AUSTRALIA's NATIONAL FRICTION TESTING PROGRAMME

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SUMMARY

The friction testing of runways in Australia is not common practice as the Australian regulatory body, CASA, only requirement regarding surface characteristics relates to surface texture. The recent modifications to the Manual of Standards (MOS) require some airports to implement friction testing from 2006.

Friction testers throughout the world acknowledge that the machines have poor repeatability and calibration problems, which make their value as a tool of regulatory compliance questionable. However, it is the value as a maintenance tool for airport managers to utilise to determine frequency of rubber removal which could potentially be of most benefit.

The purpose of this project was to develop a methodology for the analysis of runway friction testing data so that airport engineers can have confidence in the results that the devices produce.

In addition, the project took on a larger focus to assist other Australian airports with friction management in preparation for the new regulations in 2006.

1.0 INTRODUCTION

The purpose of this paper is to present a basis for SACL's current methodology for the analysis of raw runway friction testing data and present preliminary results of the National Friction Testing Programme.

2.0 DEFINITIONS

Friction Reference Strip -	This is a multi surface reference strip with friction values that is utilised to determine the harmonisation constants for a machine.
Calibration Strip -	A Calibration Strip is typically located adjacent to the edge of a runway (18 m offset from the centreline). CFME operators perform works along this strip ascertain the baseline friction values as there is typically no rubber contamination.
Normalisation Value (N_v) -	A numeric value which is added to raw friction data to achieve normalised values.
Harmonised Friction Values -	Also referred to as "calculated friction values". Friction values that have been calculated using the methodology
Raw Friction Data -	Data that is collected by a CFME prior to any calibration adjustment.

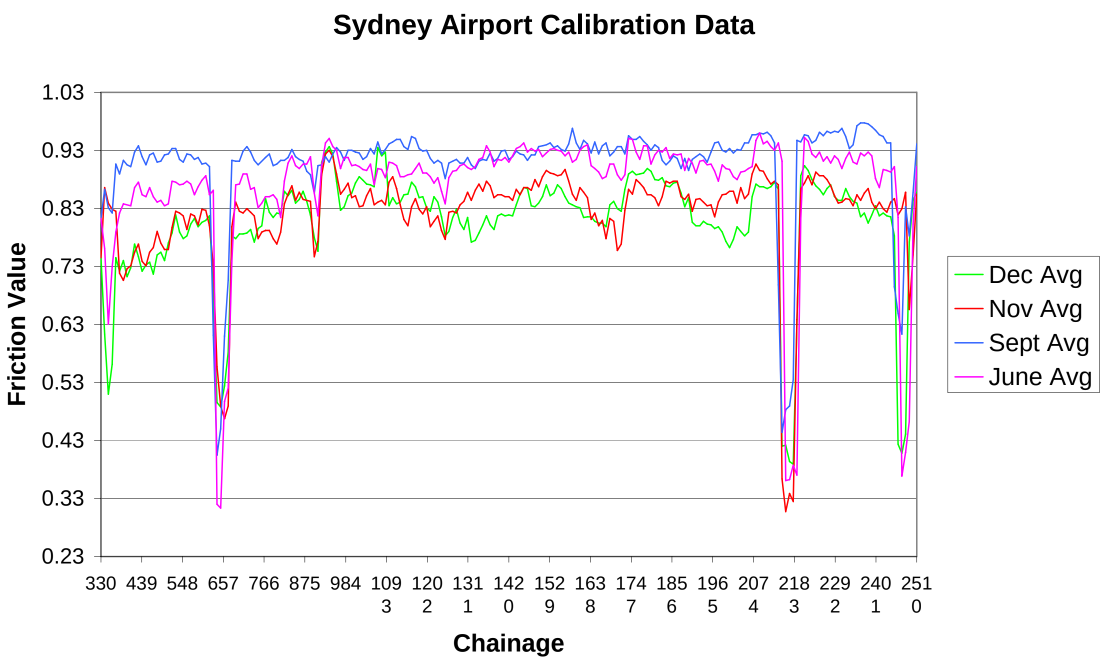
3.0 BACKGROUND

Sydney Airport has been performing friction testing since 1995 and has had difficulties in achieving consistency (good repeatability) in the results it has recorded. This phenomena has been reported to Sydney Airport by other users of CFME when Sydney Airport conducted a tour of major US Airport and attended the NASA Runway/Tyre Friction Conference at Wallops Flight Facility in 2001.

