Review of MMLS3 Applications as Specification Parameter for Highways and Airports

Discussion Submission to RPF,
May 9, 2012
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Historic Applications by MMLS3 Users since 1997 fall into two categories

- *Empirical testing with historically developed protocols and performance criteria*
- *Theoretical modelling and analyses with performance prediction and validation through trial testing and/or field observation*

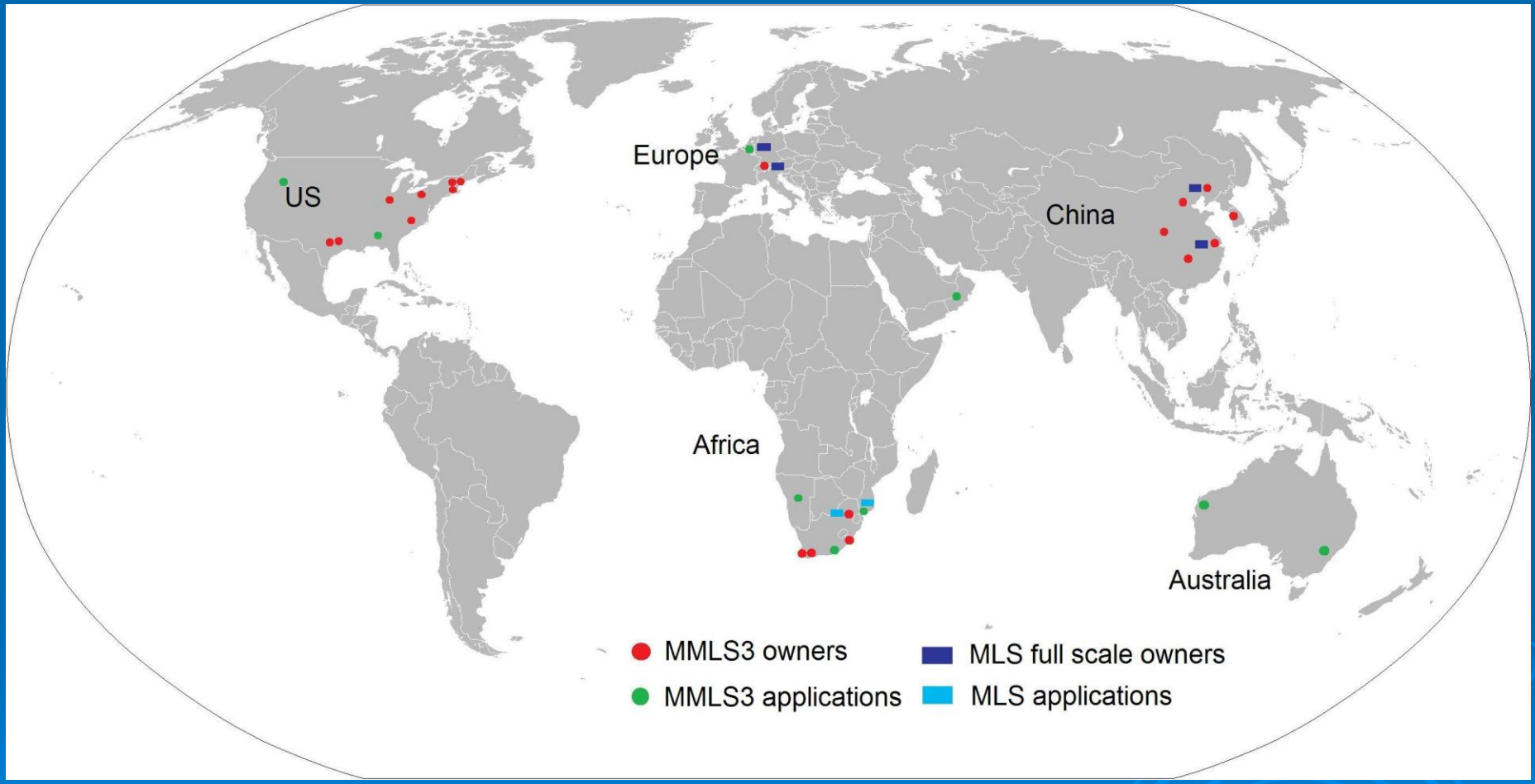
Variables that have to be considered by MMLS3 Users

- Lateral Wander
- Wheel Load
- Speed
- Contact stress
- Conditioning
  - Heat
  - Ambient
  - Cooled
  - Wet/Dry
  - Ageing

