



Sabita HiMA evaluation

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Objective

- Limited study
- Provide provisional guidance to designers for establishing potential economic advantages of HiMA pavements
- Thickness issues
- Support issues
- Cost issues

Methodology

- Select limited typical pavement structures (with non-HiMA asphalt base layers) for design traffic where HiMA may be used
- Conduct comparative mechanistic analysis
 - various layer thicknesses of HiMA
 - similar supporting layers
 - climatic conditions in Durban, Gauteng, Cape Town
- Compare data and iterate process
 - optimum HiMA layer thicknesses
 - adapting HiMA base layer thickness
- Develop recommendations for initial selection of HiMA base layer thicknesses based on the analysis

Assumptions

- HiMA
 - ε/N relationships similar to conventional asphalt / asphalt with polymer modified binders
- Rutting not typical failure condition
- Standard currently available mechanistic analysis techniques
- Existing transfer functions
- No additional laboratory or field tests

Pavement structures selected

- Typical TRH4 structures
 - Hot-mix asphalt bases
 - ES30 – 40AC, 120BC, 400C3
 - ES100 – 50AC, 180BC, 450C3
 - Foundation – 150 G7, 150 G9, G10
 - Durban road
 - R104
 - 40AC, 150HiMA, 150C3, 160G7, 150G10
 - 40AC, 100HiMA, 150C3, 210G7, 150G10

Pavement structures selected

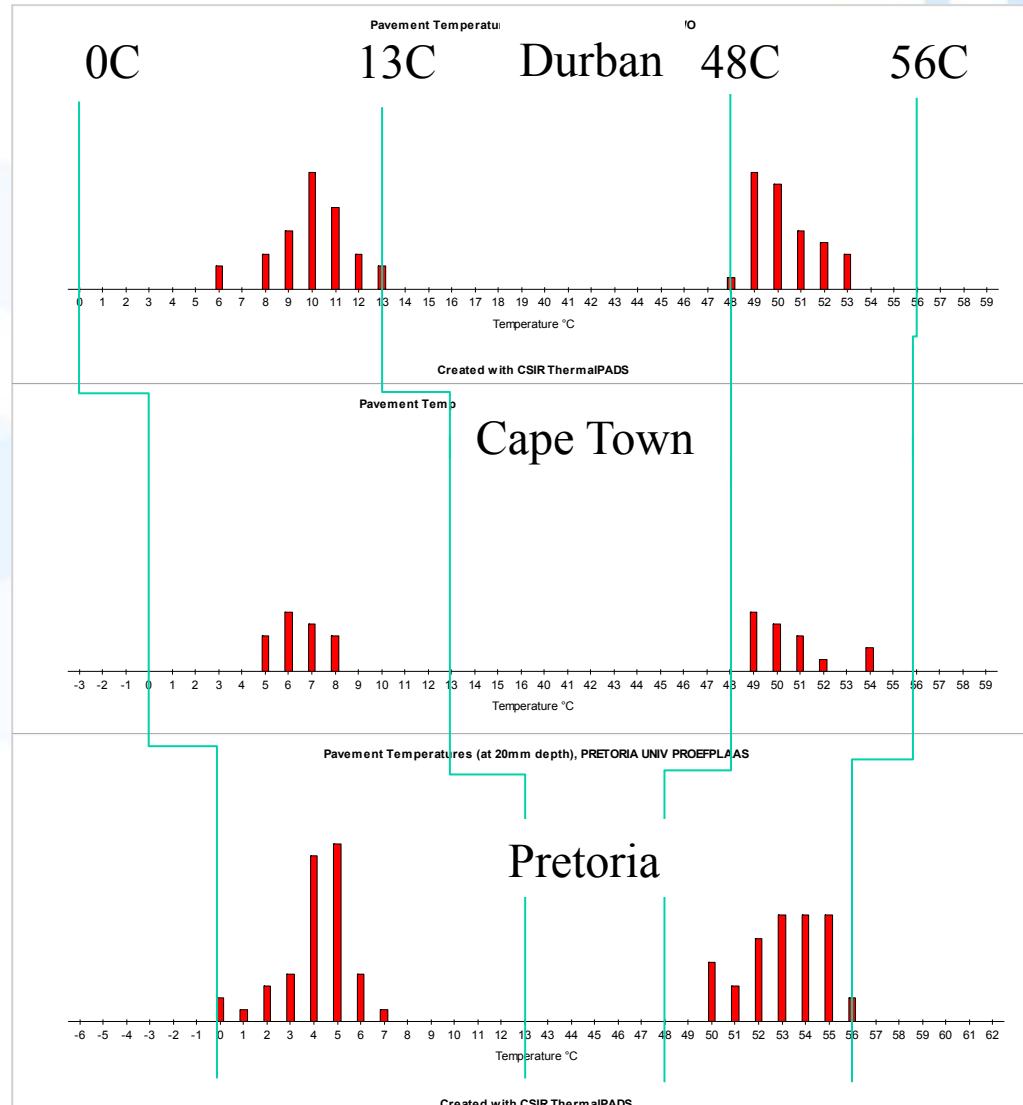
- Final decision
 - Thickness
 - 40AC, 80/100/200HiMA, 100/200/300C3, 250G7, G10
 - 40AC, 80/100/200HiMA, 100/200/300G2, 250G7, G10
 - Stiffness
 - AC – 3 500 MPa
 - HiMA – 1 000 / 10 000 MPa
 - C3 – 1 500 / 100 MPa
 - G2 – 250 MPa
 - G7 – 120 MPa
 - G10 – 100 MPa
- Load input
 - 1 x 20 kN, 700 kPa (E80)

Climatic conditions

- ThermalPADS data
- R104 temperature measurements
- Is temperature an issue below the surfacing?
 - Upper and lower part of typical HiMA base
- Temperature distributions inside base layers – ranges and effect on stiffness of HiMA
- Typically
 - Average annual minimum surface T
 - Maximum 7-day average at 20 mm depth
 - Average annual pavement temperature