This international study found that other major airports had encountered the same problems that Sydney Airport were struggling with in terms of poor repeatability of CFME equipment and concluded that the poor repeatability could be due to the following factors;

a. **Environment and Tyre Variability:** the variability in results that a fully calibrated machine will return along the same surface when temperature and tyre are different. Those performing friction testing may have noted that a machine that is fully calibrated can return significantly different values along the same pavement (such as a calibration strip) throughout the year.

   Graph 1 shows friction values taken along the Calibration Strip at Sydney Airport over a 6 month period. The results indicate that their was a variability of 15% in the results that were recorded over this period. In each case the calibration strip had not changed but the tyre and the weather conditions were different.



This machine had only recently returned from repairs and thus was in good condition. Sydney Airport then concluded that variations in pavement temperature and wear and condition of measuring tyre were factors that contribute to variation in friction testing values.

b. **Machine Variability:** the correlation between a machine and another machine of the same type.

A study by NATAM **[8]** utilising 15 BV11's in June 2000 showed that a variability of 10-20% can exist. Therefore, if a CFME operator where to record friction values of 0.5, the absolute friction value could actually be anywhere between 0.4 and 0.6.

This range is so wide that results at these extremes can be the difference between not satisfying the minimum friction levels as stipulated in Table 3.2 of the FAA Advisory Circular **[1]** or results that are satisfactory and no maintenance planning is required.

Thus, an airport could be skeptical of friction testing results that they record as there is no procedure by which to ascertain how the above factors, Machine Variability and Environment and Tyre Variability, are effecting their results.

The purpose of this paper is to present a methodology whereby airport managers can compensate for the above factors. This methodology includes

- "Normalisation' of data to compensate for Environment and Tyre Variability
- "Harmonisation" of data to compensate for Machine Variability and
- the methodology which combines the two.

4.0 NORMALISATION OF FRICTION VALUES

The Normalisation of friction testing data is permitted, if and only if ;

a. before each round of testing, several calibration runs are performed and
b. when interpreted graphically, these runs show very good correlation.

This is an indication that the machine is functioning properly. The CFME can then be used to perform friction testing works and acquire "raw data".

