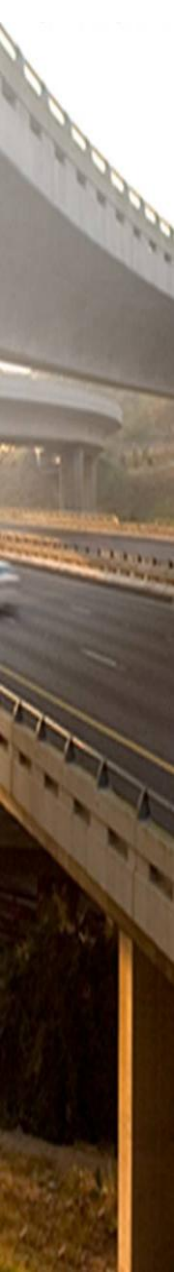
SAPDM
Thin Surfacings
Progress and Preview

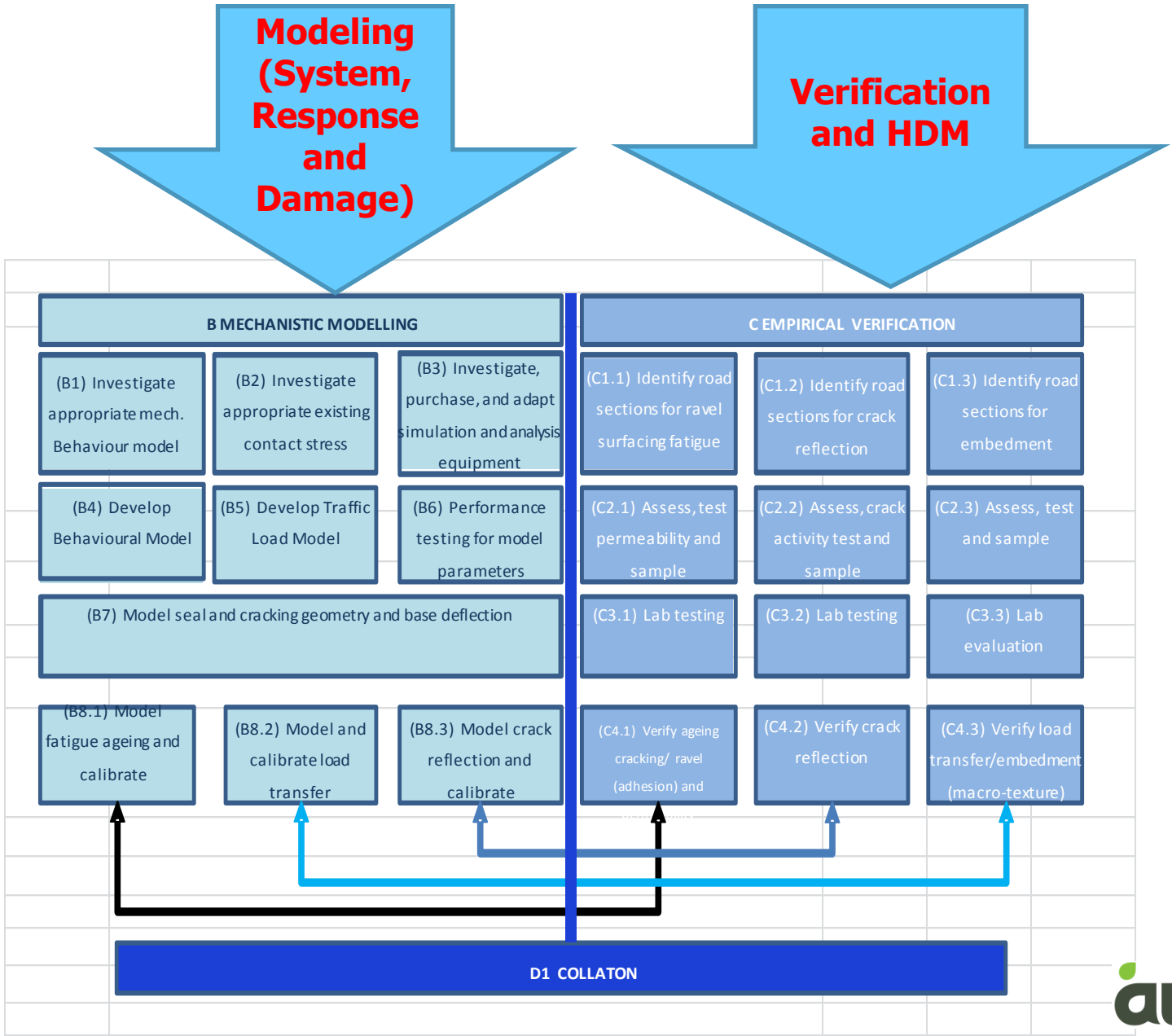
2010 – 2013
November 2013
CSIR
Dr Terence Milne

Whats news?