Application of the Protocol by MMLS3 Users

MMLS3 Applications by users						Full-scale APT links
	Lab				Field	Field/Lab
Output/Variables/ Data colllection & protocols	Special structures	Scaled/ Full-scale Pavement Layers	Cores	Briquette Pills	Surface of Layer structure	Layered pavement
Rutting and Moisture damage						
Fatigue						
Stresses/Strains						
Stiffness						
Other						

MMLS3 studies in global perspective



The reported applications cover a wide range of conditions in the countries where the research was done namely:

1. Switzerland,
2. United States
3. South Africa
4. Australia

A Bibliography will be posted on the MLS website: www.mlstestsystems.com

M7MLS3 peer reviewed publications were sorted into application categories

-Material Characteristics & Rutting Performance -12	-Comparative Response & Performance between APT Systems - 11
-Contact Stresses -2	-Dimensional Analysis - 2
-Moisture Damage - 4	-Reinforcing - 5
-Fatigue - 2	-Airports - 4
Total = 42	

Westrack Field validation

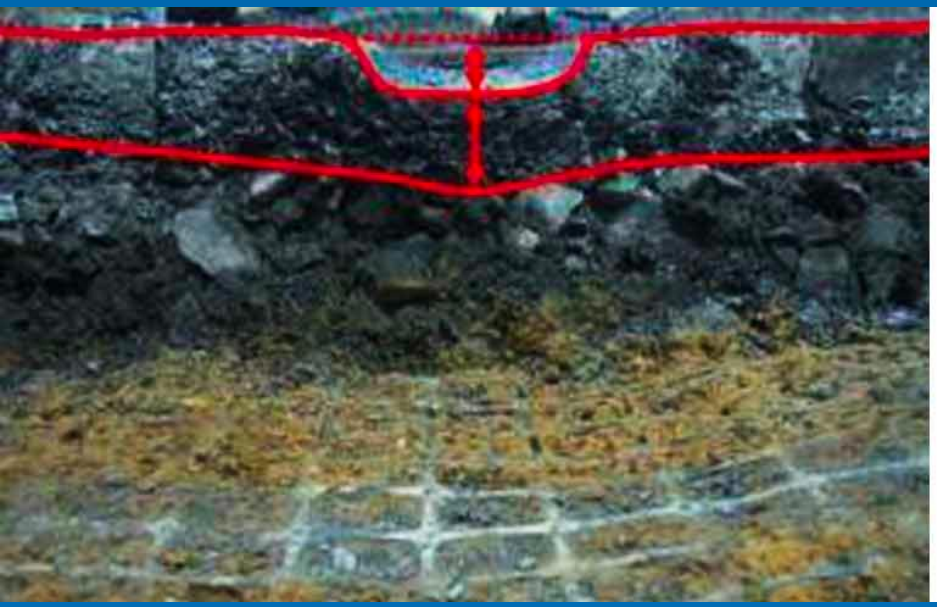
NCAT Test Track MMLS3 Field validation

Conclusions from Westrack and NCAT MMLS3 vs truck trafficking

- MMLS3 rutting performance comparable to truck trafficking in terms of *ranking* and *extent*
- Vertical stress, wander, temperature and frequency, have to be taken into account for assessment
- Note that the asphalt tested was 125 - 150 mm and the defined limits for rutting was related to 10m E80s over 2 years.
- South African applications have been adapted to local conditions relative to traffic and thickness

Evaluation of Performance of Asphalt Paving Mixes as reported in the categorized applications.