4.1 Correction Factor for Tyre Wear

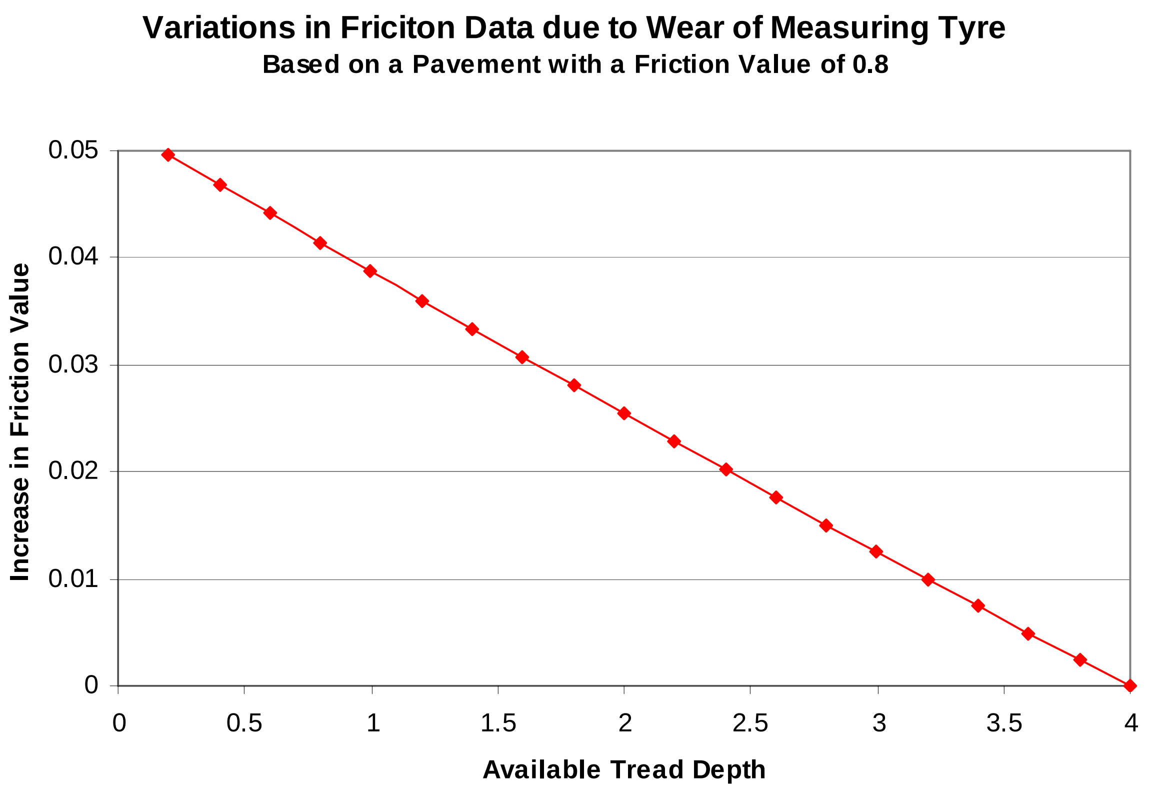
Works by OPUS Laboratories in New Zealand **[13]**, established an equation for variation for the GripTester friction values due to tyre wear. The equation is ;

$$F = GN \times \frac{(SD - CD)}{(MD - CD)} \quad \ldots\ldots\ldots\ldots (1)$$

Where ;

F = Friction Value
SD = Standard tyre diameter = 260 mm
CD = Chain cog effective diameter = 130 mm
GN = GripTester Number recorded
MD = Measured tyre diameter

Using the above equation we can calculate the changes to friction values recorded for a pavement with a Mu value of 0.8 ;



Graph 2 – Available Tread Depth vs Increase in Friction Value

Based on the above graph it is clear that as the tyre wears, friction values go up. It should also be noted that the Findlay Irvine manual **[14]** allows for the use of a measuring tyre which has up to 1 mm of tread remaining.

Depending on the GripTester value recorded the wearing of the test tyre can add between 0.02-0.05 to the value that would be recorded with a new tyre.

4.2 Temperature Variations

In 1999, research in New Zealand was conducted to determine the seasonal variations in friction testing data. The research culminated in the Transfund Report – Seasonal Weather Normalization of Skid Resistance Measurements **[15].**

This research found that variations in temperature did not have as big an impact as one would think, as the measuring tyre of the Type C GripTester operates at an elevated temperature, typically between 35-40 ^{o}C. This occurs as the device operates at a constant slip of 15%. Thus maintaining the temperature of the tyre

However, it did conclude that friction results for the Type C GripTester did varying with changes to air and pavement temperature.

It determined an equation to compensate for these variations based on air and pavement temperature.

