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BALANCING ASPHALT RUT RESISTANCE WITH DURABILITY AND SAFETY REQUIREMENTS ON RUNWAY REHABILITATIONS

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Rising to the Challenge!

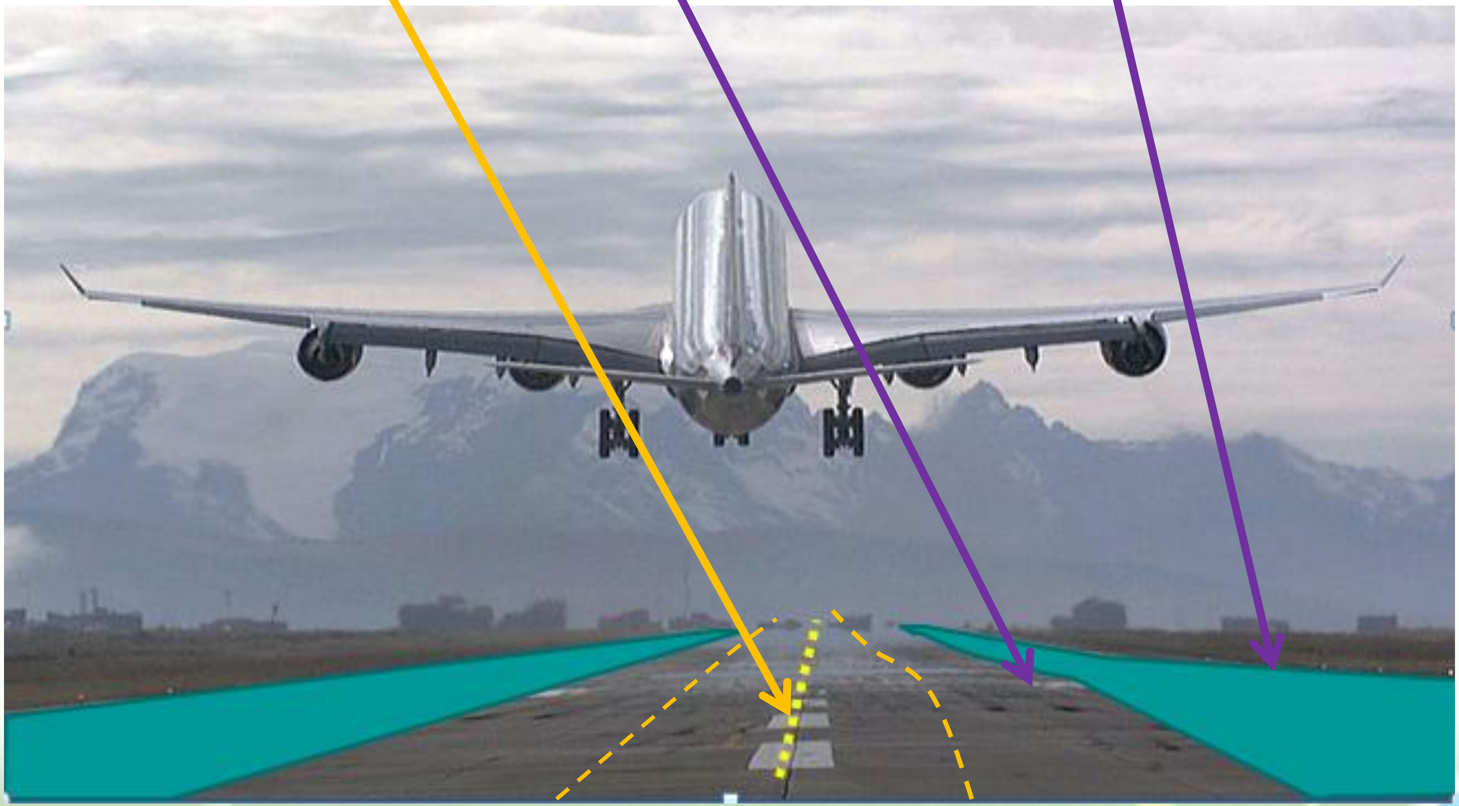
Index or framework

- **Traffic differences roads vs airfields**
- **Permanent deformation- rut**
- **HMA design procedures regarding rut**
- **Predicting or measuring rut**

  (MMLS and RSST-CH lab tetsing)
- **Environmental effects**

  (Stripping & Permeability)
- **Application of lessons learnt**
  - **Waterkloof Airforce Base (WAFB)**
  - **Hosea Kutako International Airport (HKIA)**
- **Conclusions**

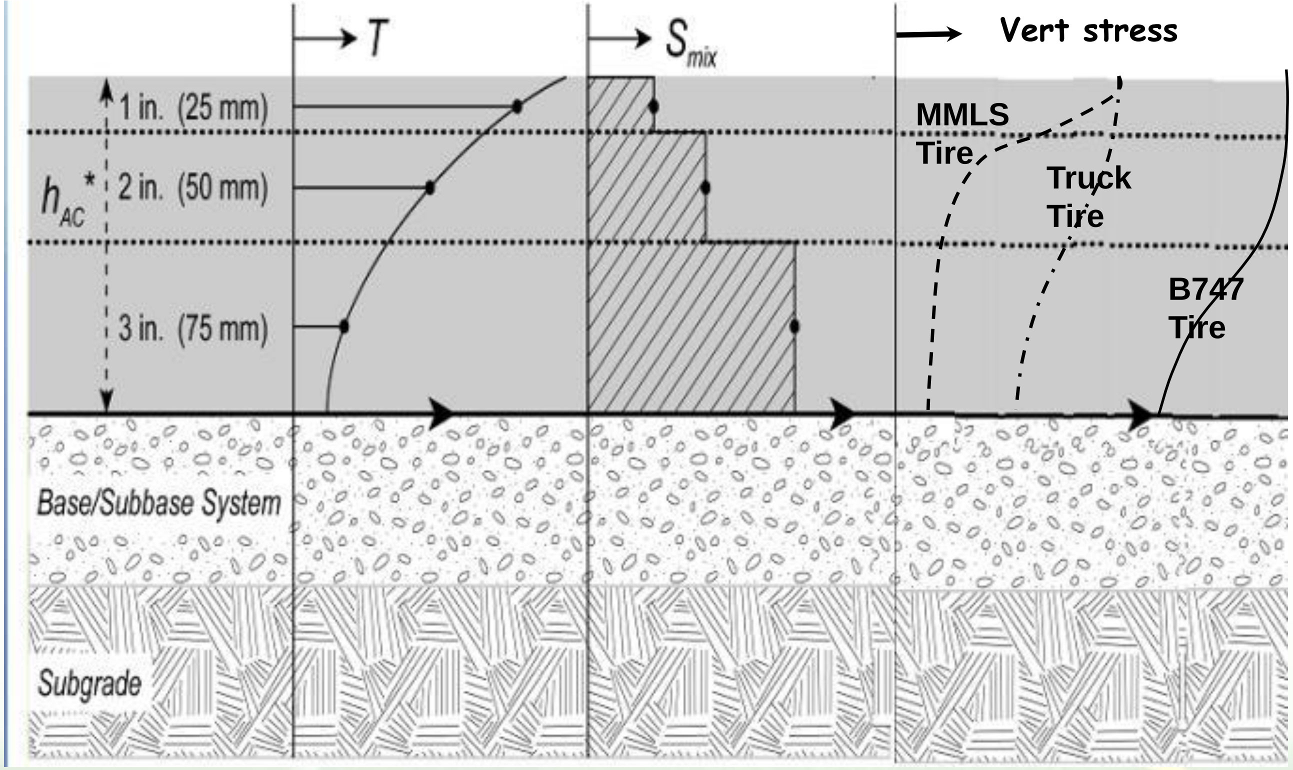
Airport pavements: Much less traffic on their central keel areas than on roads - virtually no traffic on the outer edges and shoulders.