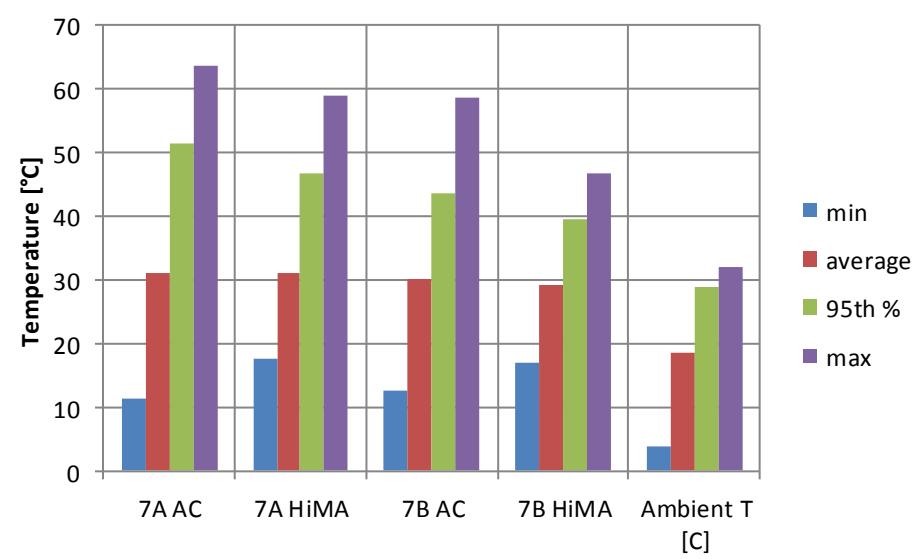
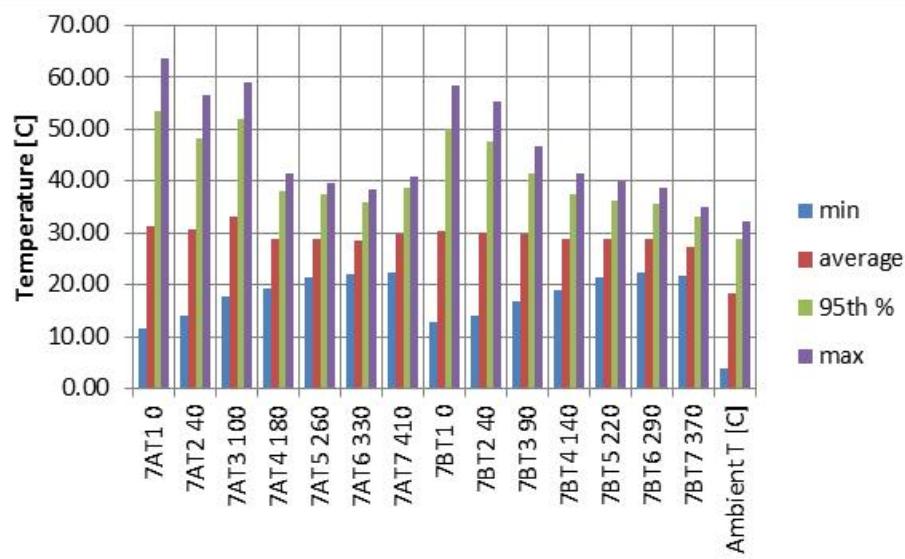
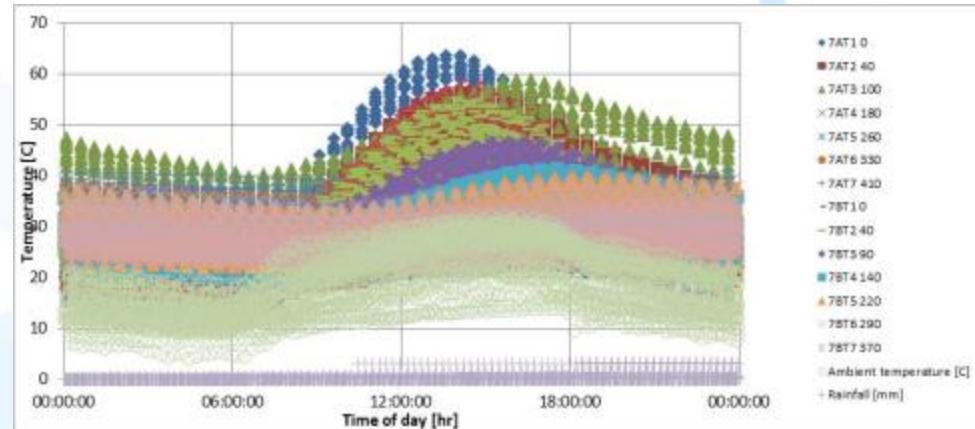
Climatic conditions - ThermalPADS

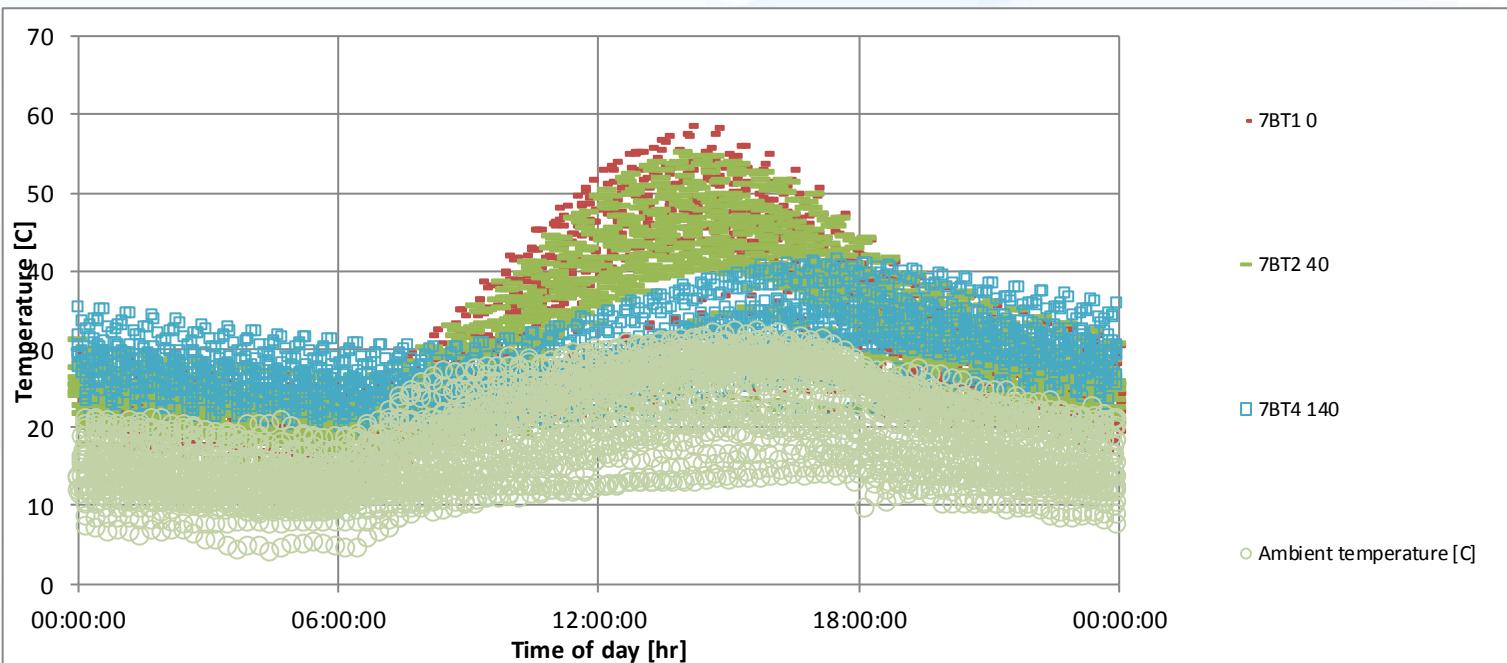
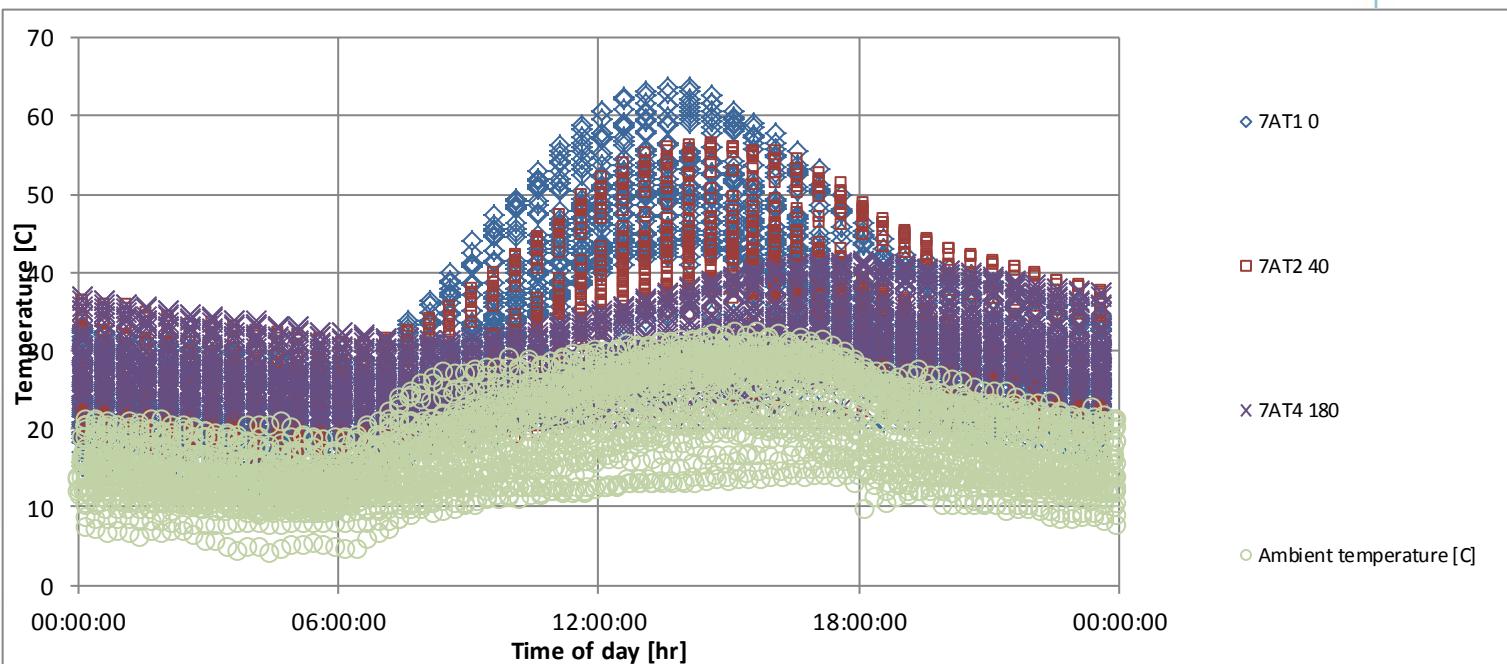
- ThermalPADS
- Min and Max ranges
- Durban, Cape Town, Pretoria
- Max 7-day @ 20 mm
 - D – 53.5
 - CT - 54°C
 - P – 55.7