Pavement Reinforcement by PSU



MLS66 test in China supplemented with MMLS3

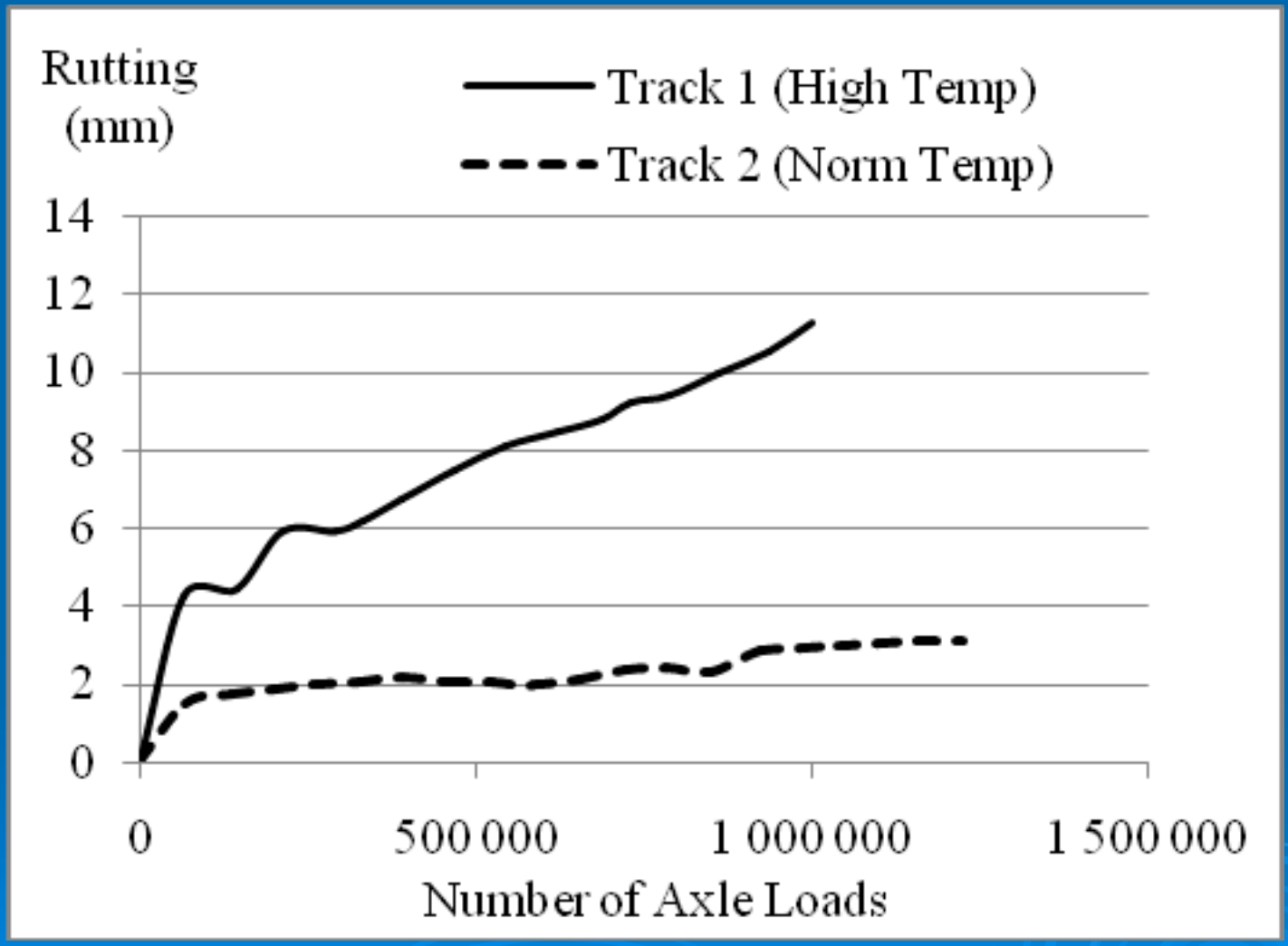


Figure CS5/2 Composite of averaged rutting performance under heated & ambient temperature

MLS10 test in Switzerland supplemented with MMLS3

Tongji MLS66 in Laboratory in Shanghai set-up for Lateral Movement

Scaling and Effect of Influence Factors

1. Contact Stresses
2. Strain and effect of Layer thickness and Structural composition
3. Temperature and Ageing influence on Stiffness
4. Particle size and Material characteristics
5. Boundary conditions
6. Rut definition in terms of downward deformation and upward heave
7. Deformation in lower layers
8. Effect of Lateral wander
9. Pavement gradient

- This explains why the MMLS3 Testing system is not an *empirical testing device with a singular purpose.* It is a trafficking system capable of being used to evaluate a range of pavement engineering issues and problems in a cost-effective manner.