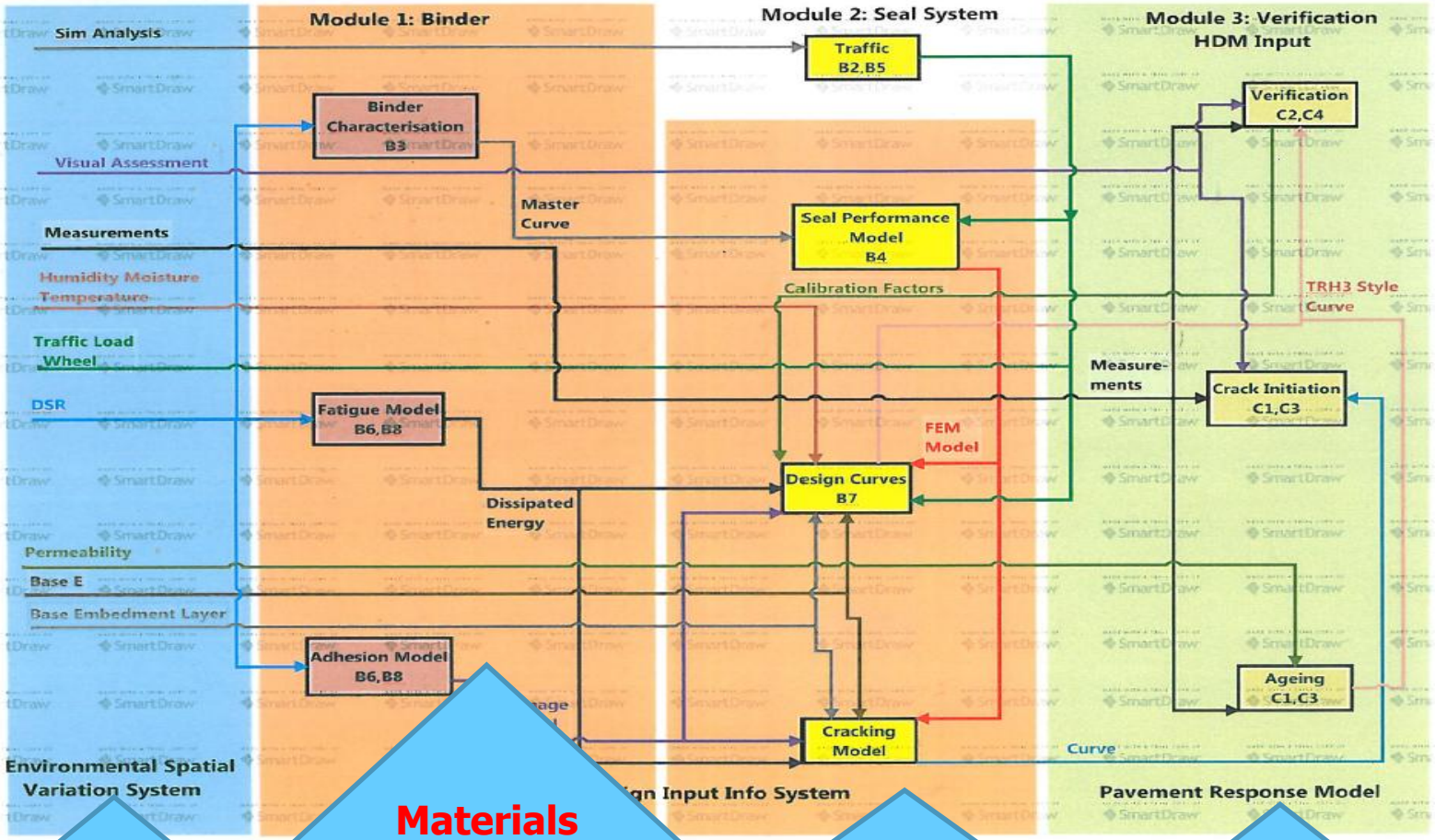
- HDM addition for pavement performance prediction
- Mechanistic Seal Materials and System Response Modeling for SAPDM (Godzilla)
- Mechanistic Empirical Design Method: Preview subject to change (TRH3)