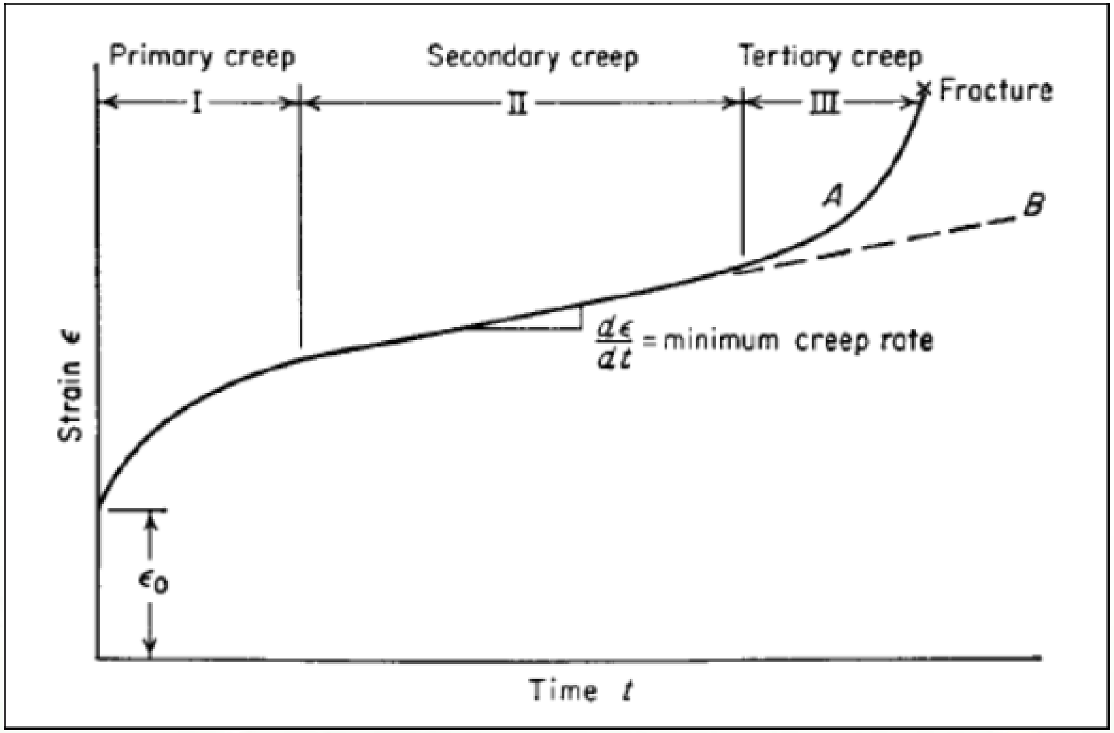
Cooley et al: Superpave application to airport pavements

Creep or permanent deformation

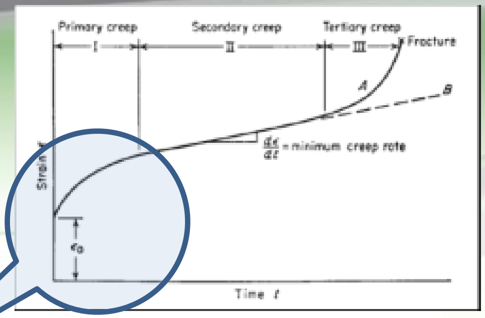
Temperature stiffness and vertical stress distribution in an HMA surface layer (Monismith et al).

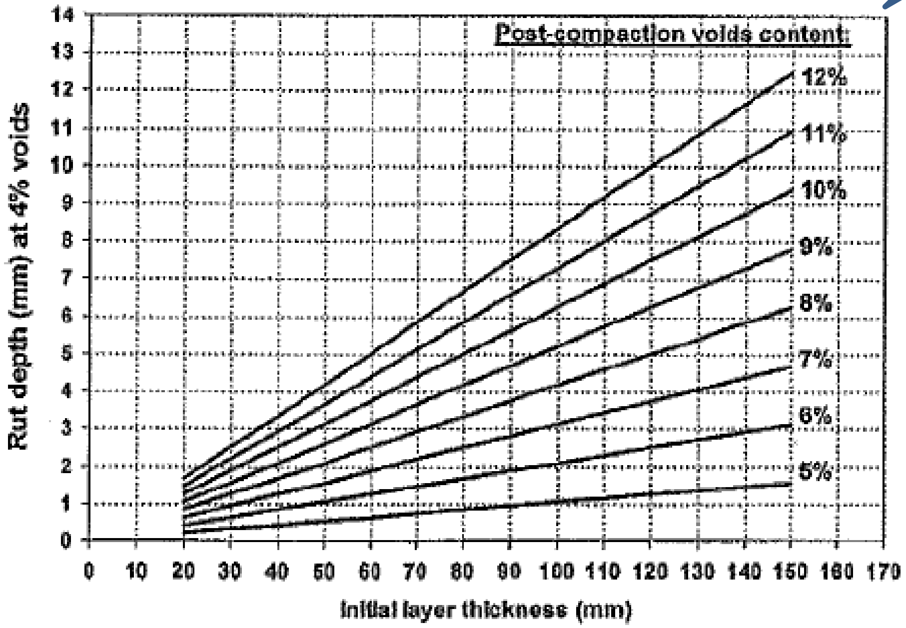


Generic creep behaviour of materials



Phase I compaction due to high void content in HMA

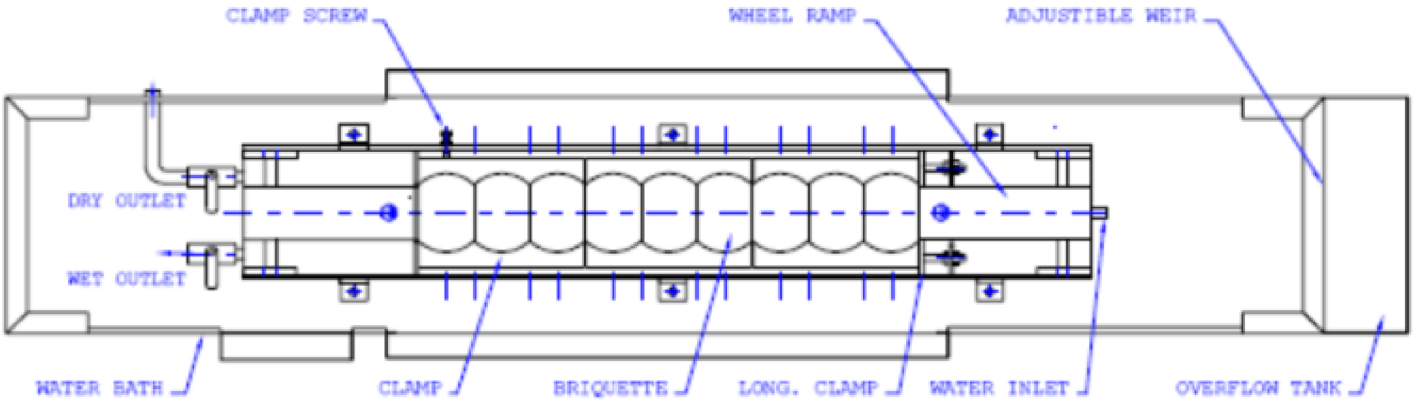


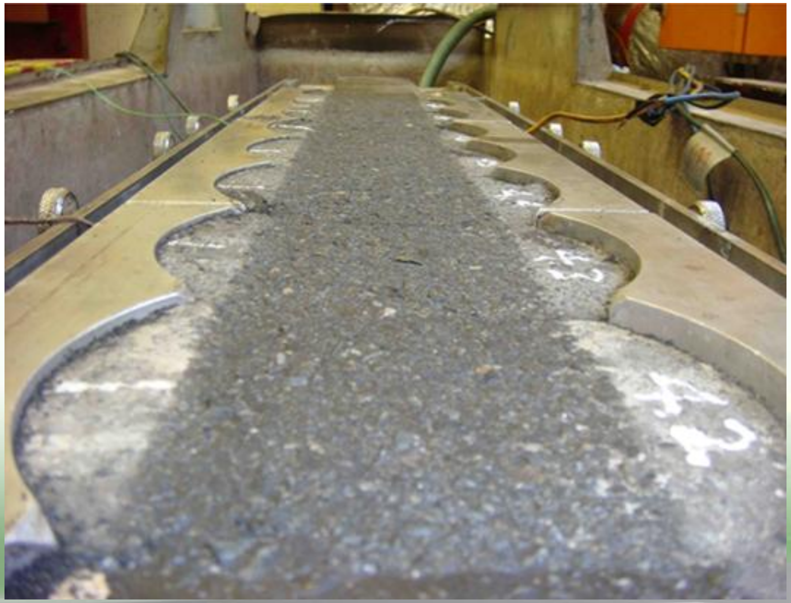


Estimation of rut depth due to initial asphalt consolidation (Verhaeghe et al CAPSA 2007)

