RUNWAY FRICTION PERFORMANCE IN NZ

Toan, DV

Technical Director, Beca Infrastructure Ltd, Auckland, New Zealand

ABSTRACT

This paper presents observations and friction data gathered in the last 10 years from a number of international and regional airports in New Zealand. The pavement types and age varied from concrete to asphalt; grooved and ungrooved asphalt, old and new asphalt, standard road mixes, FAA mixes and Superpave mixes. Analyses consider the effects of ageing and rubber build up. Comments are offered on various methods for rubber removal and improving friction characteristics.

KEYWORDS

New Zealand Runways, Friction, Age, Concrete, Asphalt.

1. INTRODUCTION

Friction on a runway is, of course, a key pavement characteristic for the safe operation of aircraft. Friction needs to be sufficiently high to allow directional control of aircraft on landing and efficient braking over the available runway distance.

Runway friction is currently highly topical due to the debate over the wish to specify mandatory grooving of the surfacing balanced against the high cost of grooving, reduced expected life and environmental impact of noise created by the grooving process.

Measurement of friction is a prudent approach to verifying available friction that allows timely planning of corrective action, if and when necessary.

The following paper presents observations on various surfacing types and variations of friction with climatic conditions and age and some examples of measured levels of frictions. Comments are also offered on methods of restoring and/or improving friction characteristics.

2. BASICS OF RUNWAY FRICTION

2.1 DEFINITIONS

- The amount of friction derived from the top of the pavement surface is the level of *skid resistance.* This resistance could be divided into two interrelated components: microtexture and macrotexture.
- *Microtexture* is the fine degree of roughness felt by touch (i.e. good friction can be likened to the feel of new rough sandpaper).
- *Macrotexture* is created by the coarser visible texture depth which has the dual functions of allowing paths for water to escape and causes distortions (or hysteretic losses) to the aircraft tyre rubber where it contacts the exposed rock aggregate asperities.
- Microtexture tend to control the level of skid resistance at speeds below 60-70 kmh, and macrotexture becomes more dominant at speeds above 90-100 kmh. Refer to Figure 3.1, (Ref. JWH Oliver, 2003).
- *Aquaplaning* is said to have occurred when the tyre rubber is separated from the pavement surface by a layer of water. This has severe impact on aircraft landing ‘’long’’ with reduced runway length in front or where aquaplaning occurs only on one side of the aircraft.