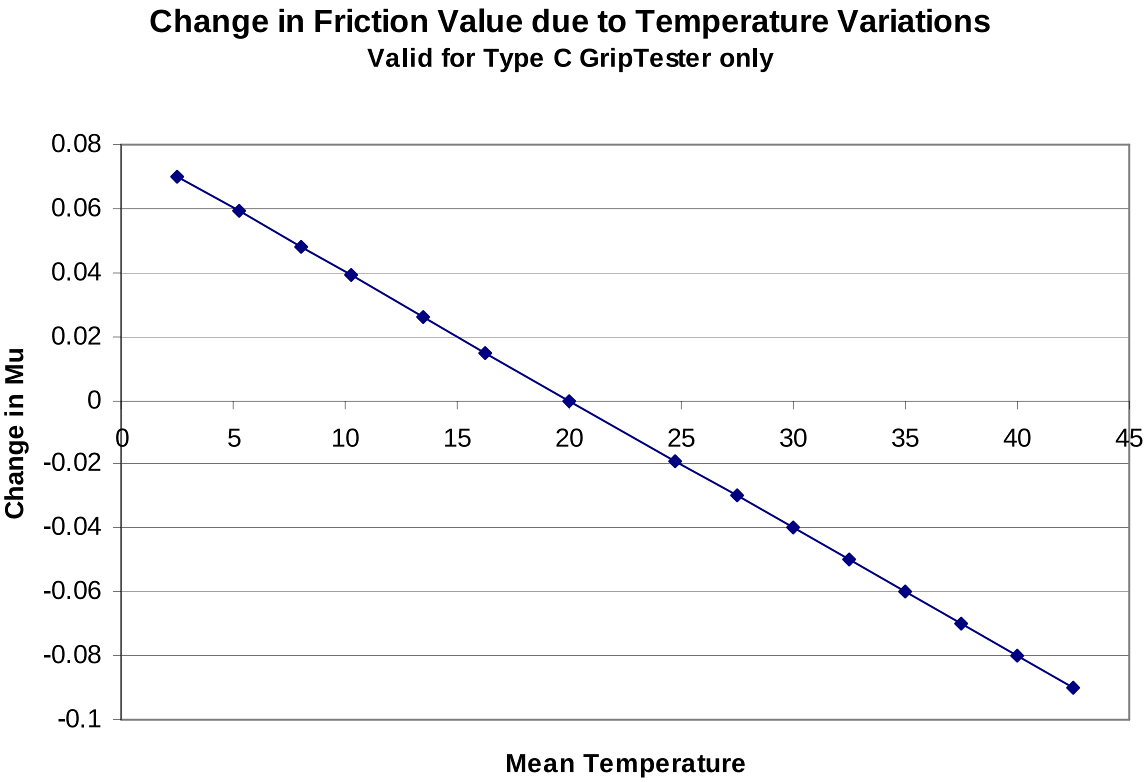
The equation is ;

$$F = GN - 0.002 \times (MT - 20) \quad \ldots\ldots\ldots\ldots.. (2)$$

Where ;

F = Friction Value
GN = GripTester Number recorded
MT = Mean Temperature, which is the average of air and pavement temperature

Graph 2 (below) shows the variation in friction values over the range of air and pavement temperatures that were recorded at Airports around Australia in 2002.



Graph 2– Change in M_u caused by Temperature Variations for Type C GripTester

These changes can be as high as 10-15% of the friction value recorded.

As such to effectively compare the results of runway friction testing data with the intervention levels provided in the FAA Advisory Circular **[1]**, the results need to be adjusted to the conditions under which the intervention levels where established, that being a mean temperature of approximately 20 degrees.

4.3 Calibration Strip

To normalise the results of friction testing data the raw data (RF_v) that was collected along a Calibration Strip must be compared to the benchmark values (CB_v). This Calibration Strip would typically be the along the edge of a runway (offset 18 m from the centreline) which has the same surface type and grooving pattern as the wheel track areas.

To be able to determine the Calibration Strip Value (CB_v), the CFME must perform at least three (3) calibration runs along the calibration strip at 65 km/h (40 mph) and 95 km/h (60 mph). Ideally, this testing should be performed at a time of the year whereby the mean temperature is as close to 20 degrees as possible. Should a minor adjustment be required, Equation 2 can be utilized.