  It differs from other tracking devices

Salient Features of MMLS3 Testing that need to be borne in mind when selecting specimen preparation, test conditioning and trafficking mode

Test Guidelines

Specimen Preparation and Trafficking							
Compaction Preparation							
Lab						Field	
1	2	3	4	5	6	7	8
Hammer	Gyrator	Roller	Roller	Roller		Roller	
Cylindrical mould			Core	Slab		Slab	
Trafficking							
Channelized				Wander		Chnl	Wander

Test Guidelines (cont)

Specimen Preparation and Trafficking (cont)						
Test Conditioning				Temp C		Temp C
Moisture			Dry		Wet	
○ Surface						
○ Internal voids*						
* By means of suction?	Y	N				
Test Temperature						
Artificial Heating	Y	N				
○ Surface						
○ Minus 25mm						
○ Other (mm)						

Test Guidelines (cont)

Trafficking Wheel Load			kN:
Tyre Pressure @ 25C			kN/m$^{2:}$
Tyre Tread (Standard/Special)			
Assumed Contact Stress			kN/m$^{2:}$
Axle Load Applications /h			
1800	*2400*	*7200*	
Airport	*SteepGrd/ Intersections >Truck*	*Highway Speed*	
Boundary Conditions			
▪ Compacted HMA+ Tack coat			
▪ Metal mould+bitumen rubber emulsion interface			

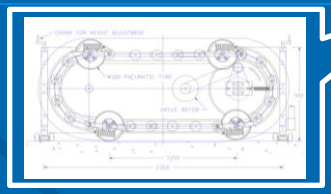
Draft Protocols for Acceptable Rutting Performance HMA > 75mm

	Lab						Field	
	Max Rutting under Trafficking to 100k axles (mm)							
Preparation & Test mode	1	2	3	4	5	6	7	8
Hwy Speed						3		3
>>Truck Steep Gradients/ Intersections	2.5	2.5	2.5	2.5	2.5	2.5		2.5
Airport	1.8	1.8	1.8	2		2.2		2.2

Draft Protocols for Acceptable Rutting Performance HMA 40 – 60 mm

	Lab						Field	
	Max Rutting under Trafficking to 100k axles (mm)							
Preparation & Test Mode	1	2	3	4	5	6	7	8
Hwy Speed					2.2		2.2	
>>Truck Steep Gradients/ Intersections	2.5	2.5	2.5	2.5	2.2		2.2	

MMLS3 APT ORGANIGRAM (1)



TRAFFICKING FACTORS

DATA COLLECTION AND ANALYSIS

ENVIRON-MENTAL FACTORS

FIELD TESTS

IN-SERVICE PAVEMENT

TRIAL SECTION

LAB TESTS

CONTROLLED ENVIRONMENT (FIELD OR LAB)

ENVIRONMENTAL CHAMBER (3.1)

TESTBED (5)

CONSTRUCTED PAVEMENT SCALED

DATA MEASUREMENTS

CORES

BRIQUETTES

VIBRATING LAB ROLLER (4)

WET TEST

DRY TEST

RUTTING

STIFFNESS

STRENGTH

FATIGUE LIFE

WET HEATER

DRY COOLING/ HEATING UNIT (3.2/3.

PROFILOMTER (2)

PSPA (6)

STATIC SCB/ITS

DYNAMIC SCB/ITS

Commercial Laboratory Applications of MMLS3 in South Africa for Road and Airport authorities

Report to MMLS3 User Group Meeting at TRB 2012 by

- *Specialised Road Technologies*
- *Roadlab*

Applications

- *28 Test for Airports*
- *108 Highways*

Summary of Commercial MMLS3 Tests S A in 12 mo

	SRT	Roadlab	Total
Total	98	38	136
Lab	98	24	122
Field	0	14	14
Dry	83	35	118
Wet	15	3	18
Cores	35	6	41
Pills	63	18	81
Speed 7200/h	89	36	125
Speed 2400/h	5	2	7
Speed 1800/h	4	0	4
Temp 50 C	88	32	120
Temp 60 C	10	3	13
Temp 65 C	0	3	3


Wap

Field MMLS3 applications with air heating ducts and surface dam for circulating water

Some Findings from Historic Applications by MMLS3 Users since 1997

- *Wet trafficking: Affected loss of strength, stiffness, micro- cracking, stripping. AASHTO T283 not always compatible Walubita et al. 2002*

- *Supplemental tests are frequently employed such as PSPA; SCB to gain confidence in the findings of the APT*

- *Raab et al 2005 reported wet trafficked cores increased rutting as much as 30 to 50 percent greater than dry cores.* 1

Some Findings from Historic Applications by MMLS3 Users since 1997

- *Research completed subsequent to the last HVS and MMLS3 test on the R80 project focused on identifying appropriate test protocols and criteria for design of HMA, yielded some interesting findings:*

1. *With trafficking speed of the MMLS3 similar to the HVS rutting deformation was similar for the same conditions.*
2. *Differences in trafficking modes (uni and bi-directional) resulted in differences in rutting performance with uni-directional more aggressive*

The papers in the referenced bibliography were reviewed and synthesized.
The findings served as benchmarks for the criteria included in DPG1 Protocol
It was concluded that the Protocol as currently drafted was compatible with the findings

Conclusions from the Case Studies…..