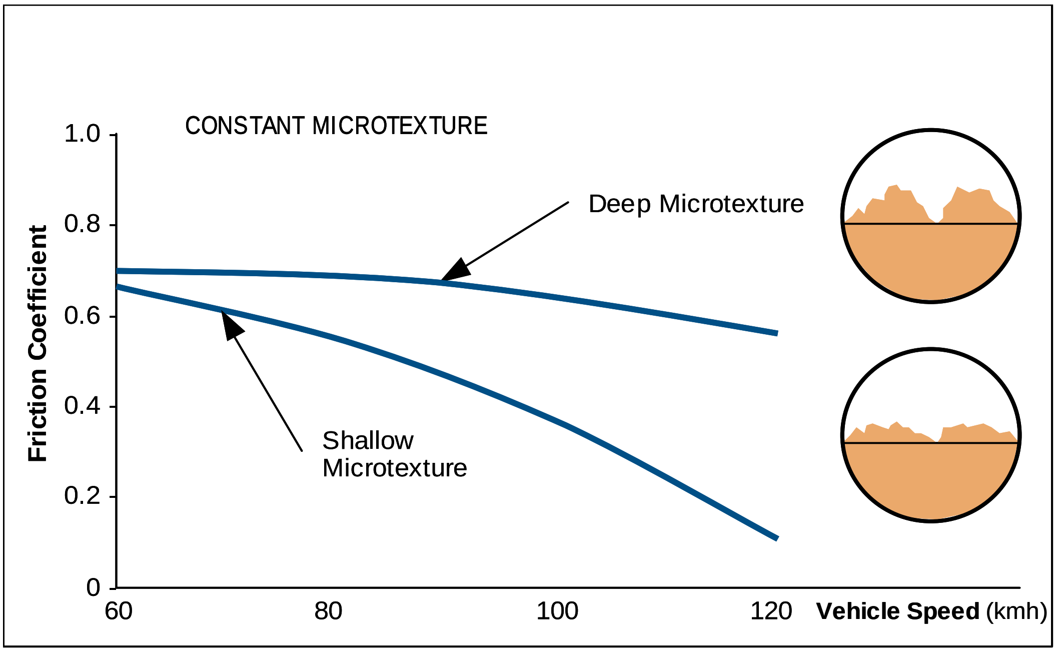

Fig 3.1 Effects of Texture on Friction
(Ref. JWH Oliver, ARRB Transport Research, 2003)

2.2 FACTORS AFFECTING MEASURED FRICTION

- *Scatter* occurs due to point to point variations on the pavement surface which is to be expected; the friction data is only relevant when averaged over a distance of 100-150m, which is commensurate with the speed of landing aircraft (about 250kmh) even though spot measurements over 10m are routinely taken.
- *Temperatures* be it air, tyre and pavement all combine to affect the level of skid resistance: the warmer and therefore softer the rubber the higher the levels of measured friction.
- *Age* of the test tyres would also affect the levels of measured friction as age tend to stiffen the rubber thereby reducing the measured level of friction.
- *Depth of tread* also affects the measured level of friction as it affects the amount of distortion or hysteretic losses in the rubber, the less the depth of tread the stiffer the rubber and therefore the lower friction measured [Wilson et al, 2003].
- In *long dry periods,* the time elapsed since the last rain before the test run will also have an influence on the results due to the effects of pollutants accumulated on the pavement surface. [Cenek et al, 2003]. On being wetted, some of these pollutants would float to the surface and the petroleum based pollutants from fuel, hydraulic fluids or oil drips would have the most negative effects. (Refer Figure 3.2 from Bennis et al, 2003).

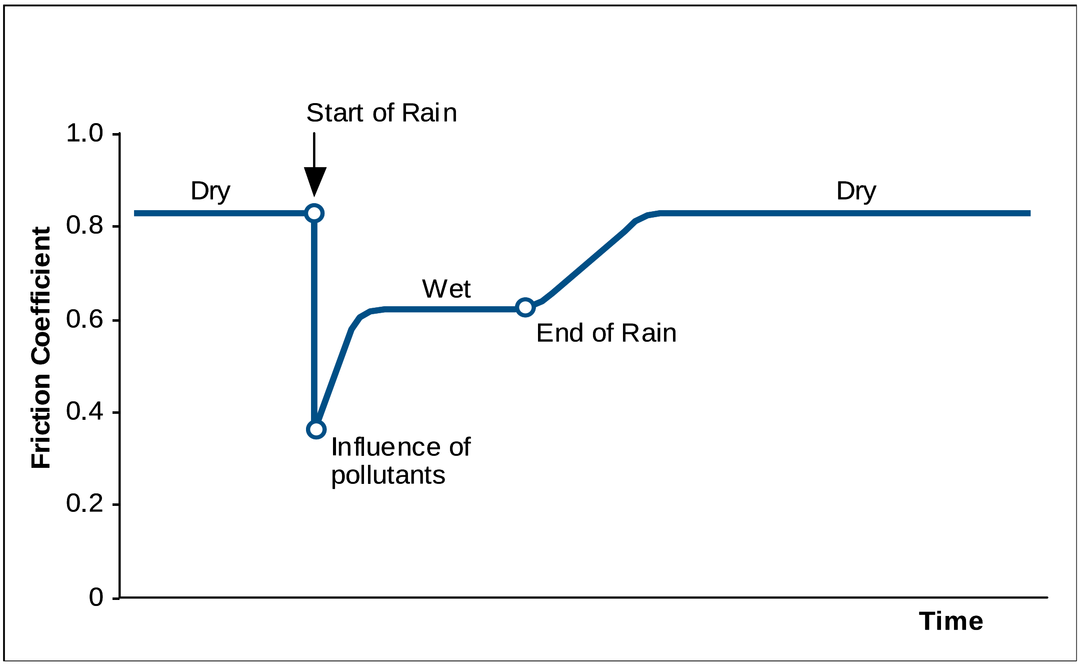

Fig 3.2 Influence of Pollution on Friction
(Bennis et al, 2003)