The Original Plan





Preview: Design Process in SAPDM



Inputs

Materials Character-isation and damage Models

System analysis

Output : TRH3 and HDM

Seal Design preview (subject to change)

- Seal design will be based on the current TRH3 platform
- TRH3 Modules will be replaced /improved by SAPDM seal models as applicable and evolve

- SAPDM seal system will be used to improve:

  - Effect of Aggregate spacing per seal type - interlock (friction) in reducing embedment (Mat behavior)
    - ✓ Improve embedment model : less embedment = more load before texture is lost

  - ✓ Effect of existing macro-texture
    - ✓ Wave length and amplitude –determine voids requiring additional binder

Seal Design preview (subject to change)

- ELV's determination (per pavement type) based on RESPONSE and DAMAGE
- Minimum binder volumes
  - Adhesive failure for minimum binder applications
- Temperature for winter sealing
  - Adhesive failure
- Flushing/loss of texture (punching)
  - Volumes of voids lost (texture or in the seal)
- Climate
  - Binder selection – Applicable DSR parameters

Seal Design preview (subject to change)

- Ageing
  - Applicable DSR parameters
  - Binder selection – reflect effect of climate
  - (Ageing : Seal design focusses on the early period when adhesion is critical, and texture depth loss as seal is trafficked)

- On Line system based on the current TRH3 curves with adjustment factors
- Expert system to ensure sanity check
- Can determine binder application sensitive to geometry and microclimate

Contribution to SAPDM

- SAPDM seal response and damage curves to Godzilla
- SAPDM cracking initiation, propagation and reflection and permeability model to Godzilla
- HDM (HDM calibration factors per binder)

Verification and HDM

- Gerrie van Zyl (My Cube)

Crack Initiation & Progression (HDM)

- Importance

Table 6.1: Ranking of Impacts of Road Deterioration Factors

Deterioration Factor	Typical Values of Factor	Potential Net Impact (%)	Sensitivity Class
Roughness-age-environment	0.2 – 5.0	10	High
Cracking initiation	0.5 – 2.0	6	
Cracking progression	0.5 – 2.0	6	
Rut depth progression	0.5 – 2.0	3	Low
Roughness general progression	0.8 – 1.2	1	
Potholing progression	0.3 – 3.0	2	
Ravelling initiation	0.2 – 3.0	1	

- New Surfacings on Granular base

  Function of Climate, base type, SNP & E80s

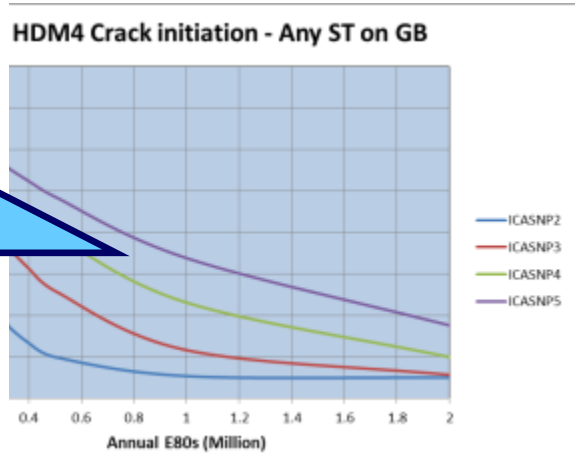
- HSOLD =0(that is, original surfacing)

$$ICA = K_{cia}\left\{CDS^2 a_0 EXP\left[a_1 \right]SN\right.$$

Where:

ICA:
Kcia: Calibration fact
CDS: Construction d
SNP: Average annua ment
YE4: Annual numbe ne)
CRT: Crack retardati in years)

High ranking : effect of cracking on road deterioration



Crack Initiation & Progression (HDM)

- There IS a difference between seal types
  - Seal type (geometry)
  - Binder type
  - Film thickness
- Goal
  - Quantify difference through HDM calibration factors
    - ✓ Seal type category
    - ✓ Climatic zone