1. Clear evidence of relationship between slow speed MMLS tests and field rutting performance of HMA under harsh full-scale trafficking:
   - *Slow heavy traffic with high tyre pressures*
   - *High temperatures*
2. *MMLS and HVS* rutting performance trends in terms of rate of rutting under similar conditions, compare well
3. Ability to scale MMLS HMA *field and laboratory performance analytically to actual field rut performance* as per *DPG1* confirmed

more…..

Conclusions (cont)

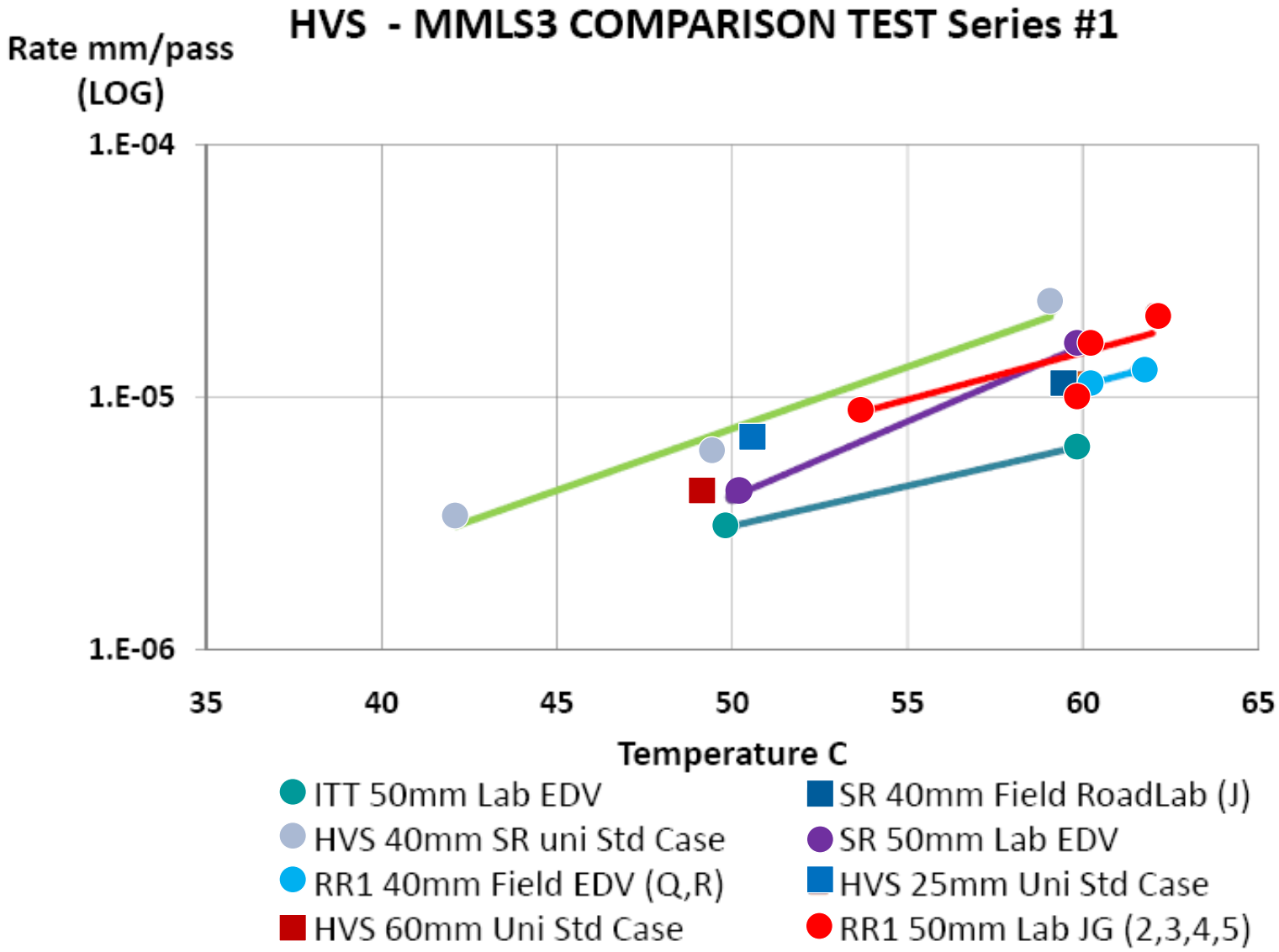
4. *Change of original 2004 Baton Rouge protocol limit of < 1.8mm rutting under 7200 appl/h trafficking for airports to the same limit under 1800 appl/h validated*
5. *Comparative case studies between full-scale trafficking and MMLS3 cover extensive and diverse geographic areas. Positive validation of guidelines in the draft Protocol DPG1 established.*
6. *Support for application of the MMLS as APT tool for evaluation of bituminous road paving mixtures*