Measurement of rut

Plan view of MMLS3 test bed

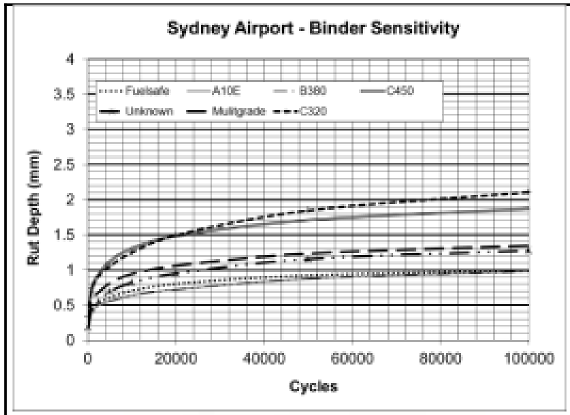


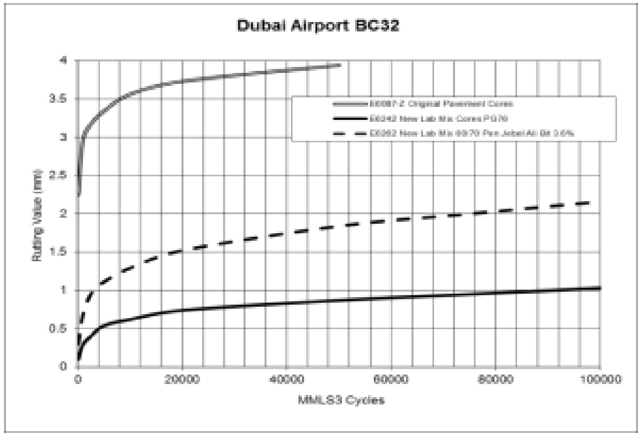


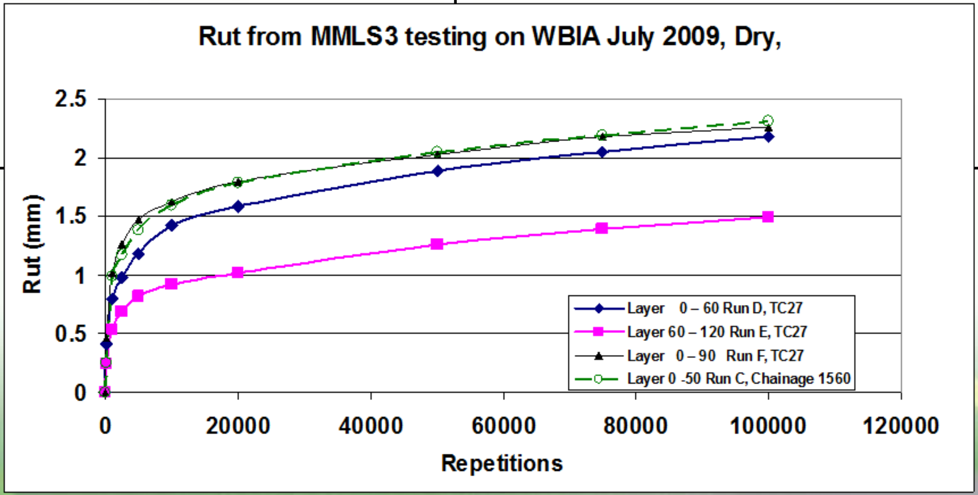
MMLS wheel speed différentiation

Baton Rouge speed protocol

Slower speed application







Rut predictions as calculated with Model Mobile Load Simulator (MMLS) test results for WBIA

Table 1 - Summary of calculated field asphalt rut depths for Walvisbay International Airport (WBIA) runway

Airside Section	Calculated rut depth at design traffic (mm)			
	6,500 departures		20,000 departures	
	Thin asphalt (58mm thick)	Asphalt + thick scratch coat (116mm thick)	Thin asphalt (58mm thick)	Asphalt + thick scratch coat (116mm thick)
Runway	2.9	(2.9+1.7*)=4.6 mm	3.8	(3.8+2.2*)=6.0 mm
Taxiway	3.9	(3.9+2.2*)=6.1 mm	5.0	(5+3*)=8.0 mm
Functional limit	9.0 mm			

*The calculated Relative Stress Potential was calculated to adjust rutting measured in the MMLS to that which would be caused by the design aircraft at the appropriate depth of pavement

Superpave Repeated Simple Shear Test at Constant Height (RSST-CH) apparatus and samples

Prepared Sample (above) and Sample After Test (below)

RSST-CH repetitions versus creep (strain) master curve.

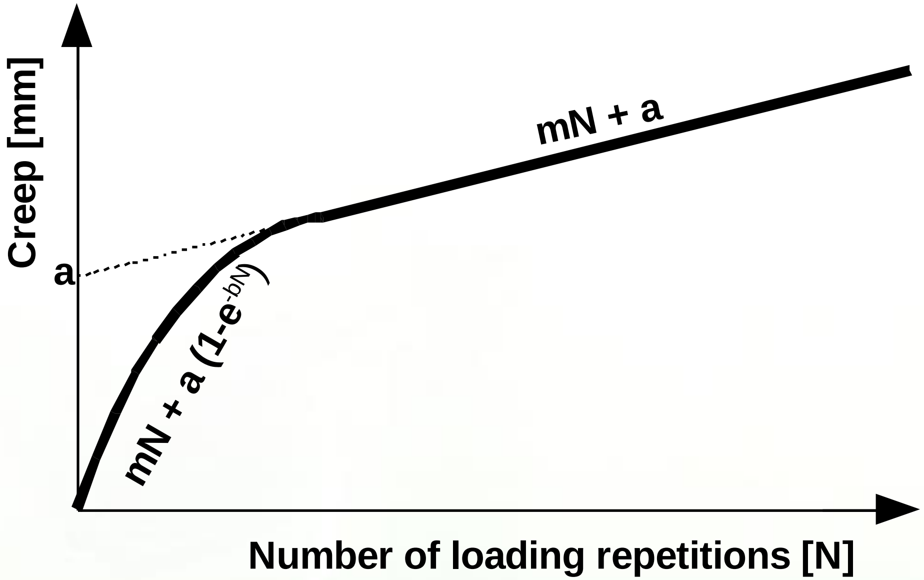


Table 2 - Summary of Repeated Simple Shear Test at Constant Height (RSST-CH) results and associated calculations

Sample	G (Complex Modulus) [MPa]	m [ε/cycle]	a [mm]	Percent strain at 5 000 load repetitions	Percent strain at 25 000 load repetitions	Deacon approximation rut calculation
4642-A	7.25E+01	2.75E-06	3.38E-03	1.7	7.2	4.25mm
4642-B	5.17E+01	6.73E-06	9.23E-03	4.3	17.8	10.75mm
4642-C	5.02E+01	9.09E-06	7.32E-03	5.4	23.5	13.5mm
4642-D	5.83E+01	3.22E-06	1.05E-02	2.5	9.1	6.25 mm
			Average	3.5	14.4	8.75 mm

Environmental Influences

Permeability and stripping on airports

Geometric problems and problems with falling head permeability measurements

- The stripping was undetected by normal visual and instrument surveys.
- Detailed investigations are needed to identify the early signs of stripping.
- Aspects such as void content, film thickness, porosity, permeability measurements and core observations can also be used to arrive at a credible quantification of the problem.