Field assessment input

- 70 Samples
  - 6 Surfacing types
    - ✓ Single seal
    - ✓ 13/6 Double
    - ✓ 19/9 Double
    - ✓ 19/6/6 Split
    - ✓ 13 Cape seal
    - ✓ 19 Cape seal
  - 2 Binder types
    - 80/100
    - SE-1
  - 5 Macro Climatic
  - 4 Traffic ranges
  - 5 Age categories

- Stiffness measurement
  - 4 Point beam test
  - Stiffness at different temp

Seal Geometry

MODEL SEAL STIFFNESS DEVELOPMENT

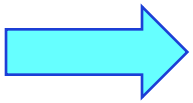
MODEL BINDER AGEING

- Binder measurements
  - Softening point
  - Penetration

- Permeability measured
- Initial binder quality
- ROC measured

Crack initiation

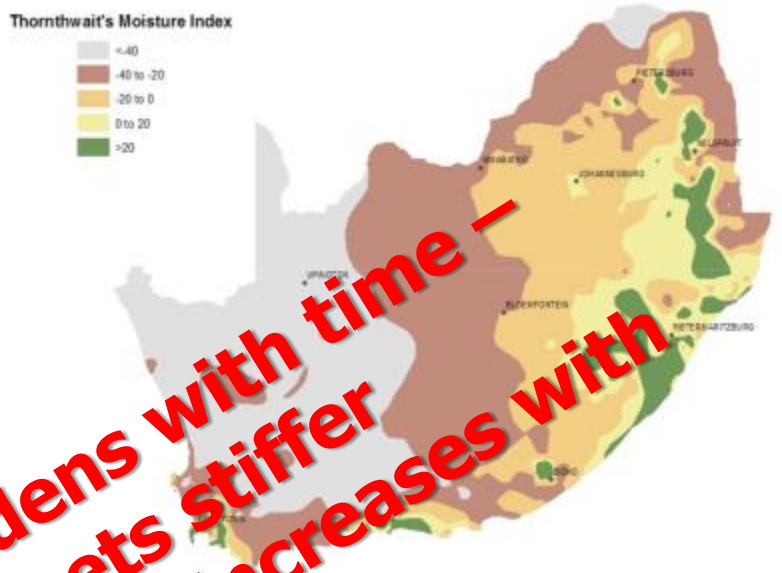
- Seal fatigue cracking function of:
  - Seal stiffness development
  - Binder Fatigue properties
  - Base stiffness (Radius of curvature)
  - Traffic loading
- Correlate
  - Binder hardening with 4PB seal stiffness
  - Observed crack initiation with 4PBfatigue



Cumulative damage to fatigue

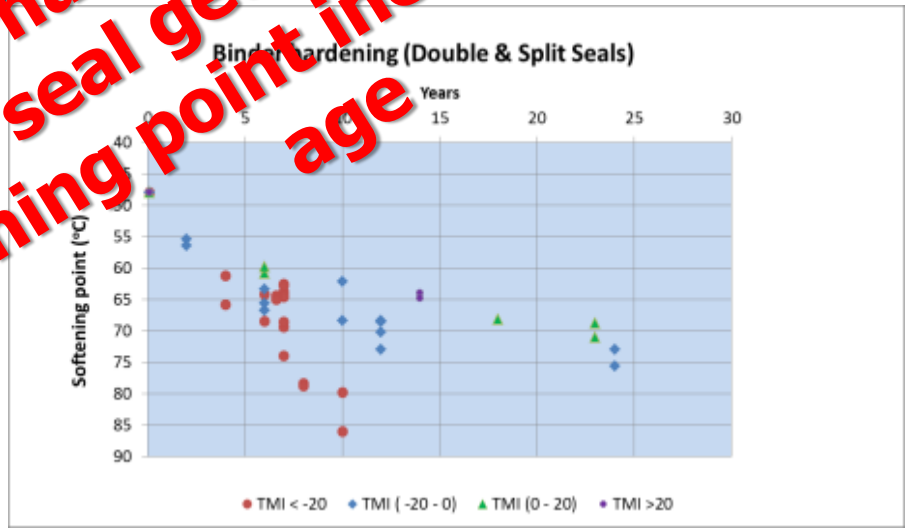
Binder hardening

- Different for
  - Different seal types
  - Age
  - Climatic zones
  - Binder type and initial quality (properties)