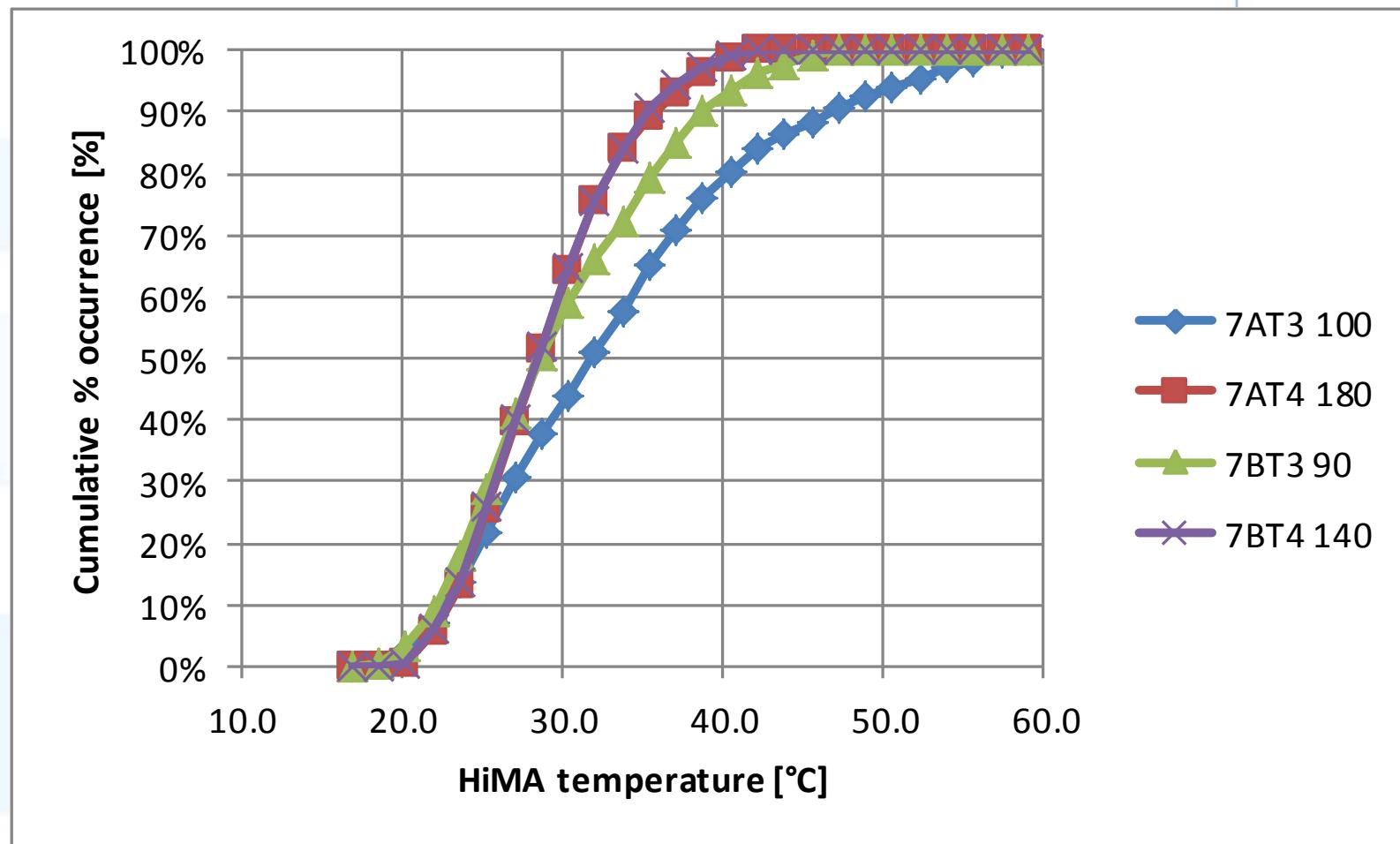
Climatic conditions – Real HiMA

- Top and bottom of HiMA layers
- Also AC and other layers
- Winter / Spring





HiMA R104 middle and bottom temperatures



Materials issues

- Surfacing layers
 - 40 AC for all analyses
- HiMA properties
 - Stiffness ranges – laboratory
 - Stiffness ranges – field data
- Supporting layers
 - Stiff support
 - Weak support
 - NB - Compaction issues for HiMA on weak support

Analysis methodology

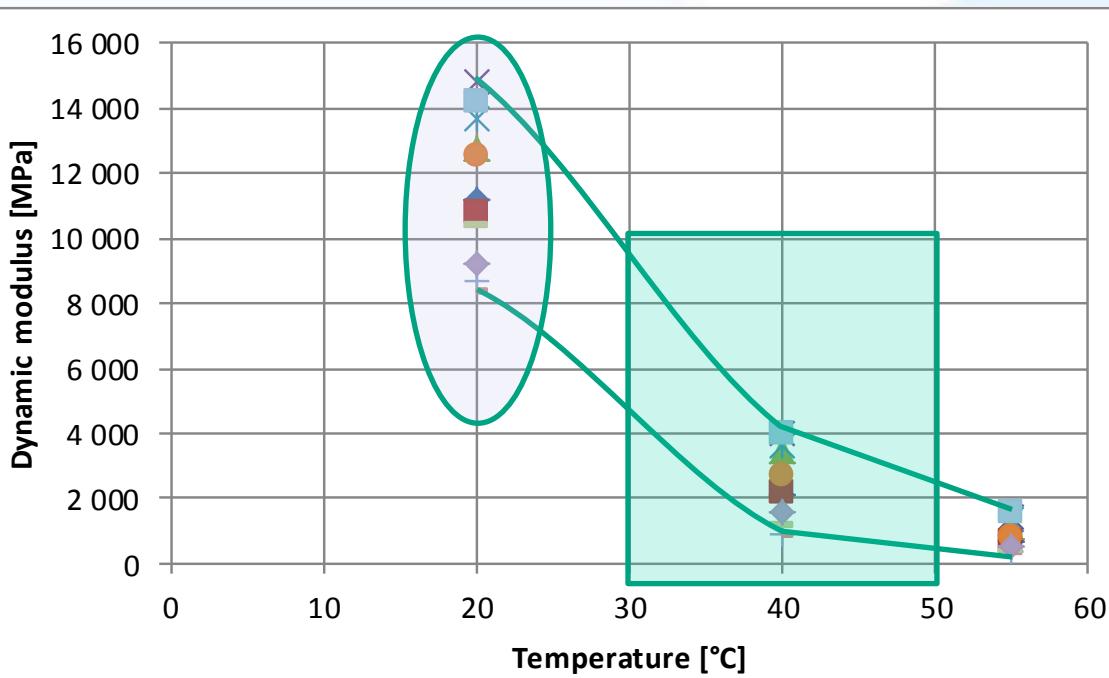
- Current SAMDM process
- Layer thicknesses
 - R104 – 100 and 150 mm
 - Rule of thumb – min 3x max aggregate
 - 40 to 80 mm min dependent on aggregate
 - French – 30% decrease **if stiff support**
 - Beware too thin, even if 3x min aggregate
- Pavement balance and depth – probably relatively shallow