3. SURFACING TYPES AND FRICTION CHANGES WITH AGE

3.1 CONCRETE

- Initially a new concrete surface (for example, with broomed finish) would have a temporary low friction due to the natural loose concrete dust on the surface. This dust can be expected to be washed away by rain and/or blown away by jet blast or prop wash in a relatively short time (a few weeks).
- Once the surface dust is lost the sand particles will become exposed providing a relatively long period of good friction, depending on the texture depth created by the finish treatment used (10-20 years).
- With time, as the texture depth reduces due to wear, the friction will gradually become lower.
- In the long term (after 30 years or so) this situation self-corrects as more fines and laitance are lost exposing the larger aggregates particles thereby restoring the rough macrotexture (provided good quality crushed aggregates had been used).
- On very busy runways, or with the use of low polished stone value aggregates, it is possible for the edges of the coarse aggregates to become rounded or worn smooth, thereby reducing the effective surface friction.

Fig 4.1 shows typical values of friction from a broomed concrete using crushed basalt aggregates.

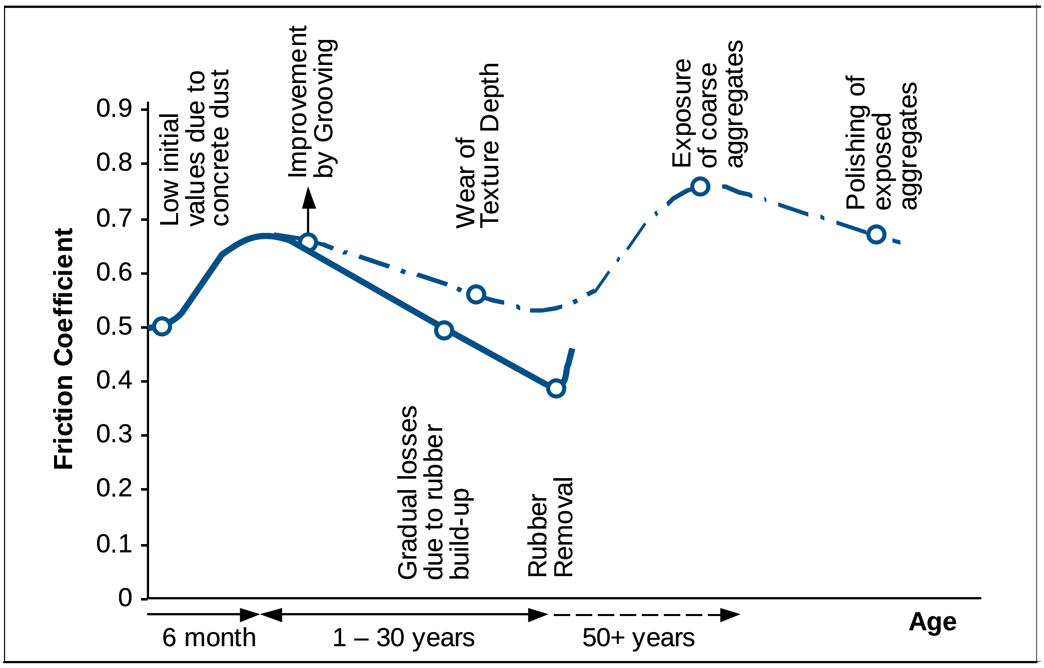

Fig 4.1 Variation in Friction with Age of a Concrete using Crushed Stone

1.1 ASPHALTIC CONCRETE

- There is a period of low initial friction for a freshly laid AC surfacing due to the residue of petroleum products and the bitumen coating on the aggregates. The residues are quickly lost due to either rain or evaporation (a few weeks) on exposure to the air and the bitumen coating is rapidly worn off (a few months).
- The AC friction then remains relatively constant for a long period, depending on the wear resistance of the aggregates (10-20 years). Aggregates with high polished stone values will tend to keep their operating friction characteristics for longer (up to 25 years or more).
- AC in New Zealand tend not to last long enough for the exposed stones to become worn smooth on runways; the life of the AC is limited by ageing i.e. embrittlement, loss of fine aggregates and/or fatigue (15-20 years).