Binder hardens with time – seal gets stiffer

Softening point increases with age



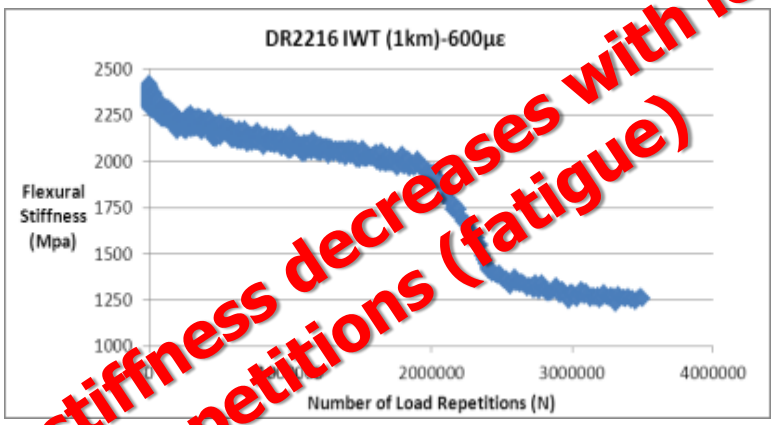
- Results

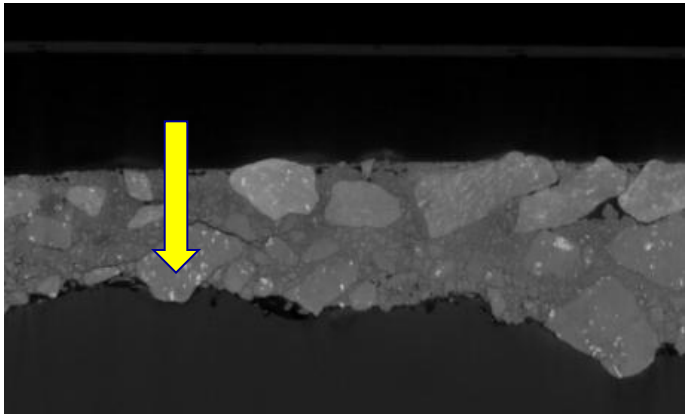
Mukandile
Relate to
PAV

Van Zyl
Input Seal
Stiffness

Quantifying Stiffness & Fatigue Characteristics

- Romei Cloete (SU M Student)

