed excellent correlation. However, the ROAR did not show good correlation which could have been due to the device working in variable slip mode.

E. Texture and Friction independently are inadequate measures to correctly determine the characteristics of a surface. F60 as a concept for combining texture and friction did provide a suitable parameter to classify a pavement’s characteristics.

Overall, the workshop provided operators with the benefit of a forum to discuss issues regarding their equipment and provided an opportunity for device owners to test against other machines.

However, to resolve the issue of the degrees of variability the region needs to consider the development of an annual workshop to test equipment and certify performance.

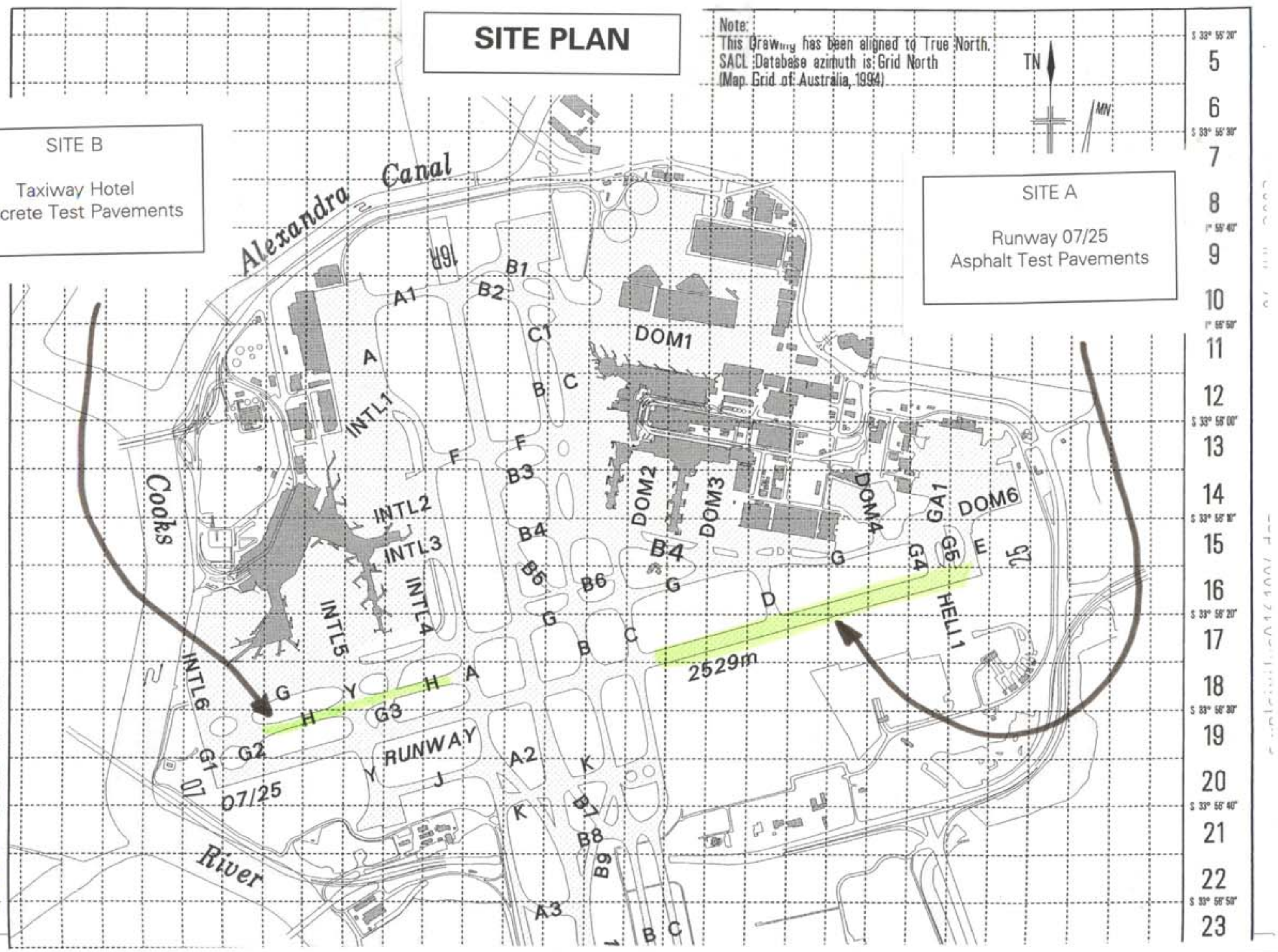
John Dardano
Sydney Airport Corporation Ltd
June 2004