Moisture damage mechanisms :

- **Moisture transport**: Moisture in (liquid or vapour state) infiltrates the asphalt mixture - asphalt binder/mastic - reaches the asphalt binder – aggregate interface.
- The main processes are:
  - infiltration of surface water (water permeability)
  - capillary rise of subsurface water and
  - permeation or diffusion of water vapour.

(Caro et al, 2008)

- **Response of the system: Changes in the internal structure - a loss of load carrying capacity of the material.**
- **The main responses are:**
  - **detachment/debonding**
  - **displacement**
  - **dispersion**
  - **film rupture/micro-cracks**
  - **desorption**
  - **spontaneous emulsification**

(Caro et al, 2008)

Classification of air void connectivity in mixtures (Chen et al)

Permeable **Semi-impermeable** **Impermeable**

Top-down connections

Not fully connected through the material

No connections with the borders, isolated

Permeability K (cm/s)	10^{-2} or higher	10^{-4} to 10^{-2}	10^{-4} or lower
Permeable condition description	Good drainage	Poor drainage	Impervious
Typical asphalt mix	Porous asphalt	Stone Mastic Asphalt	Dense graded

OR Tambo International Airport (ORTIA)
(Main runway 03R 21L overlaid 2006)

Coring (100mm) - Open Graded Friction (OGF)

- two lower layers
  - -Stone Mastic Asphalt (SMA)
  - -Open Graded Asphalt (OGA).

Limited modified Lottman tests. The average value for the wet/ dry ratio values was 76.6%.

Classification of air void connectivity in mixtures applied to OR Tambo International Airport cores after the effect analysis (Chen et al)

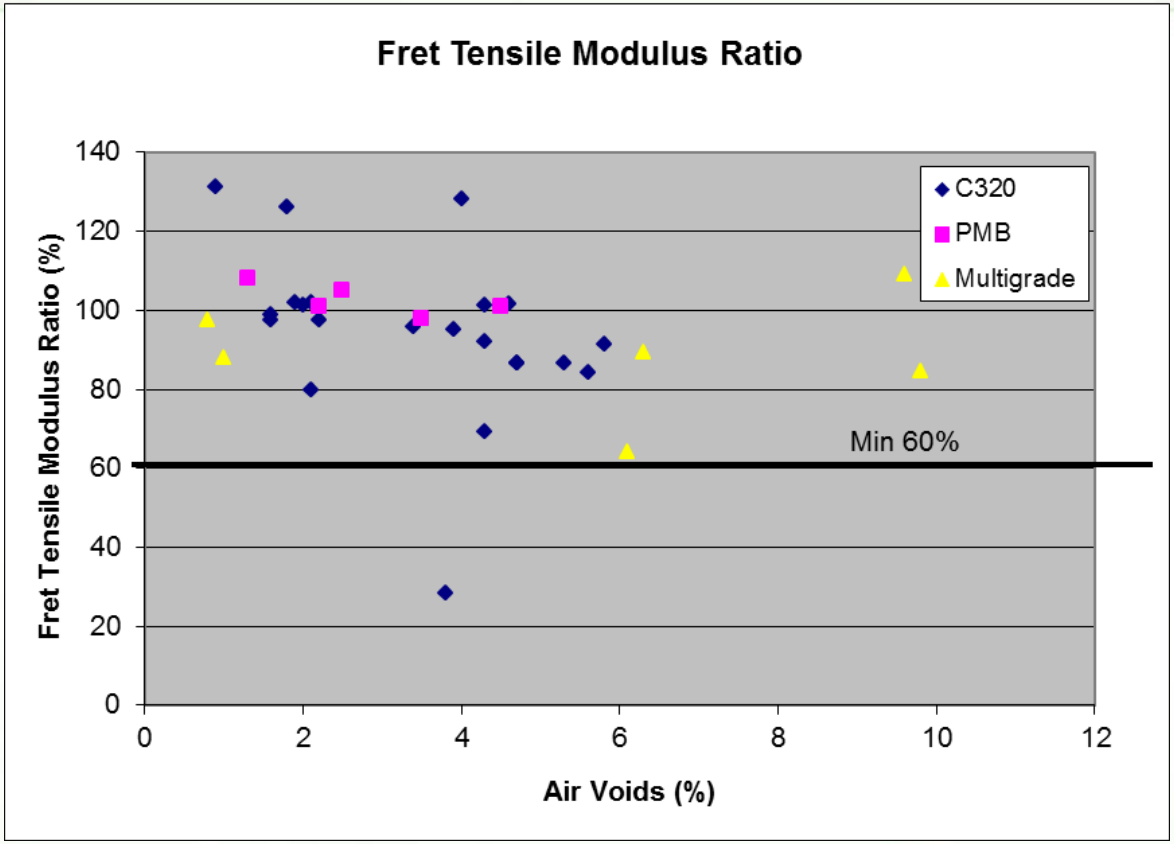
Classification	**Areas cored**		
	Keel area %	**Off-keel area %**	**Total area %**
Permeable	**11**	**20**	**31**
Semi-Permeable	**6**	**7**	**13**
Impermeable	**37**	**19**	**56**
Total	**54**	**46**	**100**

Australian airport stripping statistical analysis found

(Emery et al)

- More stripping in ***taxiways*** than runways,
- Stripping could ***not be related to wheel tracks***.
- Stripping is ***more prevalent in areas with higher annual rai***nfall.
- ***Stripped layers were thinner*** than either the ‘not stripped’ or marginally stripped layers.
- The degree of stripping did not vary by asphalt age- ***Factors other than age cause stripping***.
- The individual in **wetter climates** (mean annual rainfall ***bitumens perform differently in their resistance to stripping***> 1000 mm),
- Hot mix asphalt:
    - ***Unmodified bitumen*** (Class 320, similar to 40/50 pen) -***more likely to be stripped,***
    - ***Multi-grade bitumen*** (Class 1000/320) -***less likely to be stripped***,
    - ***Polymer-modified bitumen*** (A10E, in the 6% SBS class) - ***slightly more likely to be stripped..***
    - In the ***drier areas*** (mean annual rainfall < 1000mm), ***hot-mix asphalt made with unmodified bitumen appears less likely to strip***.