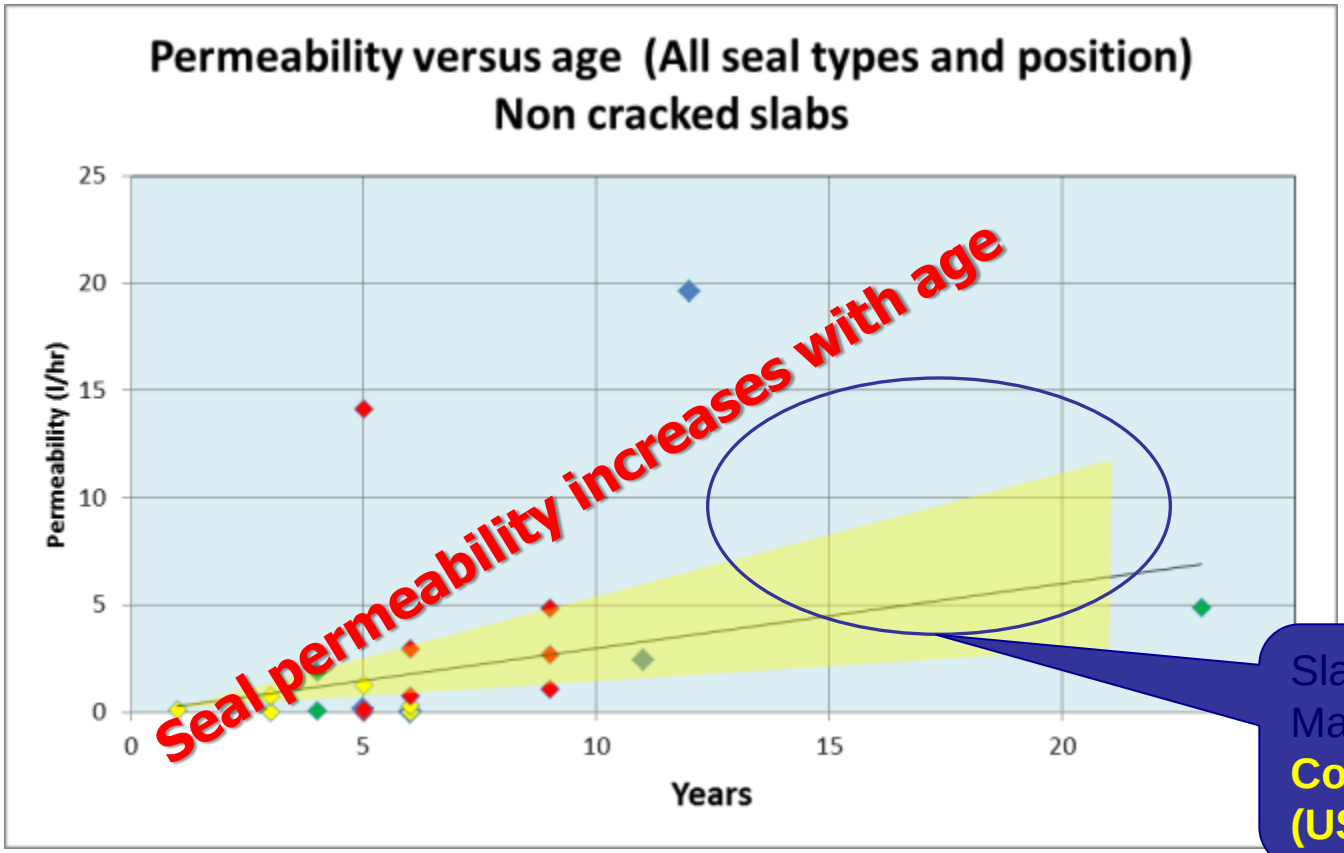




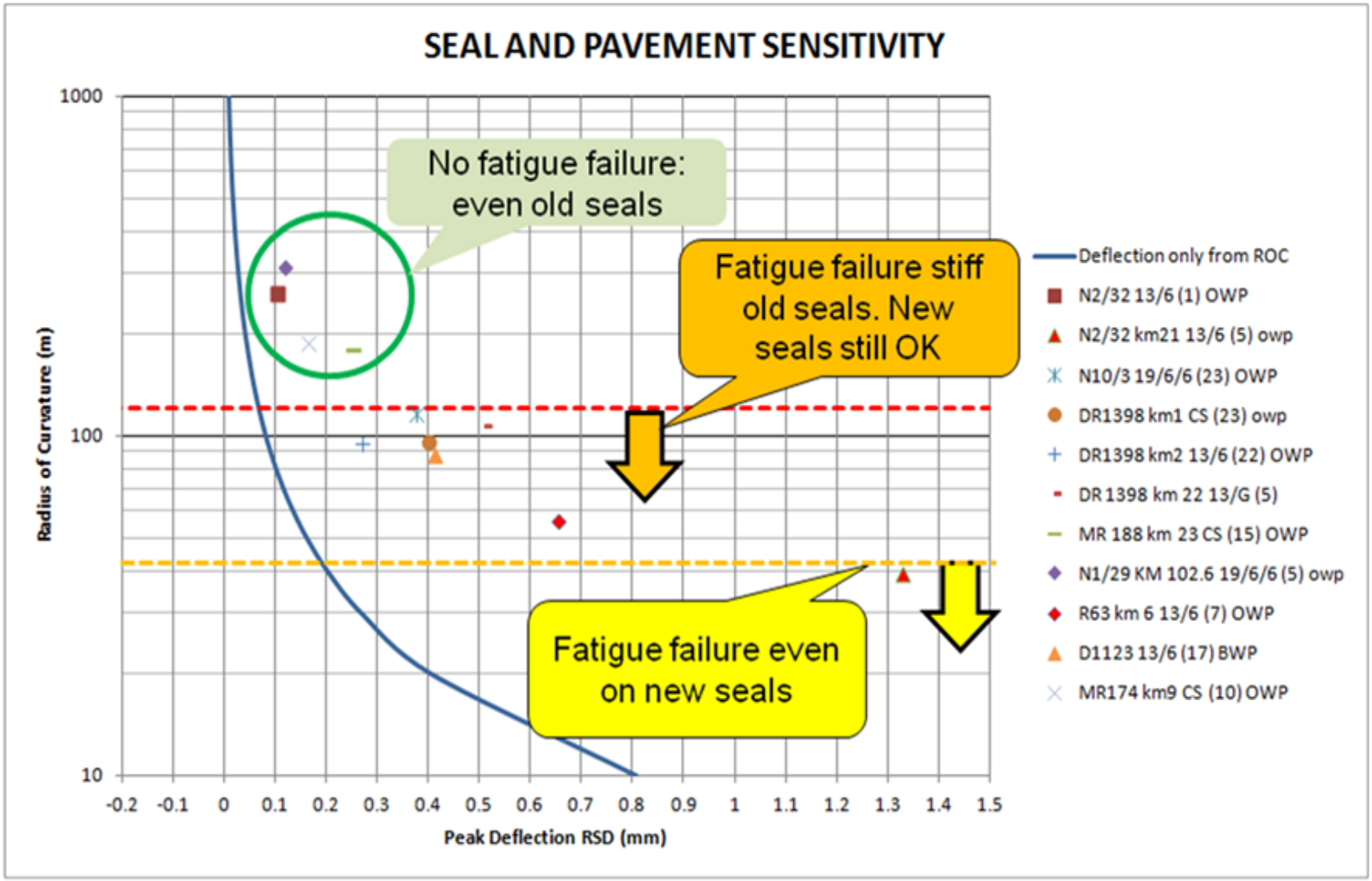
Seal stiffness decreases with load repetitions (fatigue)