To be able to determine Normalisation Value on subsequent testing, the CFME operator must ;

i. again perform at least three (3) calibration runs along the calibration strip at 65 km/h (40 mph) and 95 km/h (60 mph).

ii. The average of these values is then corrected for tyre wear (as per section 4.1); and

iii. then compared to the benchmark values that were recorded along the Calibration Strip (CB_v) so as to determine the "Normalisation Value (N_v)."

$$N_v = CB_v - RF_v \ldots\ldots\ldots\ldots (1)$$

This can be presented as per Table 1 below being the average of the difference between the Calibration Reference Strip (CB_v) and the average of the calibration runs performed before each round of testing (CR_v)

Runway 16L		**Example 1**		**Example 2**	
	CBv	CRv	Nv	CRv	Nv
0-150	0.81	0.64	0.17	0.71	0.07
150-300	0.82	0.67	0.15	0.75	0.08
300-450	0.85	0.68	0.17	0.8	0.12
450-600	0.78	0.62	0.16	0.75	0.13
600-750	0.77	0.63	0.14	0.77	0.14
750-900	0.79	0.62	0.17	0.80	0.18
900-1050	0.80	0.64	0.16	0.76	0.12
1050-1200	0.82	0.67	0.15	0.74	0.07
1200-1350	0.76	0.62	0.14	0.68	0.06
1350-1500	0.79	0.63	0.16	0.71	0.08
Average	0.80	0.64	0.16	Average	0.11
Std Dev			0.01		0.04

Table 1 – Example of Calibration Table

In example 1, the average results returned for a calibration run performed at 65 km/h (40 mph) were 0.64 and the benchmark values along the Calibration Strip were 0.80. Therefore, the normalisation value at 65 km/h (N_{65}) would be 0.16.

In Example 1, the standard deviation between the differences was 0.01. This indicates that there is good correlation between the results. However, in Example 2 the standard deviation of the differences is 0.04. This indicates that there is poor correlation between the benchmark values that were established along the Calibration Strip and the raw friction data.

Therefore, the CFME operator can not normalise the data and must investigate the causes to determine why there is such a wide range of differences (ie calibration of the machine, the calibration strip pavement).

4.4 Normalised Friction Value (NF_v)

To determine the "Normalised Friction Value (NF_v)" the Normalisation Value (N_v) must be added to all the Raw Friction Values (RF_v)." Therefore, the equation ;

$$NF_v = N_v + RF_v \; \ldots\ldots\ldots\ldots. \; (2)$$

Whilst the methodology of Normalisation will greatly improve the repeatability of the results, it will also allow the airport manager to where the CFME data lies in relation to machine variability which is typically +/- 20%.

To ascertain Harmonised Friction Values, the normalised data must be calibrated and empirically linked to the harmonised friction data gathered at NASA Wallops Flight Facility via the process of Harmonisation.

5.0 HARMONISATION OF FRICTION VALUES

The harmonization procedure utilizes simple straight line equations to convert normalised friction values to harmonised friction values.

This equation is;

$$F_v = A_v + B_v * NF_v \ldots\ldots\ldots\ldots. \; (3)$$

Where ;

F_v	Harmonised Friction Value
A_v	Harmonising Constant
B_v	Calibration Ratio
NF_v	Normalised Friction Value
V	Speed at which the testing was performed

CFME operators should use both a reference device, a series of test pavements (Friction Reference Strip) and the process of 'Harmonisation' to benchmark the raw data that is recorded.

NASA's Wallops Flight Facility in Virginia, USA, has several test surfaces which have harmonised friction values gained from many years of parallel friction testing at this facility. Utilising the methodology of 'Harmonisation", the harmonisation constants (A and B) can be determined for a particular CFME.

This is done by graphically displaying Harmonised Values versus Recorded Values. The "y" intercept is the Harmonising Constant (A_v) and the slope of the line is the Calibration Ratio (B_v).

A friction reference strip would need to have 6-10 different surfaces to establish enough points to determine the harmonisation constants.