Typical durability results from Australian airports (Emery et al)

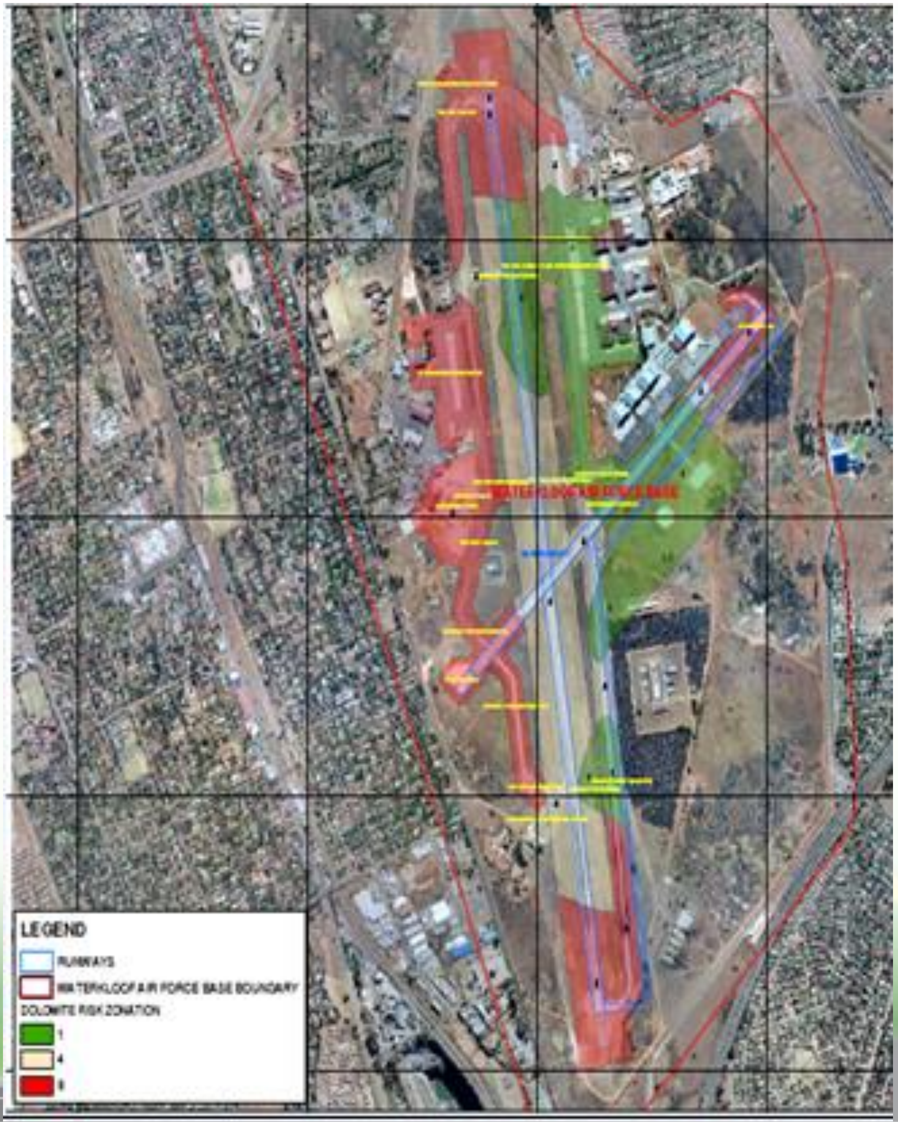


As in the case with OR Tambo ITS wet/dry ratio tests are not reliable as stripping potential

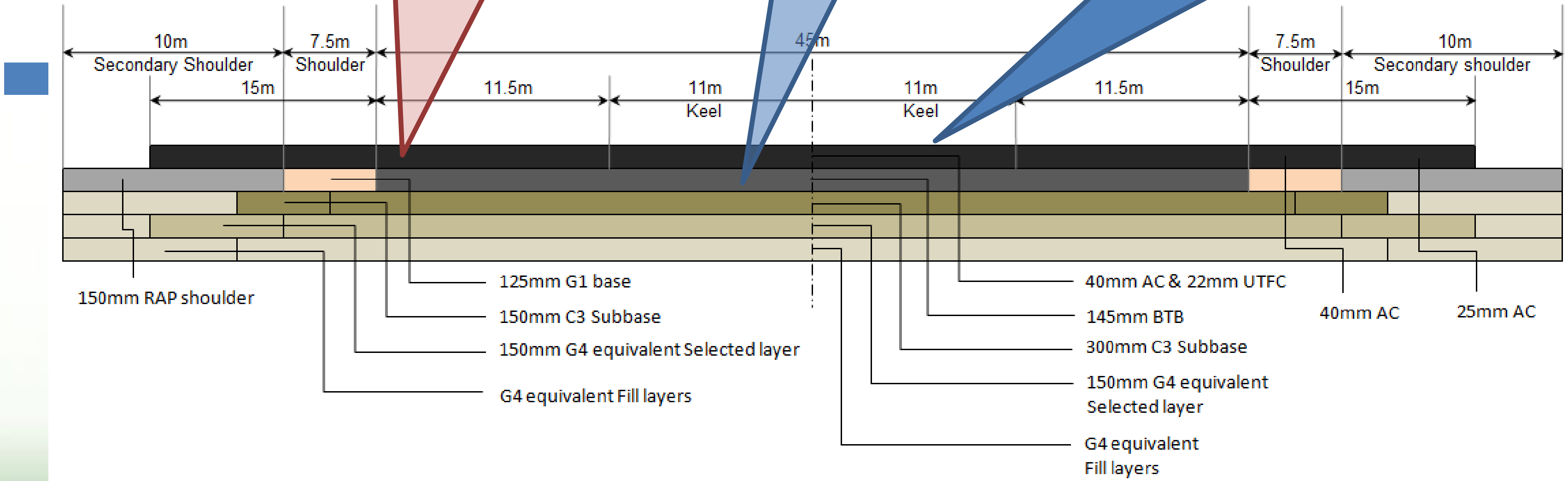
Debonding and delamination on Hosea Kutako International Airport (HKIA)