Draft Test Protocol (DPG1,2008) is

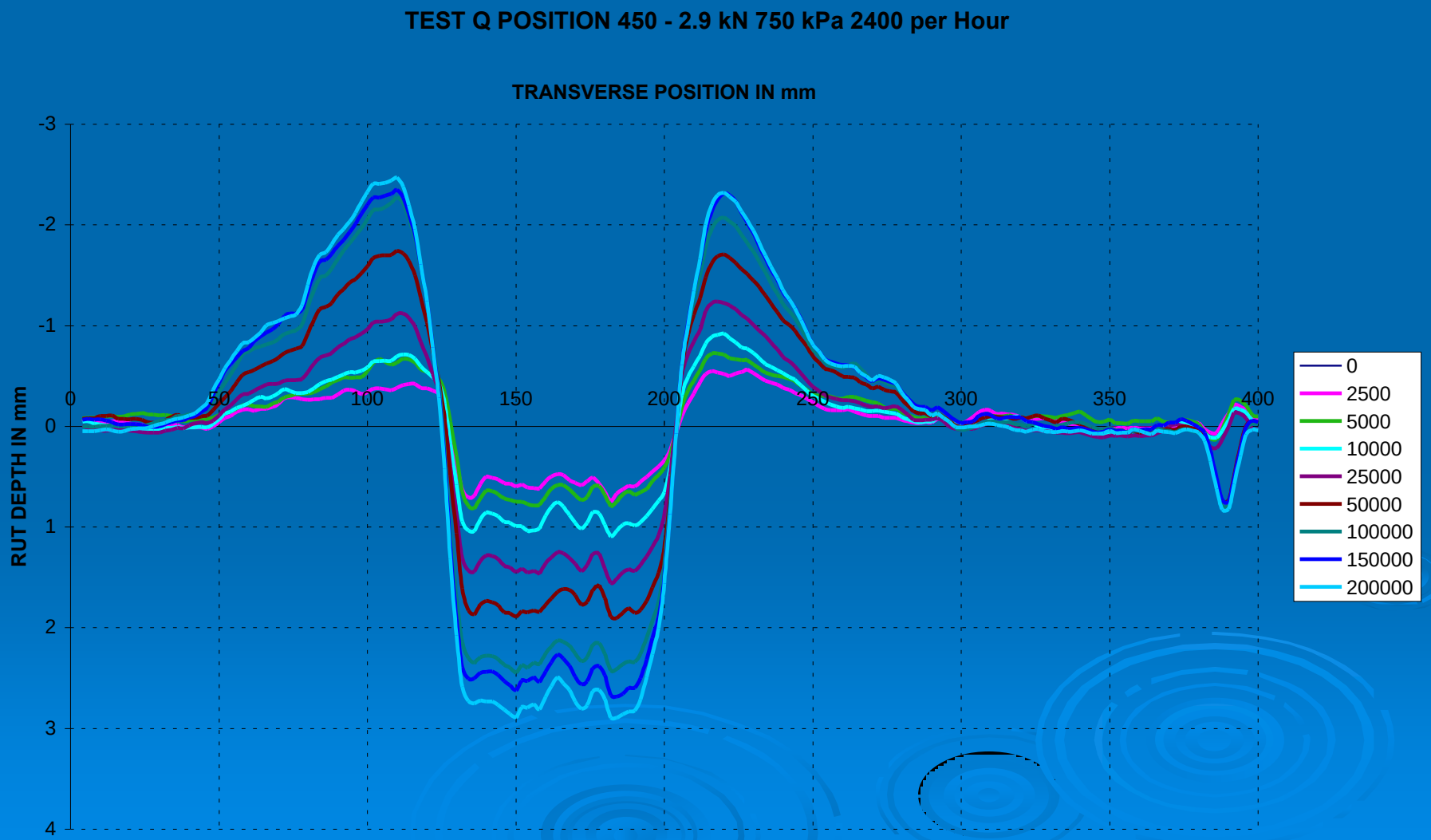
Method for evaluation of permanent deformation and susceptibility to moisture damage of bituminous road paving mixtures using the Model Mobile Load Simulator (MMLS3)