6.0 METHOLODOLGY FOR ANALYSIS OF FRICTION TESTING DATA

With the concepts of Harmonisation and Normalisation explained above, the question that needs to be answered is how does an airport engineer apply these processes to raw data that is collected to harmonise friction values. This process involves ;

a. Determination of Harmonisation Constants

Each CFME operator will be required to establish the harmonisation constants for their machine. This must be done by collecting raw friction data over a Friction Reference Strip with 6-10 different surface types of harmonised friction values (such as those at NASA's Wallops FF)

The linear relationship between the raw friction values and the harmonised values should then be plotted on a graph and thus the harmonisation constants can be established.

b. Development of Benchmark Values along the Calibration Strip

At their respective "home" airports, each CFME operator should then develop a Calibration Strip. Each operator should simulate conditions as close as possible to the mean temperature of 20 degrees. The average of these results shall be taken the benchmark values for the Calibration Strip (CB_v).

c. Routine Runway Friction Testing

The CFME operator can then perform routine friction testing at their respective home ports. The CFME operator shall ;

i. Measure diameter of test tyre
ii. Collect data along the Calibration Strip
iii. Collect data along the Runway surface

d. Normalisation of Data

Raw data collected along the Calibration Strip is corrected for tyre wear (as per section 4.1), then compared to the benchmark values (as per section 4.3) and thus the Normalisation value is calculated. This value is added to all raw data to determine "normalised" friction values.

e. Harmonisation of Data

Once the data has been normalised, the harmonisation constants A and B can be applied to the data to determine harmonised friction values.

7.0 IMPLEMENTATION OF METHODOLOGY BY SYDNEY AIRPORT

The implementation of the methodology at Sydney Airport was a two step process.

A. Determination of Harmonization Constants

In August 2003, Sydney Airport held a Runway Friction Testing workshop including correlation trials. One of the devices used at the trial had just returned from the manufacturer where it had been repaired and calibrated. This device was used as the reference device.

SACL's friction tester, GT267, was harmonized to the reference device obtaining a correlation co-efficient of 0.97, which is deemed to be an acceptable level of correlation.

The harmonization constants for GT267 were determined to be;

A = -0.04 and B = 0.95

B. Determination of Calibration Strip benchmark values

As no temperature correction is required with a mean temperature of 20 degrees, extensive testing of the calibration strip was performed in the warmer months of 2003 to determine a benchmark value for the calibration strip.

A number of new test tyres were used and testing was conducted on the evenings of the 14-17 January 2003. The analysis of the results indicated that the average result (CBv) was **0.88**.

7.1 Results of Methodology

In 2003, Sydney Airport collected data along Runway 16L/34R on five occasions. The results are presented in the table below ;

Rwy 16L - Friction Results	17/01/2003	22/03/2003	17/08/2003	23/10/2003	11/12/2003
Central Third Average	0.68	0.73	0.75	0.72	0.8
Tyre Diameter	256	254	259	258	253
Adjusted Friction Value	0.70	0.77	0.76	0.73	0.85
Harmonisation (A=-0.04, B = 0.95)	0.63	0.69	0.68	0.65	0.76
Cal Strip Average	0.83	0.90	0.87	0.82	0.96
Normalisation (CBv = 0.88)	0.05	-0.02	0.01	0.06	-0.08
Calculated Friction Value	0.67	0.67	0.69	0.71	0.69

The “central third average” represents raw friction data collected along the 3 m offset of runway 16L and is the average friction value for the central third of the runway.

The testing raw data returned a maximum of 0.80 and a minimum of 0.68 with an average of 0.74. However the variability was +/- 0.06 or 8%.

After each test, the diameter of the test tyre was measured and data was collected along the calibration strip. When this methodology is applied to the raw data ;

a. the maximum value decreased to 0.71 and the minimum value decreased to 0.67 with an average of 0.69
b. the calculated friction value was on average 0.05 lower than the raw data.
c. the calculated friction value tolerance was +/- 0.02 or 2.9%.