Analysis inputs

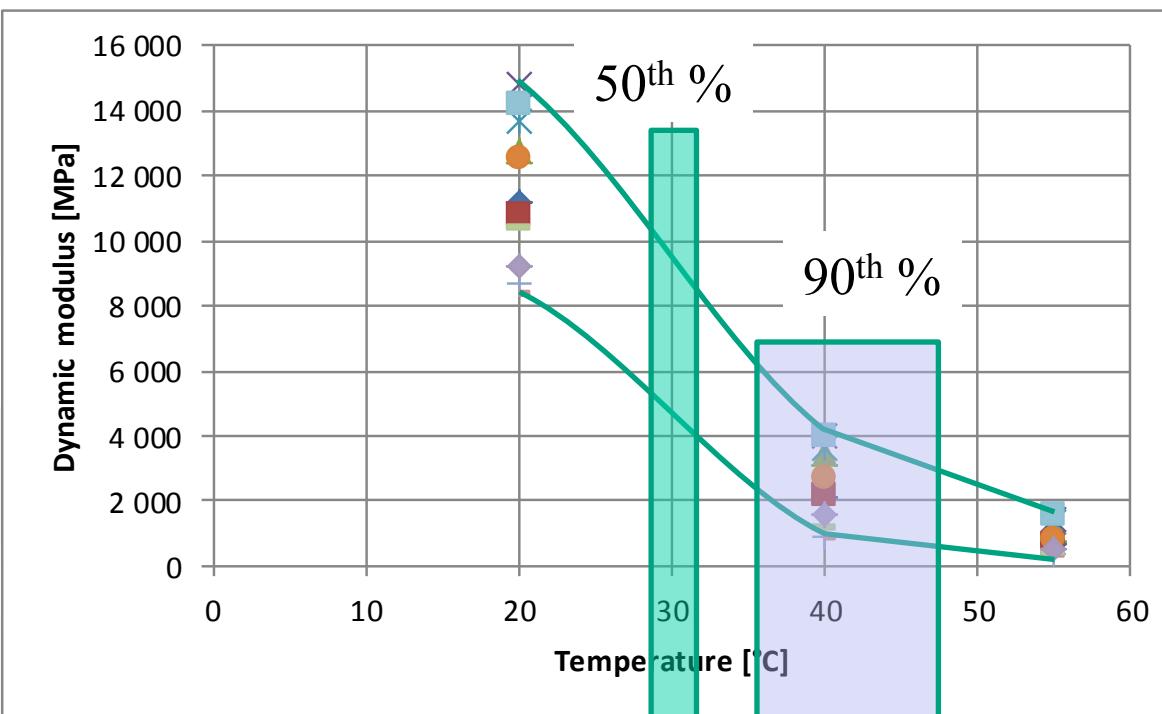
- HiMA stiffness
 - LTPP Durban
 - 6 000 (fresh) to 20 000 MPa
 - 20 to 30 °C ambient
 - R104
 - Ambient average 20°C
 - HiMA average 30°C
 - Similar to LTPP
 - Warning
 - in situ went up to 40 to 50 °C (95%)
 - only winter / spring currently

Analysis inputs

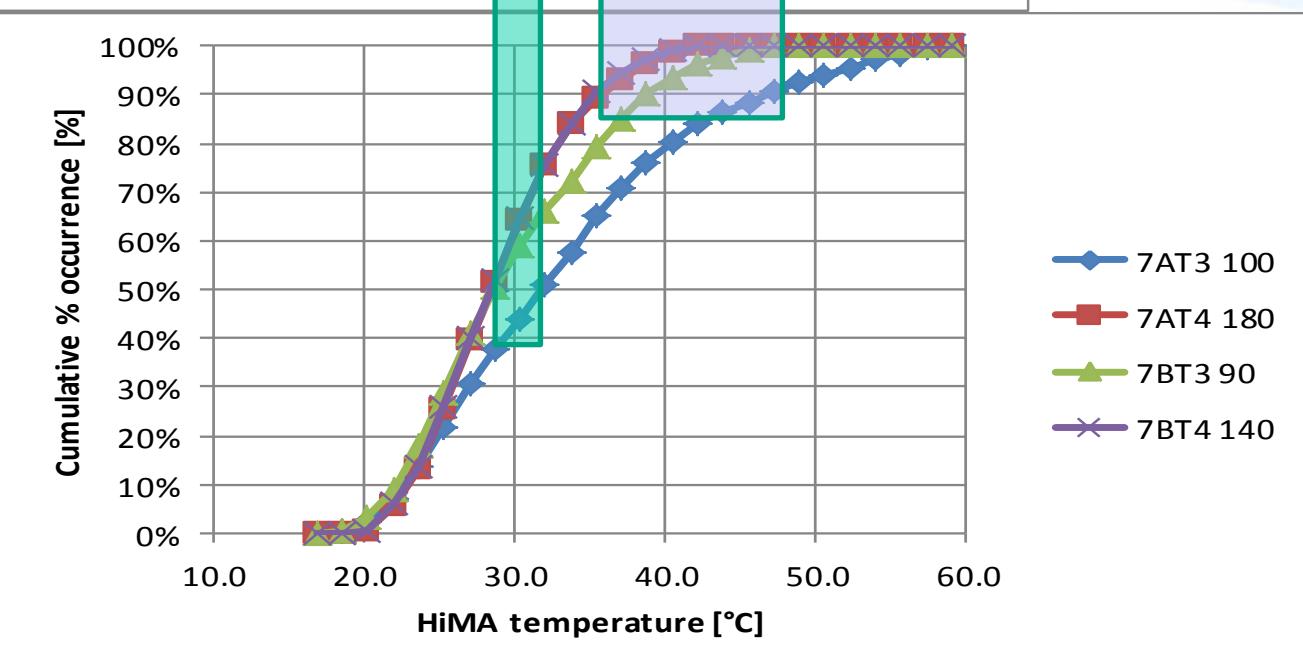
- Range of possible stiffnesses for analysis
- 1 000 to 10 000 MPa
 - depending on temperature (all at 10 Hz)
 - from laboratory evaluation
- FWD mostly done at 20°C



HiMA R104 Lab stiffness



In situ HiMA R104 winter / spring temperatures



Analysis outcome

- Typical structure
- Comparison between HiMA and BTB and other materials
 - Only stiffness difference
 - same transfer functions at this stage
 - Beware of too high stiffness values in analysis
 - R104 temperatures etc.
- Material property effects
- Layer thickness effects
- Temperature effects

Performance requirements

- Sabita Manual 33
- Standard mechanistic analysis
- Dynamic modulus at 10 Hz at 3 temperatures
- Check testing frequency for traffic speed