Putting lessons learnt together

Waterkloof Airforce Base reconstruction due to sinkhole problems



Waterkloof Airforce Base asphalt design

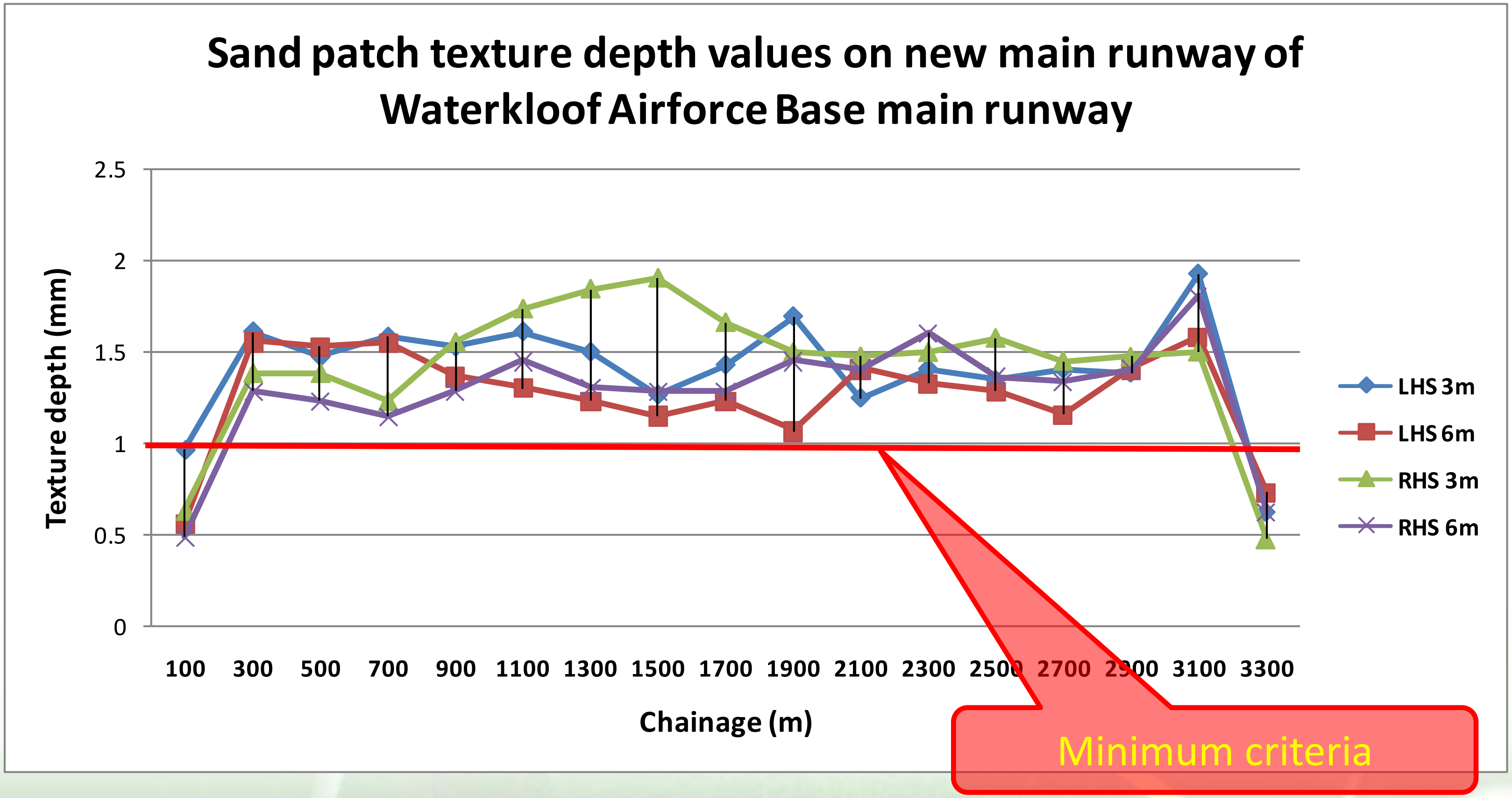


40mm HMA surfacing with SASOBIT WMA compaction aid, bc 5.3%, void content 3% to 5% ,

145mm BTB Continuously graded HMA, bc 4.7%, void content 3% to 6%,

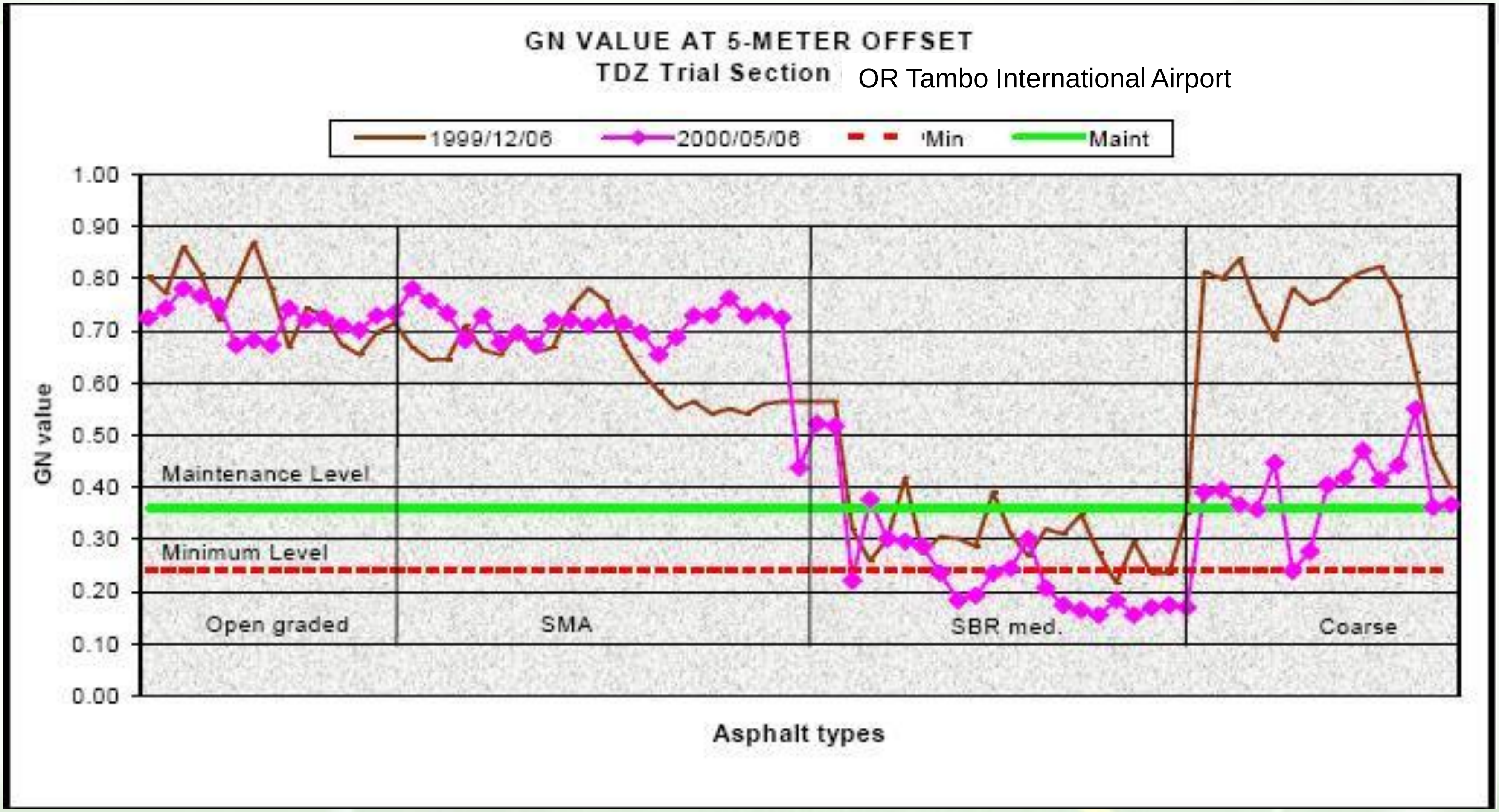
22mm proprietary UTFC

Improved macro texture application on Waterkloof Airforce Base (WAFB) main runway