Figure 4.2 shows the typical variations in friction values of an AC over it's life.

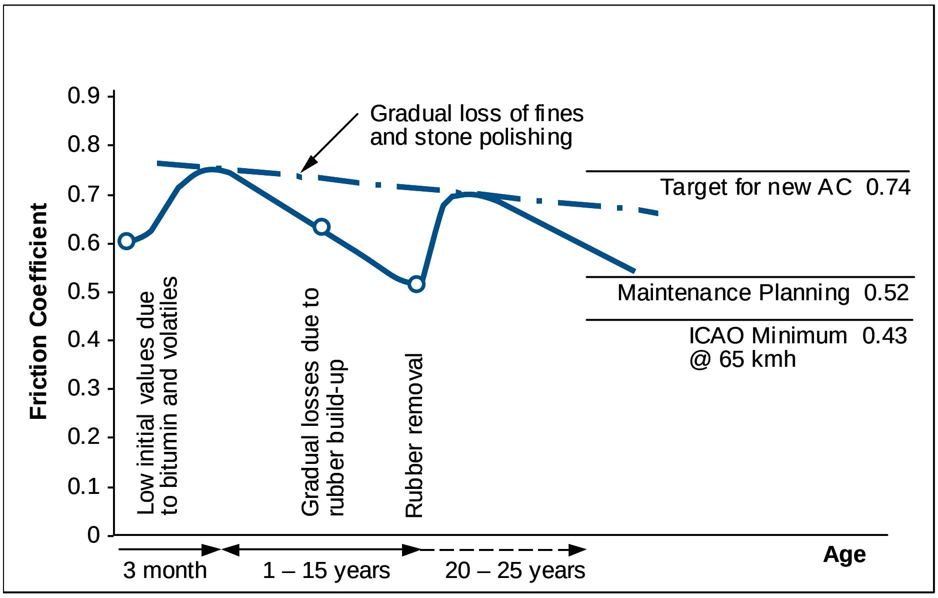

Fig 4.2 Variation in Friction with Age of an Asphaltic Concrete using Crushed Stone

4. OTHER FACTORS AFFECTING FRICTON

Besides age, other factors that will affect friction characteristics of the pavement surfacing are: weather, pollutants and rubber build-up.

4.1 WEATHER

Weather has a significant effect on friction on a runway.

Friction would naturally be at it's highest in dry weather. However in long, dry spells the pavement surface tend to accumulate pollutants such as fuel, hydraulic fluids and oil drips, dust etc.

After such periods of dry weather, friction could become for a short period (0.5-1.0hour) dramatically reduced in heavy rain. This is due to the flushing to the surface of the petroleum based pollutants in combination with the film of water causing friction to drop. Once the rain run-off is sufficient to remove the pollutants a higher ''wet friction'' level is achieved.

Figure 3.2 shows the likely variations in friction due to changes in climatic conditions [Bennis et al, 2003].

4.2 RUBBER BUILD UP

Table 5.1 shows the ICAO observation approach to assessment of rubber build up and Table 5.2 shows the recommended frequency of observations or testing.

It is noted that the matt rubber laid down by landing aircraft is relatively benign, whilst the vulcanised shiny build up due to repeated landing over the same stretch of pavement does adversely affect friction. This is due to both the reduction in macrotexture as the rubber fills in the hollows and loss of microtexture as the rubber coating smoothes over the surface asperities.