Summary of performance requirements

Property	Test	No. of specimens	Method	Requirements	
				HiMA Class	
				Class 1	Class 2
Workability	Gyratory compactor, air voids after 45 gyrations	3	ASTM D6925	≤ 10%	≤ 6%
Durability	Modified Lottmann, TSR	6	ASTM D4867M	≥ 0,80	≥ 0,80
Resistance to permanent deformation	RSST-CH, 55°C, 5000 reps	3	AASHTO T320	≤ 1,1% strain	≤ 1,1% strain
Dynamic modulus	Dynamic modulus at 10Hz, 15°C	3	AASHTO TP62	≥ 14 GPa	> 14 GPa
Fatigue	Beam fatigue test at 10 Hz, 10°C, to 50% stiffness reduction	9	AASHTO T321	≥ 10 ⁶ reps @ 300 µε	≥ 10 ⁶ reps @ 390 µε

Permanent Deformation

- From Sabita Manual 33
- Just checked

Permanent deformation

Currently, the South African design method does not contain damage models for permanent deformation. A reasonable estimate of the permanent deformation in the HiMA layer can be made by using the models in the Mechanistic Empirical Pavement Design Guide – MEPDG – (NCHRP 1-37A), recently introduced in the USA. Recent work on the SAPDM projects indicates that they may be suitable to some extent. The MEPDG model uses the vertical strain (EZ_Z) at the centre of the layer below the centre of the tyre as the main predictor of permanent deformation.

The final calibrated model for laboratory and field data for the relationship between elastic and plastic strain in MEPDG is shown below:

$$\frac{\varepsilon_p}{\varepsilon_r} = k_1 * 10^{-3.4488} T^{1.5606} N^{0.479244}$$

Where:

ε_p = the accumulated plastic strain

ε_r = the resilient strain at the middle of the layer

T = temperature (°F),

N = the number of load repetitions

k_1 = a function of total asphalt layer(s) thickness (h_{ac}) and total depth to computational point (depth), to correct for the variable confining pressures that occur at different depths. (i.e. the term "depth" = total depth to the computational point).

$$k_1 = (C_1 + C_2 * \text{depth}) * 0.328196^{\text{depth}}$$

$$C_1 = -0.1039 * h_{ac}^2 + 2.4868 * h_{ac} - 17.342$$

$$C_2 = -0.172 * h_{ac}^2 + 1.7331 * h_{ac} + 27.428$$

Fatigue failure

- TRH4 1995 thick asphalt bases
- Thus no difference in calculated life if all properties are the same (BTB vs HiMA)

$$N_f = 10^{A \left(1 - \frac{\log \epsilon_t}{B}\right)} \quad \text{for all road categories}$$

Stiffness	A	B
1 000	16.44	3.378
2 000	16.09	3.357
3 000	15.78	3.334
5 000	15.52	3.317
8 000	15.09	3.227

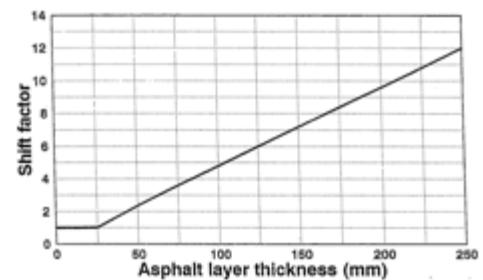


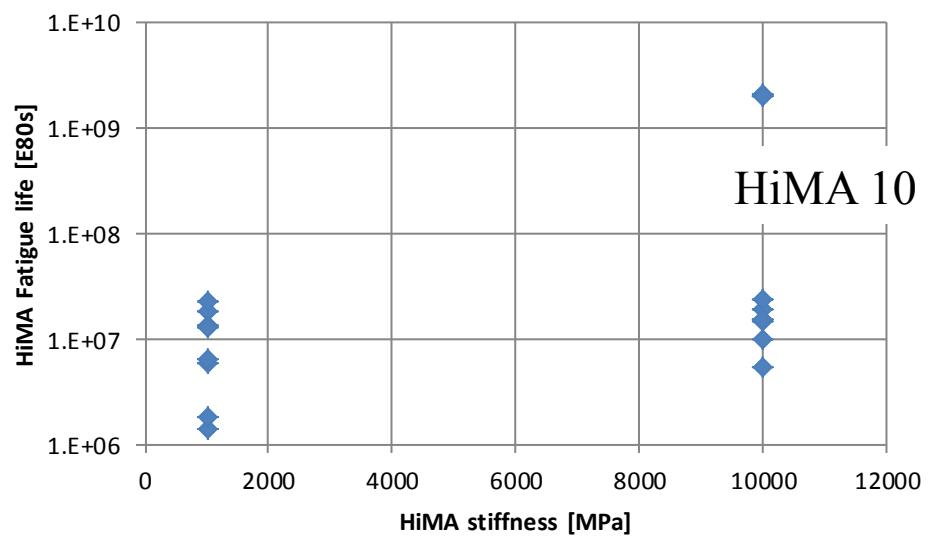
FIGURE 16: FATIGUE CRACK PROPAGATION SHIFT FACTOR FOR ASPHALT LAYERS (19)

Analysis outcome

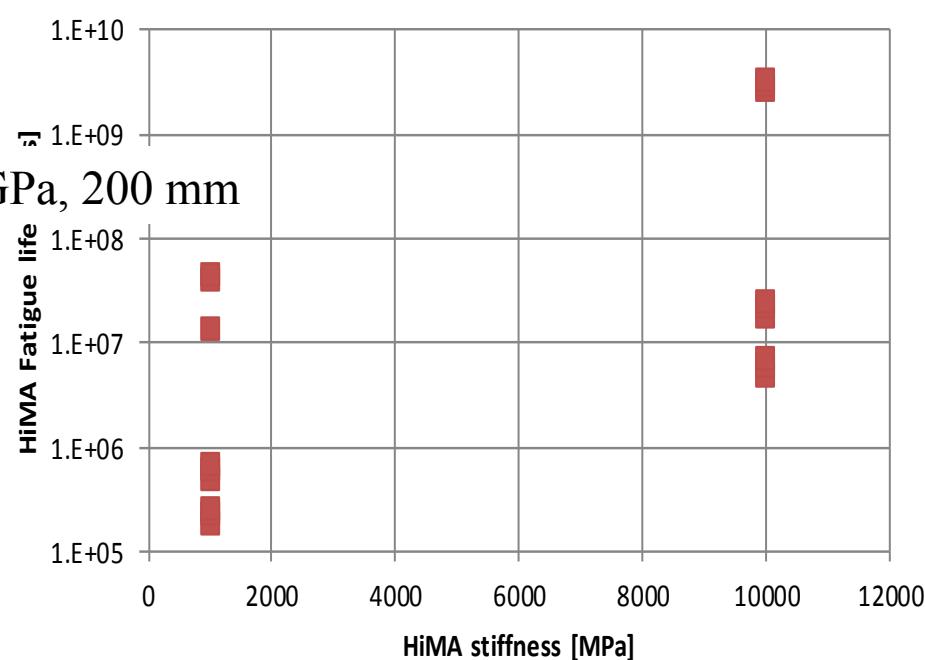
- Effect of HiMA stiffness
 - Increase stiffness
 - Higher fatigue life
 - Also comparison between weaker material and stronger material – **currently same transfer function**
- Effect of HiMA thickness
 - Increase thickness
 - Higher fatigue life
- Effect of Subbase (C3 / G2) thickness
 - Increase thickness
 - Higher fatigue life
 - Not as sensitive as HiMA E and h