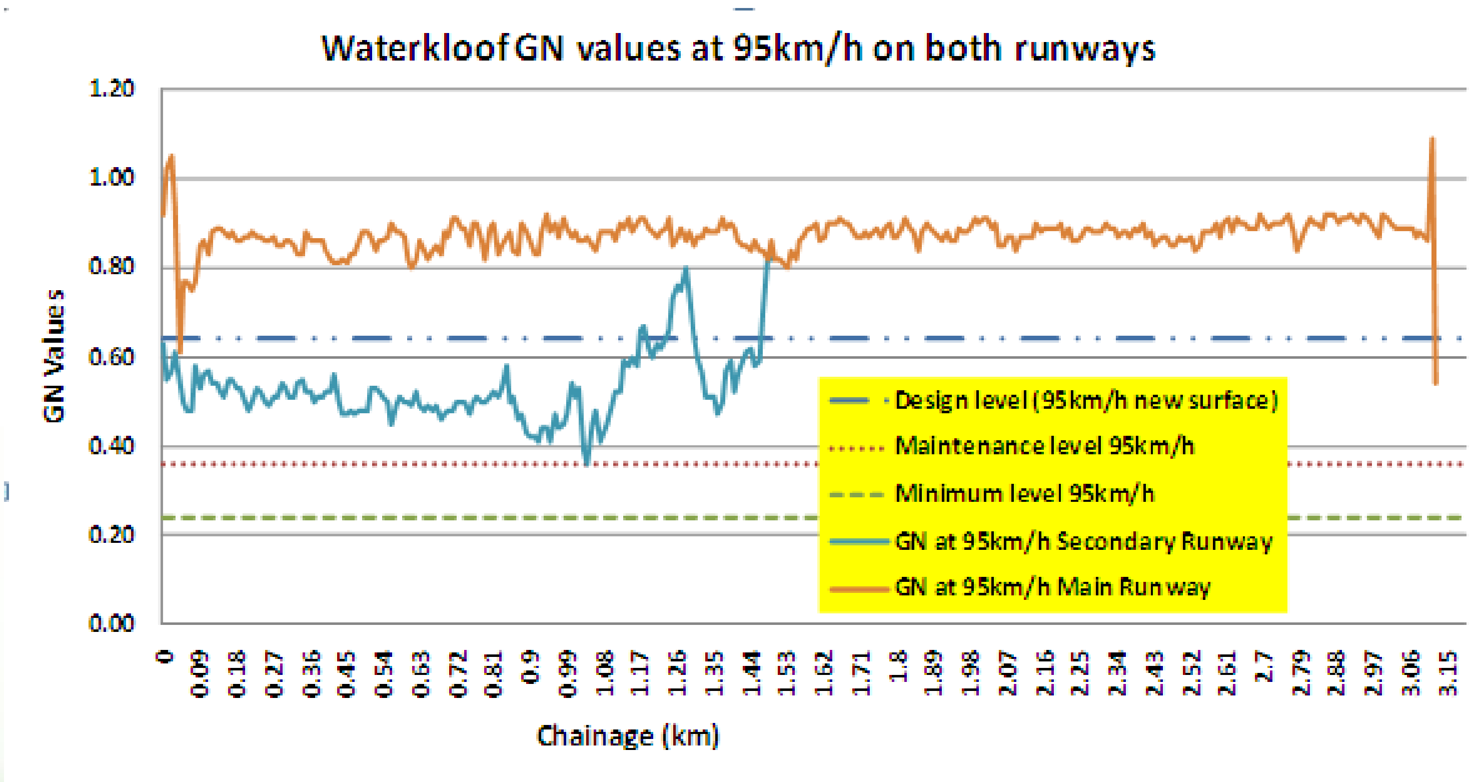
Minimum criteria

Learning from other experiences in SA regarding SFC

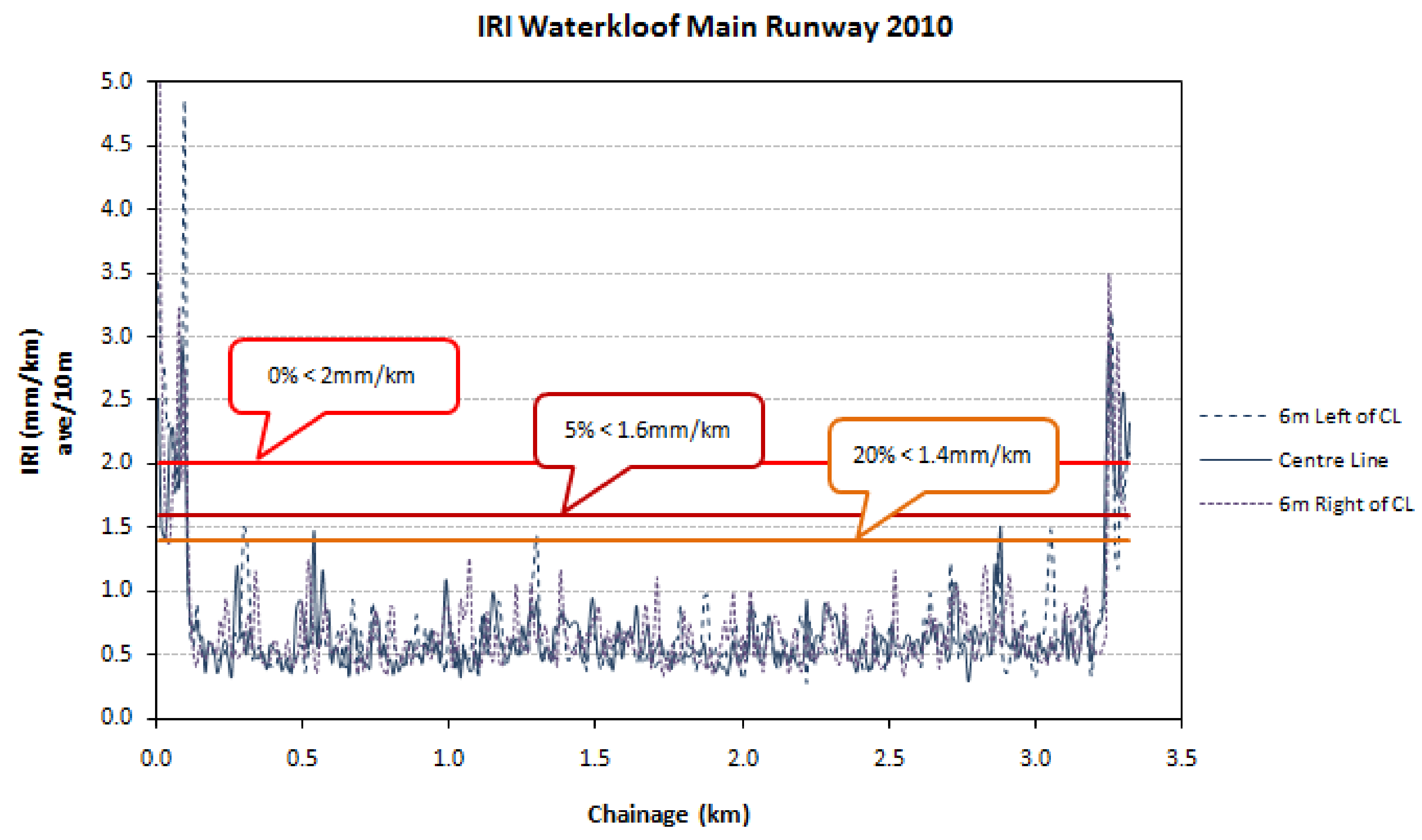


OR Tambo International Airport

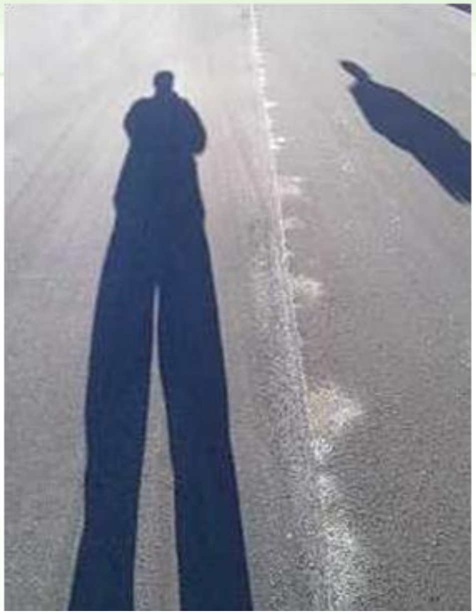
Improved Grip test results on Waterkloof Airforce Base (WAFB) main runway vs secondary runway



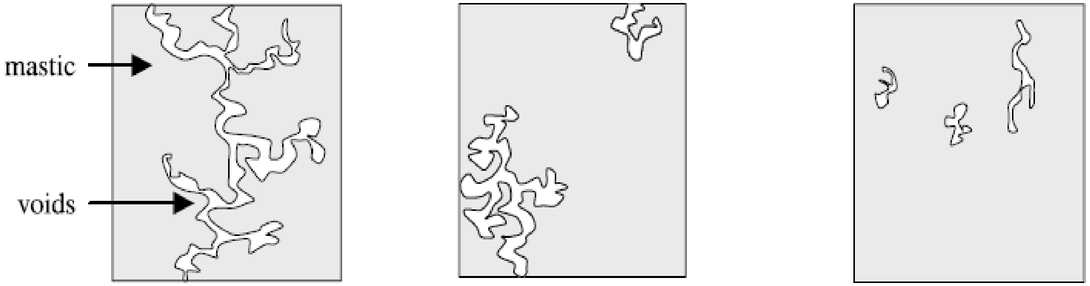
Riding quality measurements on Waterkloof new main runway