Table 5.1 – Inspection Method For Visual Estimation of Rubber Deposit Accumulated On Runway
(Ref, ICAO Services Manual, Part 2)

Track Marks	Exposure	Classification of Rubber Deposit Accumulation Levels	Estimated Range of Mu Values Averaged 500 Foot Segments in Touchdown Zone	Suggested Level of Action To Be Taken By Airport Authority
Intermittent tracks	95% exposed	Very Light	0.65 or greater	None
Tracks Overlap	80% to 94%	Light	0.55 to 0.64	None
Central 5m covered	60% to 79%	Light to Medium	0.50 to 0.54	Monitor
Central 12m covered	40% to 59%	Medium	0.40 to 0.49	Removal in 120 days
Central 15m covered, 50% vulcanised and bonded to pavement	20% to 39%	Medium to Dense	0.30 to 0.39	Removal in 90 days
75% vulcanised and bonded	5% to 19%	Dense	0.20 to 0.29	Removal in 60 days
Completely vulcanised and bonded, rubber glossy	0% to 4%	Very Dense	Less than 0.19	Removal in 30 days or ASAP

Table 5.2 – Friction Survey Frequency
(Ref, ICAO Services Manual, Part 2)

Daily turbo-jet aeroplane arrivals for runway end	Annual aeroplane weight for runway end (million kg)	Minimum friction survey frequency
Less than 15	Less than 447	Once per year
16 to 30	448 to 838	Once every 6 months
31 to 90	839 to 2 404	Once every 3 months
91 to 150	2 405 to 3 969	Once every month
151 to 210	3 970 to 5 535	Once every 2 weeks
Greater than 210	Greater than 5 535	Once every week

Table 5.3 shows the ICAO recommended target friction values for new pavements, trigger levels for surface rehabilitation planning and minimum levels which should trigger notices to Airmen (NOTAM).

To address the gradual drop in friction or skid resistance it is necessary to remove the rubber build up. Various methods are available to either chemically break up the vulcanised (shiny) build-up or the thinner (matt) rubber laid down by the aircraft tyres on touch down. The chemicals available are considered, in New Zealand, to be environmentally unfriendly and mechanical methods are required.

Of the mechanical methods e.g. power-wire-broom, sand-blasting and water-blasting, water-blasting has been found to least degrade the pavement skid resistance. Both power brooming and sand blasting tend to leave the surface smoother i.e. with reduced macrotexture and although rubber is removed, so are surface asperities and texture depth. Water blasting also results in some loss of texture depth but less wear on the rock asperities: the effect on friction is less, which is attributable to the lower degree of polishing of exposed aggregate edges by the water.

The most effective method of water blasting is the use of machines with high pressure, low volume jets via ruby nozzles in either fixed arrays or revolving turrets.

These fine nozzles, when used with skilled control, could also re-establish texture depths. Examples of this improvement in texture are in concrete where matrix and sand could be preferentially worn-off relative to the coarser aggregates; similarly in asphaltic concrete the water jets could be used to remove excess bitumen (in the case of flushing) and fines (in the case of fatty mix) to re-establish surface texture.

Figure 6.1 shows the typical reduction in friction over landing zones on a runway.

Table 5.3 (extract from ICAO Annex 14 Attachment A)

Test equipment	Test tyre		Test speed (km/h)	Test water depth (mm)	Design objective for new surface	Maintenance planning level	Minimum friction level
	Type	Pressure (kPa)					
(1)	(2)		(3)	(4)	(5)	(6)	(7)
Mu-meter Trailer	A	70	65	1.0	0.72	0.52	0.42
	A	70	95	1.0	0.66	0.38	0.26
Skiddometer Trailer	B	210	65	1.0	0.82	0.60	0.50
	B	210	95	1.0	0.74	0.47	0.34
Surface Friction Tester Vehicle	B	210	65	1.0	0.82	0.60	0.50
	B	210	95	1.0	0.74	0.47	0.34
Runway Friction Tester Vehicle	B	210	65	1.0	0.82	0.60	0.50
	B	210	95	1.0	0.74	0.54	0.41
TATRA Friction Tester Vehicle	B	210	65	1.0	0.76	0.57	0.48
	B	210	95	1.0	0.67	0.52	0.42
Griptester Trailer	C	140	65	1.0	0.74	0.53	0.43
	C	140	95	1.0	0.64	0.36	0.24

5. NEW ZEALAND FRICTION DATA

Table 6.1 shows typical values from Beca's project files of friction from Mu Meter and Griptester equipment. The figures given are all averages for friction test runs. When two figures are shown, these correspond to test runs each way along the wheel tracks of the runways, about 3m to 5m from the centre line.