Analysis outcome - Life vs HiMA stiffness

C3 Subbase



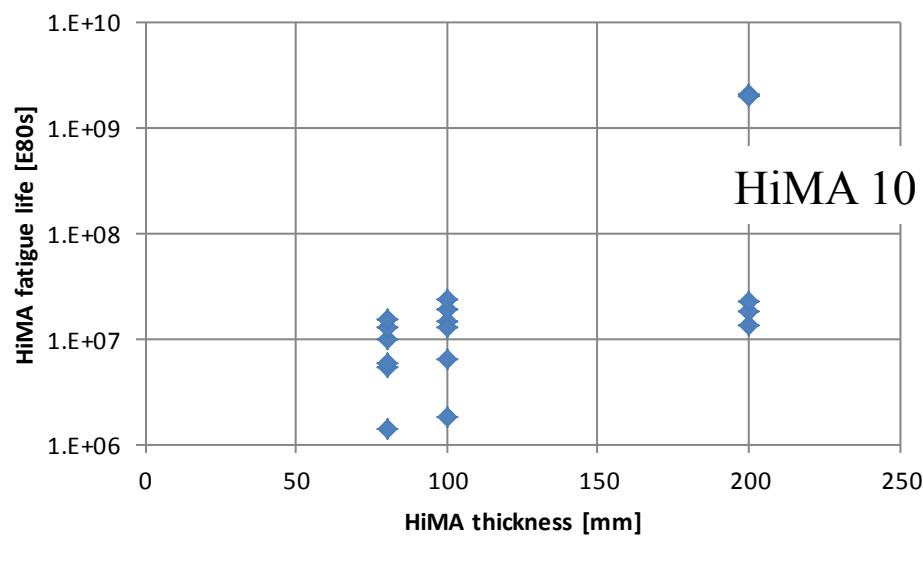
G2 Subbase



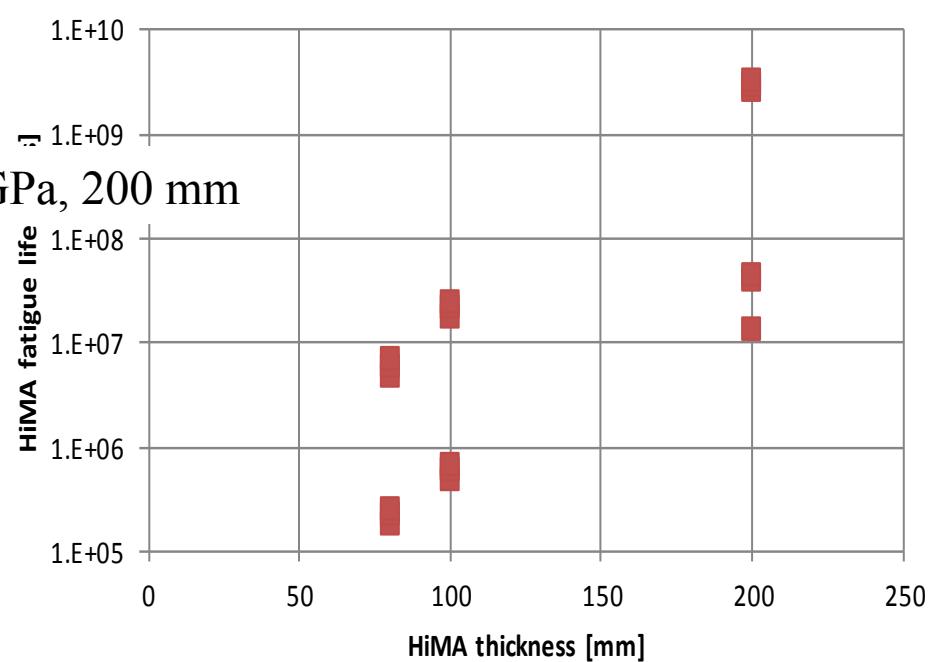
C3 vs G2
Similar lives

Analysis outcome - Life vs HiMA thickness

C3 Subbase



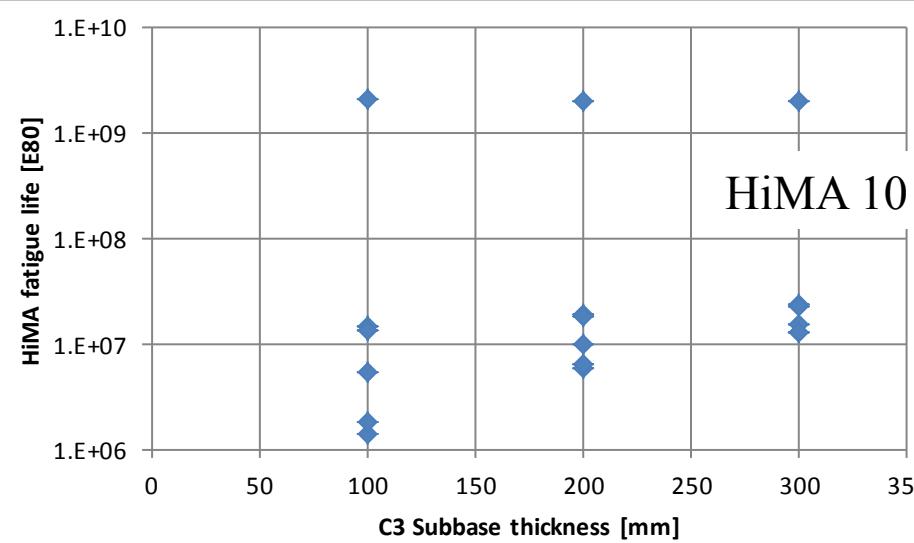
G2 Subbase



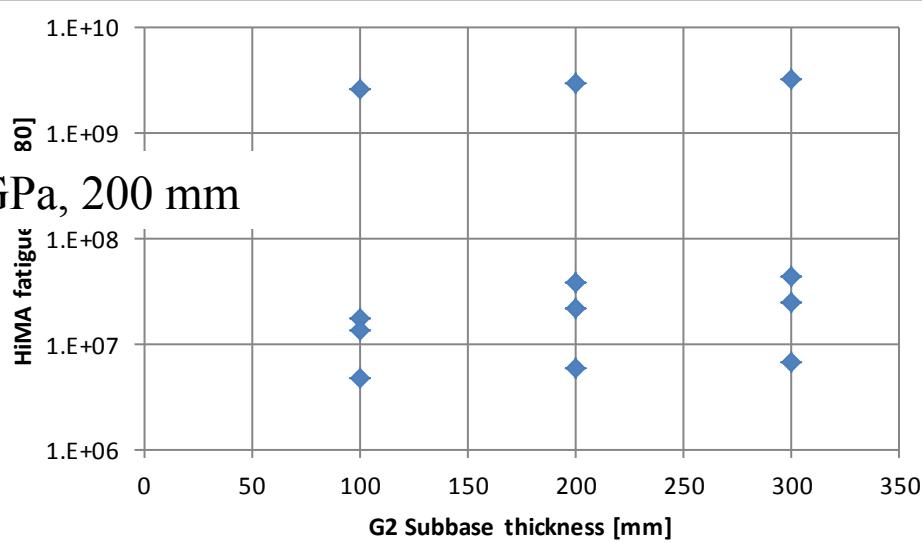
C3 vs G2
Similar lives

Analysis outcome - Life vs C3 thickness

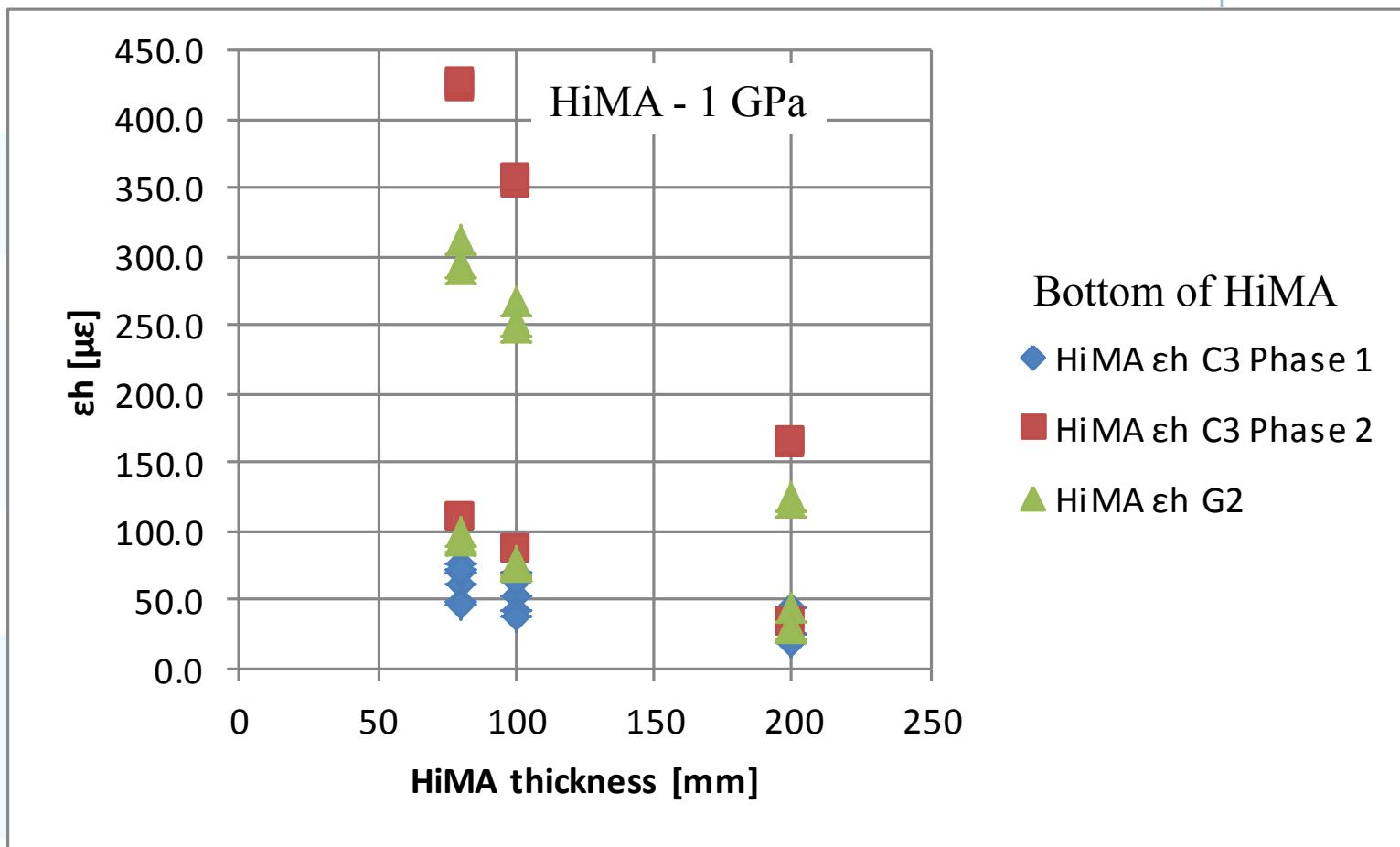
C3 Subbase



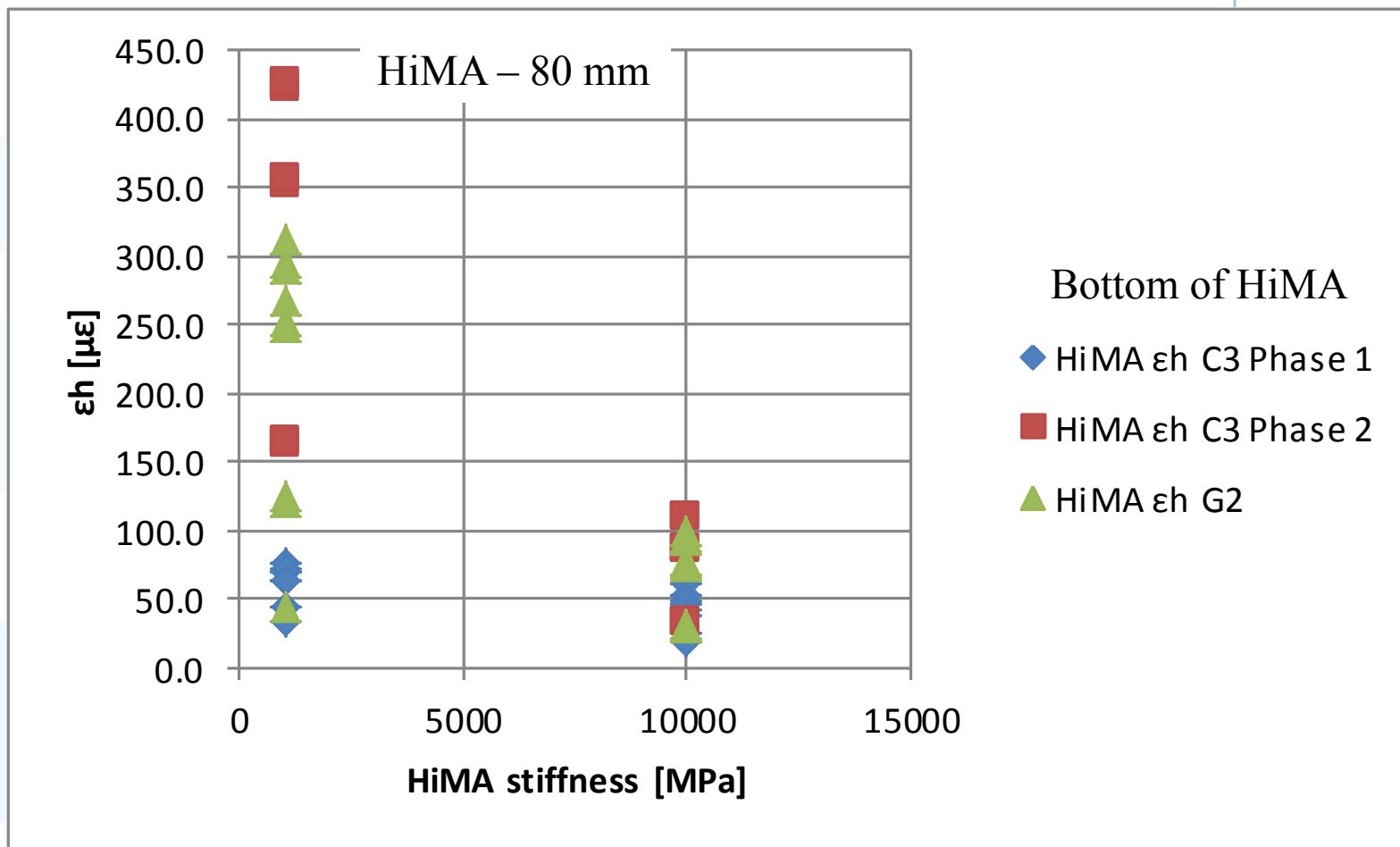
G2 Subbase



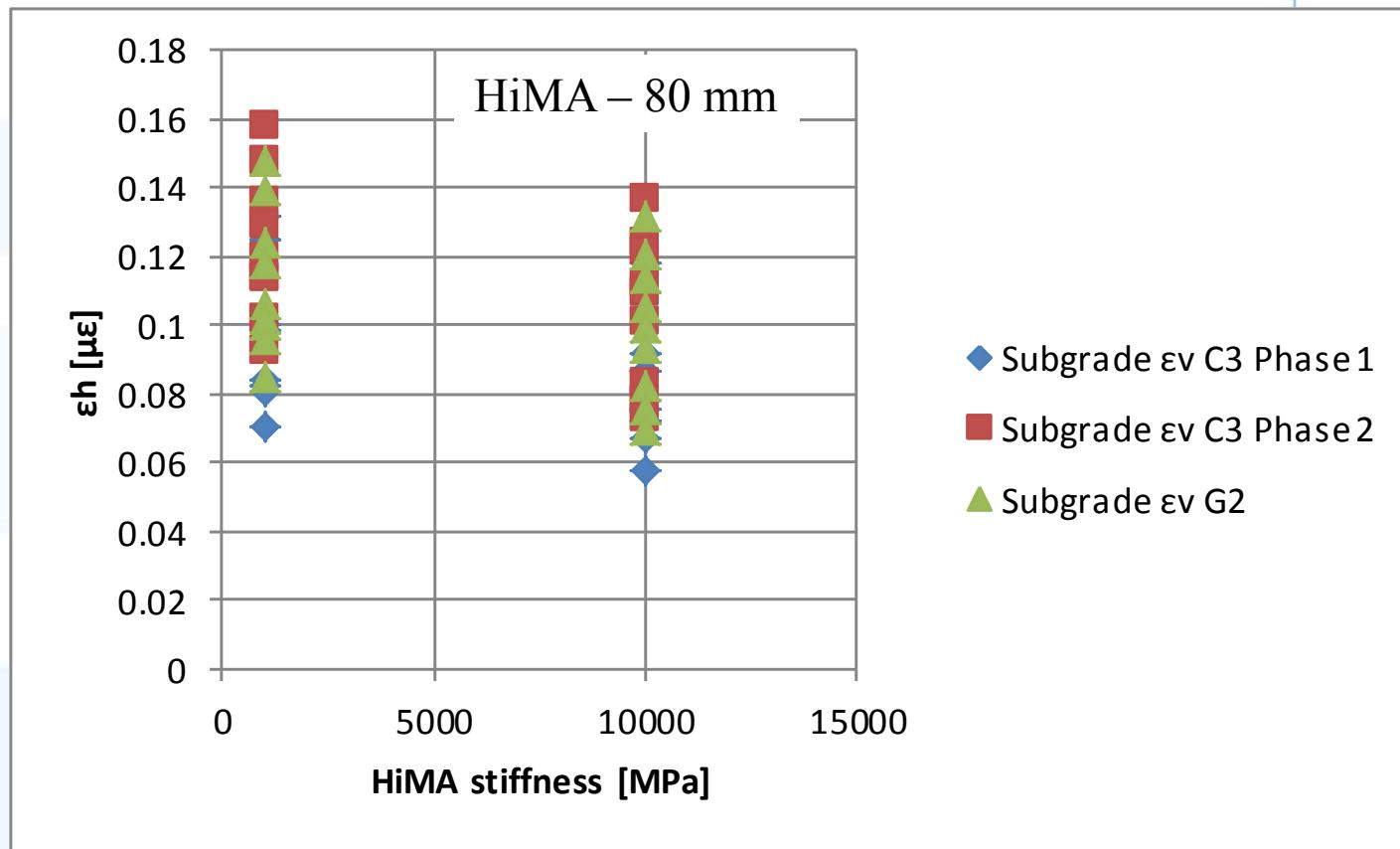