NB: load frequency and temperature are the important test variables…….

HVS and MMLS3 on R80 Pretoria-West


HVS - MMLS3 COMPARISON TEST Series #1
Rate mm/pass (LOG)
1.E-04
1.E-05
1.E-06
35
40
45
50
55
60
65
Temperature C
ITT 50mm Lab EDV
HVS 40mm SR uni Std Case
RR1 40mm Field EDV (Q,R)
HVS 60mm Uni Std Case
SR 40mm Field RoadLab (J)
SR 50mm Lab EDV
HVS 25mm Uni Std Case
RR1 50mm Lab JG (2,3,4,5)

Rutting Profiles - Heave (left and right@ 450mm)
MMLS3 Data Processing (R80 Pta West)



Since the original report by Epps et al 2002 the mechanistic approach has been succesfully applied in a variety of ways to render the system as one that *passes the test of reasonablness*

CS 4 Dubai and Australia (Airport pavements) [Client/Supervising Consultant]

Application: MMLS3 used to evaluate pavement performance under Boeing 777 trafficking on a Taxiway

MMLS3 - Boeing 777 simulation on a DIA Taxiway

Conclusion: MMLS3 test found viable to evaluate pavement performance under aircraft trafficking of a taxiway!

Dubai Intl Airport (DIA)
Analytical Rutting Performance Prediction using MMLS

- MMLS used to calculate estimate of field rutting to compare with measured rutting of HMA pavement
- Boeing 777-300 adopted as design aircraft at DIA for comparative analyses modelled at 1533kPa tyre pressure and 269kN tyre load.
- The MMLS was modelled at 700kPa and 2.9 kN tire load (equivalent to maximum take-off weight).
- *Methodology in MMLS3 Protocol DPG1 (2008)*
- *Originally published by Epps et al (2003) Comparing Pavement Response and Rutting Performance for Full-Scale and One-Third Scale Accelerated Pavement Testing* Jnl Transportation Eng Vol. 129, #4, pp. 451- 461.

MMLS3 on Taxiway Analysis

Wearing	BC20 PG76 Cariphalte Fuelsafe –
Intermediate	BC20 PG76 SBS Modified Binder
Intermediate	
Basecourse	BC32 60/70 Bitumen
Basecourse	BC32 60/70 Bitumen
Basecourse	BC32 60/70 Bitumen
Subbase	CT Fine Crushed Rock
Subgrade	Natural Sandy Subgrade CBR=15

Rutting results from analytical procedures

Dubai Intl Airport

- Remarkably close to actual measured values.
- As example - Taxiway M north of Runway 12R30L: ruts measured 32-34 mm compared to calculated scaled rut depth of 28.3mm.
- Traffic volumes were estimated to have been
- 20 000 aircraft movements.