Of note are the relatively small improvement gained by grooving (see the 1996 to 1997 friction values for Runway W). However, the good level of friction achieved continued to be maintained for many years. Also note the improvement following rubber removal in the +5 years results.

Figure 6.1 shows the effects of friction losses due to rubber build up in the touch down zones (Ref. Opus 2004).

Table 6.1 NZ Airport Friction Data (Beca Database)

Surface Type	Date	Test Speed (kmh)	Equipment	Friction (Average)
AC (Runway I)	1995	96	Mu Meter	0.58-0.63
AC (Runway D)	1995	95	Mu Meter	0.58-0.60
AC (Runway C, Grooved)	1995	96	Mu Meter	0.67-0.71
AC (Runway C)	1995	96	Mu Meter	0.50-0.56
AC (Runway W)	1996	65	Griptester	0.63-0.66
AC (Runway W, Grooved)	1997	65	Griptester	0.74
		95	Griptester	0.64
AC (Runway W, Grooved	1998	65	Griptester	0.71-0.75
+1 year)		95	Griptester	0.63-0.64
AC (Runway W, Grooved	2001	65	Griptester	0.72
+ 4 years)		95	Griptester	0.60
AC (Runway W, Grooved	2002	65	Griptester	0.74-0.77
+ 5 years and rubber removal)		95	Griptester	0.66-0.68
AC (Runway N, Slurry Sealed)	1999	65	Mu Meter	0.74-0.80
		95	Mu Meter	0.75-0.78
AC (Taxiway, Superpave)	2002	65	Griptester	0.72-0.75
		95	Griptester	0.65-0.67
AC (Runway O, Superpave)	2003	65	Griptester	0.88-0.91
		95	Griptester	0.78.0.84
Concrete (new)	2002	65	Griptester	0.65-0.76
Concrete (waterblasted)	2003	65	Griptester	0.71-0.76
Concrete (30+ years)	2002	65	Griptester	0.78-0.81

Note: AC = Asphalt

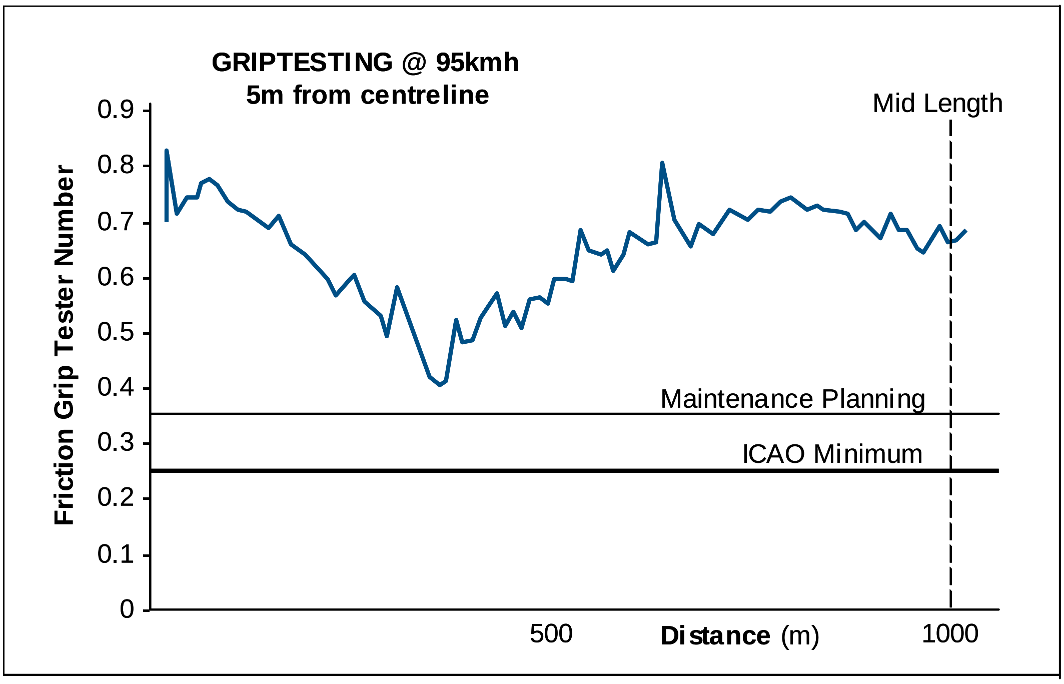

Fig 6.1 Typical Effect of Rubber Build-up
(Ref. Opus, 2004)