Analysis outcome – ϵ_h vs HiMA thickness



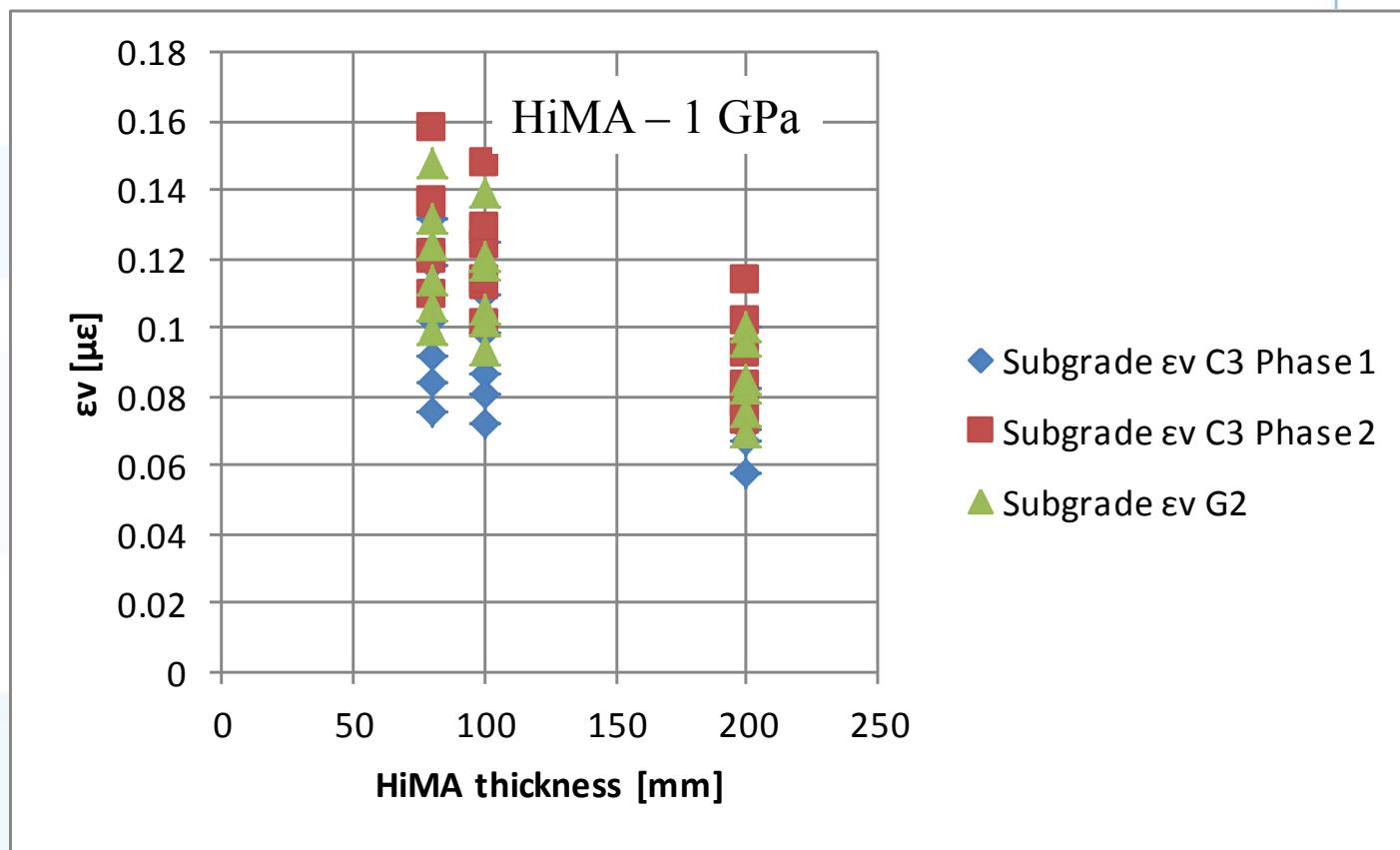
Analysis outcome – ϵ_h vs HiMA stiffness



Analysis outcome - HiMA stiffness vs ϵ_h G10



Analysis outcome - HiMA thickness vs ε_v G10



Cost issues

- Typical range of costs from industry
- Issues around costs and cost sensitivity
 - Imported vs local binders
- HiMA vs BTB
 - R 1 200/t vs R 840/t (imported 10/20 bitumen)
 - R 1 000/t vs R 840/t (local 10/20 bitumen)
- HiMA vs A-P1 base
 - HiMA around R 500/t more expensive (imported 10/20 bitumen)
- Cost is higher (25 to 44%)
- Expected performance improvement?
 - Currently difficult to motivate as same transfer functions are used (only stiffness maybe different).....

Conclusions

- Lack of HiMA specific transfer functions
- General standard pavement principles applicable
- Beware of actual temperature / stiffness values
- Minimum thickness based on practical requirements
- Minimum support stiffness and thickness based on practical requirements (compaction platform)
- Warning – current transfer functions – same response as BTB at higher cost!!!