White deposit at longitudinal joints on HKIA after excessive rain



Permeable **Semi-impermeable** **Impermeable**



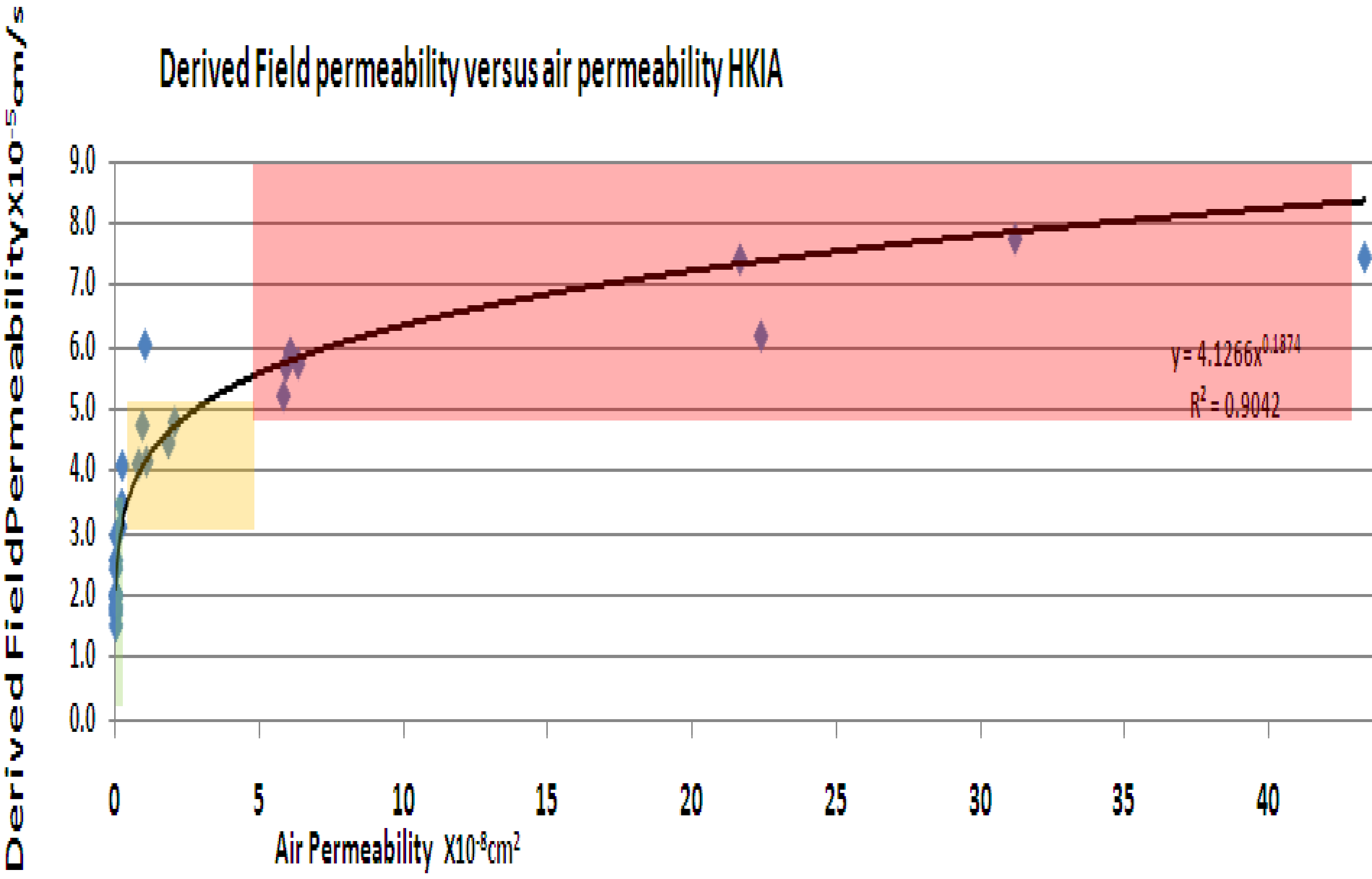
Top-down connections

Not fully connected through the material

No connections with the borders, isolated

Results from tests and evaluation of cores on HKIA linked with white deposits

CORE #	LOCATION	White(W) or Black (B)	Chen et al visual rating	Voids (%)	Density (%)	Air permeab. $(x10^{-8}/cm^2)$	water permeability (l/h/m2)	Lottman (TSR)	Cooley et al Field perm K
D1A	APRON	W	Permeable		90.1		458		
D1B	APRON	W	Permeable		89.6	6.08	450		
D1C	APRON	B	Impermeable		95.9	0.03	0.1		
D1D	APRON	B	Impermeable		95.8	0.03	0.1		
D1E	APRON	W	Permeable	8.2	92.6	2.07		0.72	4.85
D1F	APRON	W	Permeable	7.5	93.1	1.85			4.52
D2A	APRON	W	Permeable		93.5	1.09	375		
D2B	APRON	W	Permeable		93.4	0.82	330		
D2C	APRON	W	Permeable	5.9	94.4	0.23			3.55
D2D	APRON	W	Permeable	5.5	94.3	0.18		0.43	3.11
D2E	APRON	B	Semi-permeable	5	95.3	0.03			2.67
D2F	APRON	B	Impermeable		95.6	0.03		0.61	
D2G	APRON	B	Impermeable	4.2	95.8	0.03		0.82	2.02
D2H	APRON	B	Semi-permeable	4.3	95.8	0.03			2.03
D2J	APRON	W	Permeable		91.8	5.84	495		
D3A	RWY 08-26	W	Permeable	9.8	91.2	5.93			5.73
D3B	RWY 08-27	W	Permeable	9.9	91.1	6.35		0.42	5.78
D3C	RWY 08-28	B	Impermeable		96.2	0.03	0.1		
D3D	RWY 08-29	B	Impermeable		96	0.03	0.1		
D4A	APRON	W	Permeable	7	90.8	0.25			4.16
D4B	APRON	W	Permeable	7.9	92.9	0.95		0.81	4.79
D4C	APRON	B	Semi-permeable	4.8	95.3	0.03			2.54
D4D	APRON	B	Semi-permeable	5.3	98.2	0.04		0.66	3.05
D4J	APRON	W	Permeable		90.3	22.39	2235		
D5A	TAXIWAY	B	Permeable	10.2	90.8	1.04			6.07
D5B	TAXIWAY	W	Permeable	14.4	85.9	31.2			7.76
D6A	TAXIWAY	B	Permeable	13.9	87.2	21.66			7.40
D6B	TAXIWAY	W	Permeable	14.1	88.1	43.32		0.72	7.47
		Key	Impermeable	x < 4.5	x < 95	x < 0.04	x < 0.5	x > 0.8	
			Semi-permeable	4.5 < x < 6	95 > x > 93	0.04<x< 5	0.5 < x <100	.8< x < 0.70	
			Permeable	x > 6	x< 93	X > 5	x > 100	x < 0.7	


Derived Field permeability versus air permeability HKIA
Derived Field Permeability x10⁻⁵cm/s
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
35
40
Air Permeability X10⁻⁸cm²
y = 4.1266x^0.1874
R² = 0.9042

CONCLUSIONS

- Runways carry less traffic than a typical highway - much higher loads.
- The hot-mix asphalt requirements for runways different from those of roads
- More focus on rut resistance and durability.
- The Marshall method is still the dominant design method for airfield hot-mix asphalt
- Require additional consideration of permanent deformation resistance.
- Laboratory hot-mix asphalt rut test devices are increasingly used
- Accelerated Pavement Testers - scaled - MMLS - good results and laboratory Repeated Simple Shear Test at Constant Height (RSST-CH)- used with success

CONCLUSIONS continued

Durability issues-traffic levels on airfield.

Most ageing distress - cracking and ravelling - easily observed

Stripping can go largely undetected

Can lead to other distress - delamination

Stripping on airports found in very low traffic areas and in dry climates. Analysis of cores from Australian airport pavements found that:

- air voids content,
- pavement structure,
- rainfall
- pavement age have the highest influence,
- repeated loading has a marginal effect.

CONCLUSIONS continued

Implementation of lessons learnt

- Hot-mix asphalt for runways which balance the compromise between rut resistance and durability.
- Different mixes used on different areas of the airport and individual pavement segments to accommodate the various operational conditions and related durability requirements
- Application of visual rating of cores provide early warning regarding permeability and stripping problems