8.0 NATIONAL FRICTION TESTING PROGRAMME

The friction testing of runways in Australia is not common practice as the regulatory body, CASA’s only requirement relates to surface texture. The recent modifications to the Manual of Standards (MOS) require some airports to implement friction testing from 2006.

In 2002/03, Sydney Airport commenced a project titled “ The National Friction Testing Programme”

The purpose of this research and development project is to develop a methodology for the analysis of runway friction testing data that can be utilised by all airports within Australia to ascertain the frictional properties of their respective runway surfaces as a maintenance tool, and also as a regulatory tool from 2006.

8.1 Goals of Project

The research project is expected to be completed by the end of 2005. Its goals include ;

- To develop a series of test pavements at Sydney Airport for use by all airports to harmonise their data against international friction values

- To develop a Calibration Strip at each airport taking part in the project for their use to normalise friction testing data.

- To verify and develop the proposed methodology for the analysis of runway friction testing data.

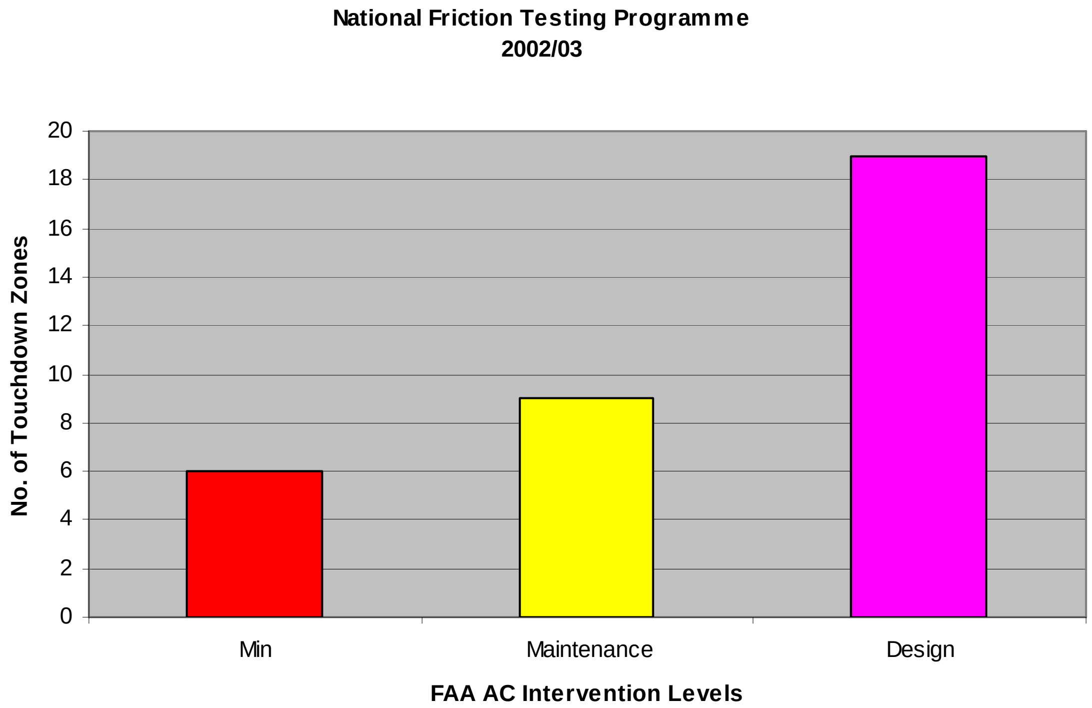
- To provide airports with reliable friction testing data

8.2 2003 Test Results

Fourteen airfields were tested in Stage 1 of the works (Nov 02 – Mar 03) including;

- 8 commercial airports (from Code C domestic to Code E International)
- 4 defence airfields and
- 2 joint user (defence/commercial) airports

Under this programme, eighteen (18) runways were tested in various part of Australia where conditions during testing varied from +40 degree Celsius in the northern parts of Australia to 5 degrees Celsius in the southern parts.