APPENDIX A

Map of Sydney Airport – Location of Test Sites

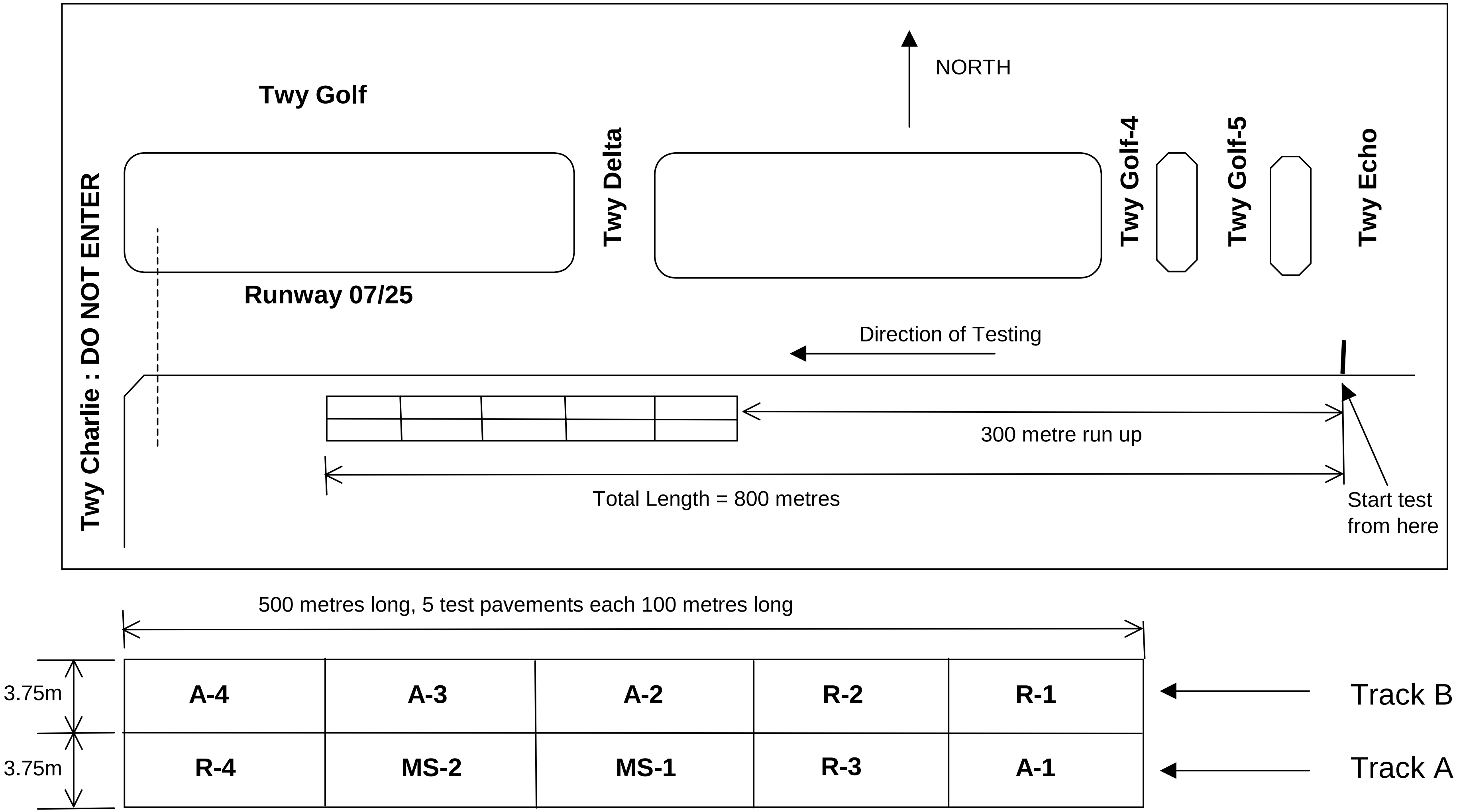
Schematic Diagram of Site A

Schematic Diagram of Site B



- This plan has been compiled from precision survey data and the digitising of any applicable 1:250 or 1:500 Survey Detail Sheet.
- All heights shown are based on A.H.D.
- Coordinate values shown are based on Map Grid of Australia 1994 (MGA94)

SITE A : RUNWAY 07/25



SITE B : TAXIWAY HOTEL