6. METHODS OF IMPROVING SKID RESISTANCE

6.1 CONCRETE

Once the exposed aggregate becomes polished it is likely that the friction characteristics of a concrete would reduce to become marginal. A method of restoring friction would be to lightly grind the surface, this would restore microtexture to the exposed coarse aggregates and also expose their sharpened edges. To restore the macrotexture it is possible to judicially use high pressure water blasting to remove some of the matrix fines.

An alternative would be to groove the surface which would achieve an improvement to the macrotexture. Groves cut 6mm wide and about 8-10mm deep leaving shoulders about 20-30mm wide would provide an improvement of about 0.15 to 0.20 relative to the ungrooved surface (based on Griptester tests with 1mm of water at 95kmh).

Under normal circumstances, with sound rocks used as aggregates, it is not likely that the concrete surfaces would polish so much as to require rehabilitation to restore friction during it's design life (20-40 years). The limitation to the life of the slabs are more likely be due to overloading (growth in aircraft weight) and/or fatigue.

6.2 ASPHALTIC CONCRETE.

Besides AC made of aggregates from soft fine grained rocks or those with low polished stone values, it would be unlikely that an AC surface would become so worn as to require friction enhancing work. Any loss of friction within the life of an AC surfacing (10-15 years in NZ conditions) would likely be caused by poor construction (e.g. flushed surface or over-fatty surface with too much fines - excepting of course, the effects of rubber build up discussed above).

With low texture and corresponding low friction caused by a surfacing with too much fines or flushing, a suitable method of treatment that may be effective for the short-medium term would be the use of high pressure water jetting. This technique could be used to remove some of the bitumen/fines matrix to expose more texture depth and thereby improve friction. It is noted that over-use of water jetting could leave a loosened surface, vulnerable to stone losses or stripping.

An alternative technique would be to use a form of slurry sealing (with a tough and long lasting binder) using sharp, crushed stone grit sizes in the medium/coarse sand range. This has shown improvements in Gripster values in the order of 0.1 or better.

Another method of enhancing friction is to groove the AC. The benefits relative to a good AC surface would be a minor improvement (i.e. 0.70 to 0.72 typically) but for an AC surface with poor friction the option is worth considering when balanced against the constraints discussed earlier.

7. CONCLUSIONS

This paper provides some practical remarks and observations on the factors influencing runway friction and shows typical values of friction measured at NZ airports over a variety of surfaces.

8. ACKNOWLEDGEMENT

I wish to thank staff from Dunedin International Airport, Wellington International Airport and Auckland International Airport for the assistance in progressing our understanding of friction characteristics and for the use of the data collected.

9. REFERENCES

10.1 Bennis TA et al, ‘’PIARC State-of-the-Art on Friction and IFI’’, 1st Annual Australian Runway and Roads Fricton Testing Workshop, August 2003.

10.2 Cenek P.D. et al, ‘’Lessons Learnt from Conducting Friction Surveys of Runways and Roads’’, 1st Annual Australian Runway and Roads Fricton Testing Workshop, August 2003.

10.3 Oliver JWH, ‘’Factors Affecting the Correlation of Skid Testing Machines and a Proposed Correlation Framework’’, 1st Annual Australian Runway and Roads Fricton Testing Workshop, August 2003.

10.4 Opus Consultants, ‘’ Skid Resistance Testing, DIAL (project file)’’, September 2004.

10.5 Wilson et al. ‘’Variability of Highway Pavement Skid Resistance – A case study in New Zealand, Northland’’, 1st Annual Australian Runway and Roads Fricton Testing Workshop, August 2003.