During this programme, thirty six (36) touchdown zones were tested and the results of the raw data (no harmonization or normalization) showed that ;

- 42% were below the maintenance planning level;
- 1 in 6 did not comply with minimum friction levels stipulated within the FAA Advisory Circular [2]

These statistics demonstrated the effects of variation of friction values caused by temperature and tyre wear.

8.3 2004 Test Results

Following the Sydney Friction Workshop in August 2003, SACL undertook the “same’ programme again, this time armed with the temperature and tyre wear equations listed in section 4 of this paper.

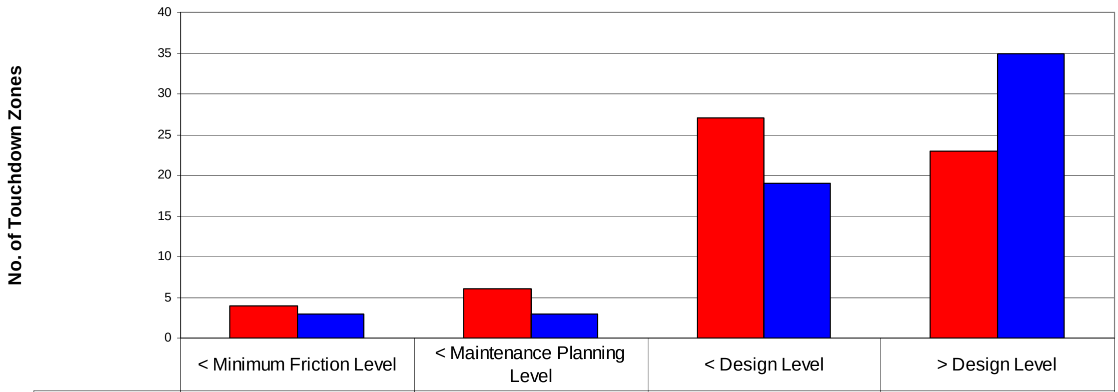
In the 2004 programme, many new airports (11) joined the programme. These airports predominately had maximum Code C operations.

Thus, the twenty five (25) airfields that were tested between Feb – May 04 included;

- 16 commercial airports
- 6 defence airfields and
- 3 joint user (defence/commercial) airports

The results of the programme are show below ;

Australian Runway Friction Testing
Results of Testing Programme 2003/04



	< Minimum Friction Level	< Maintenance Planning Level	< Design Level	> Design Level
Raw Data	4	6	27	23
Analysed Data	3	3	19	35

During the 2004 programme, sixty (60) touchdown zones were tested and the results of the raw data (no harmonization or normalization) vs calculated data are illustrated in the above graph. The results of the comparison indicated that if the methodology is accurate ;

– one in three (3) runways tested were below the maintenance planning level. When the methodology is applied this reduced to one in 5.
– one in seven (7) did not comply with minimum levels. When the methodology is applied this reduced to one in 10.

Thus, if the methodology proposed by this paper were accepted, then the use of raw friction testing data and the interventional levels stipulated in the FAA Advisory Circular [2] ;

a. 40% error rate in identification of runways that require rubber removal
b. 25 % error rate in identification of runways that exhibit friction levels that are below the minimum level stipulated in the FAA Advisory Circular [2] ;

8.4 Current Programme

In FY2005, all airports included in stage 2 of the project are to be retested. The results of the works shall be compared to the Stage 2 works.

For each airport three (3) sections of runway pavement in the central third of the runway shall be selected and compared to the 2004 data.

For the experiment to be considered a success, 95% of the 70+ sections around Australia must show friction results (GripNumber) within 0.03 of the previous years result.

9.0 CONCLUSIONS

For airport engineers who are new to runway friction testing this paper will provide a methodology for the analysis of data so that they can more confidently establish that their runways conform to the relevant international standards.

10.0 REFERENCES

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