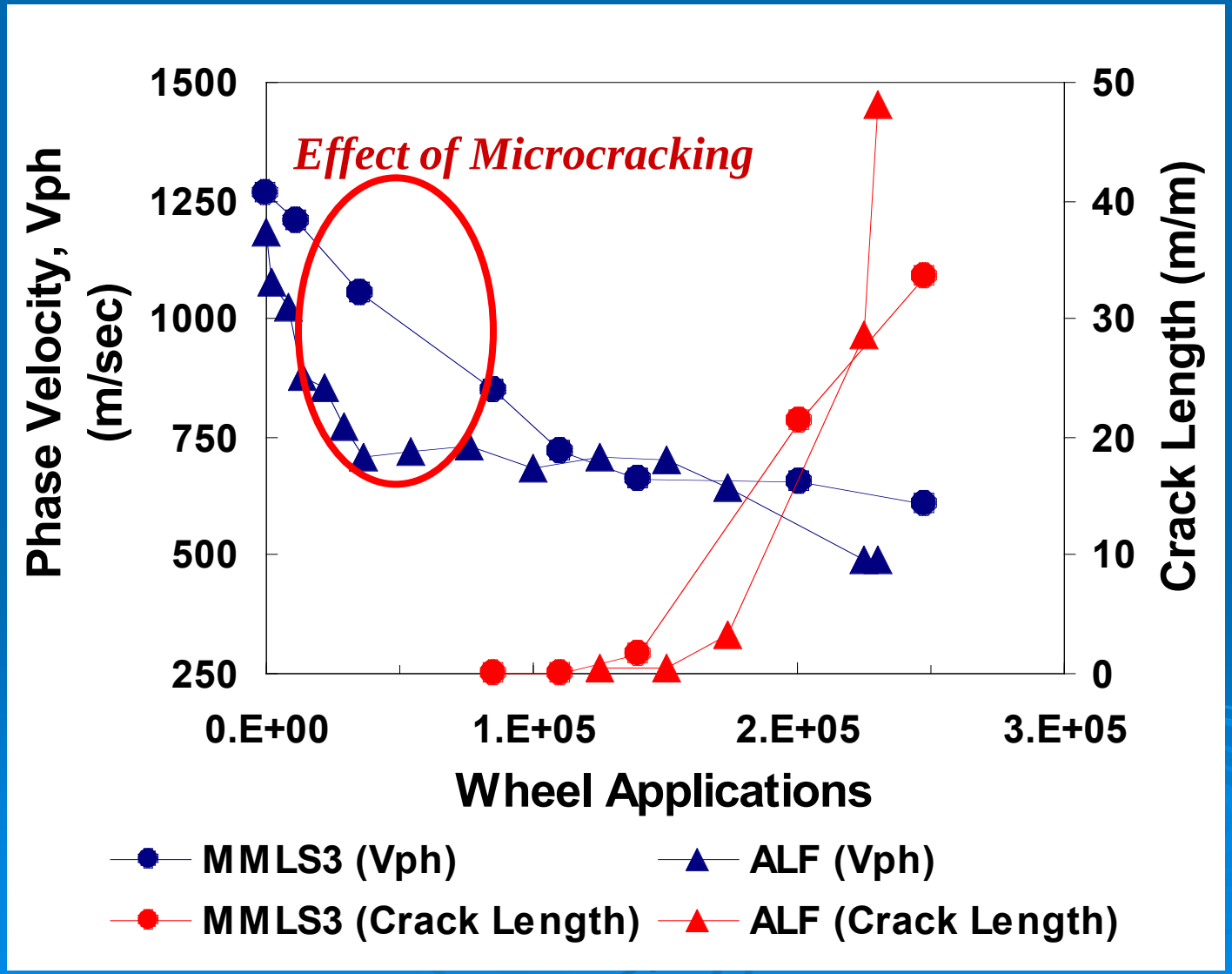
Cape Town Intl Airport

- The design of the HMA was also done with on the basis of a quantitative analytical approach. Fatigue evaluation was also included in the process.

A case study of *Fatigue and Surface Wave Tests under MMLS3 and ALF trafficking* is an example *(Lee & Kim @ NCSU)*

- A mechanistic approach was also found successful in relating rutting and fatigue response and performance prediction in the application of the MMLS3 to ALF full-scale tests
- They found that algorithms similar to MEPDG Design Guide could be used with adjustment for the MMLS3 loading frequency using the time-temp superposition principle with growing damage. This rendered the performance prediction to be reasonable

CS of Fatigue and Surface Wave Tests under MMLS3 and ALF trafficking (Kim @ NCSU) in Paper Hugo et al. 2012 APT2012 conference



Fatigue cracks after MMLS3 trafficking of Scaled Pavement at NCSU (Kim et al 2012)

Paper submitted to APT2012 conference

Closing Remarks

- *Draft Test Protocol: (DPG1,2008)* was referenced to more than 60 percent of commercial asphalt tests in So Africa in 12 months
- Ref source: www.sabita.co.za
  - Search & Download under *Reports*
- The importance of correct specification for tests in terms of speed and temperature of trafficking is evident
- *The Organigram Outlines the System and engineers and technologists are urged to carefully formulate the test specifications as designs*