Marvil Permeability

- Only proportion through to base



Crack assessment vs ROC

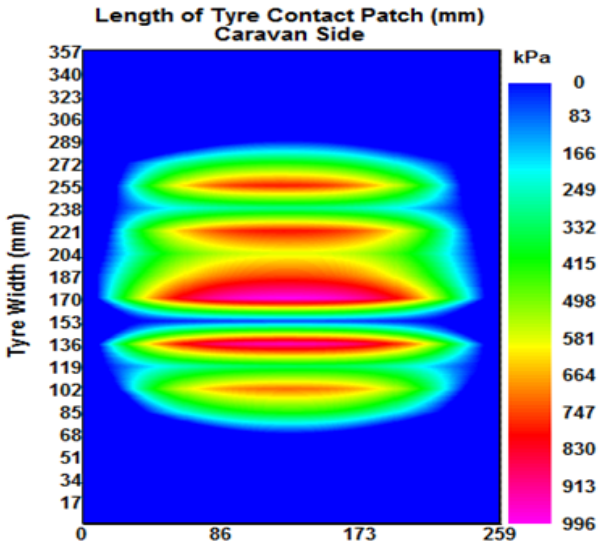


Seal System

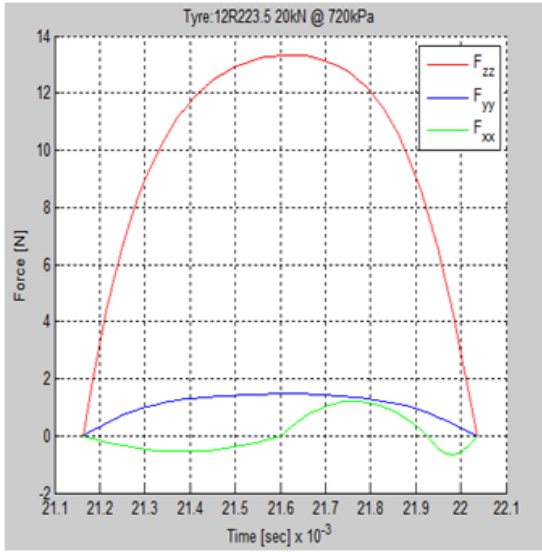
- Johan Gerber

Tyre loading & traffic loading

Measured Tyre Loading [B1]	→	Applicable Research	→	Refined Traffic Loading [B5]
• Tyre type • Vertical load (kN) • Tyre inflation pressure (kPa)		• Position under tyre • Free rolling wheel • Driven/Brake wheel • Travelling velocity • Surface texture • Travelling slope		• Converted from 3D to 2D • Point load signals (N) • Adjusted according to research

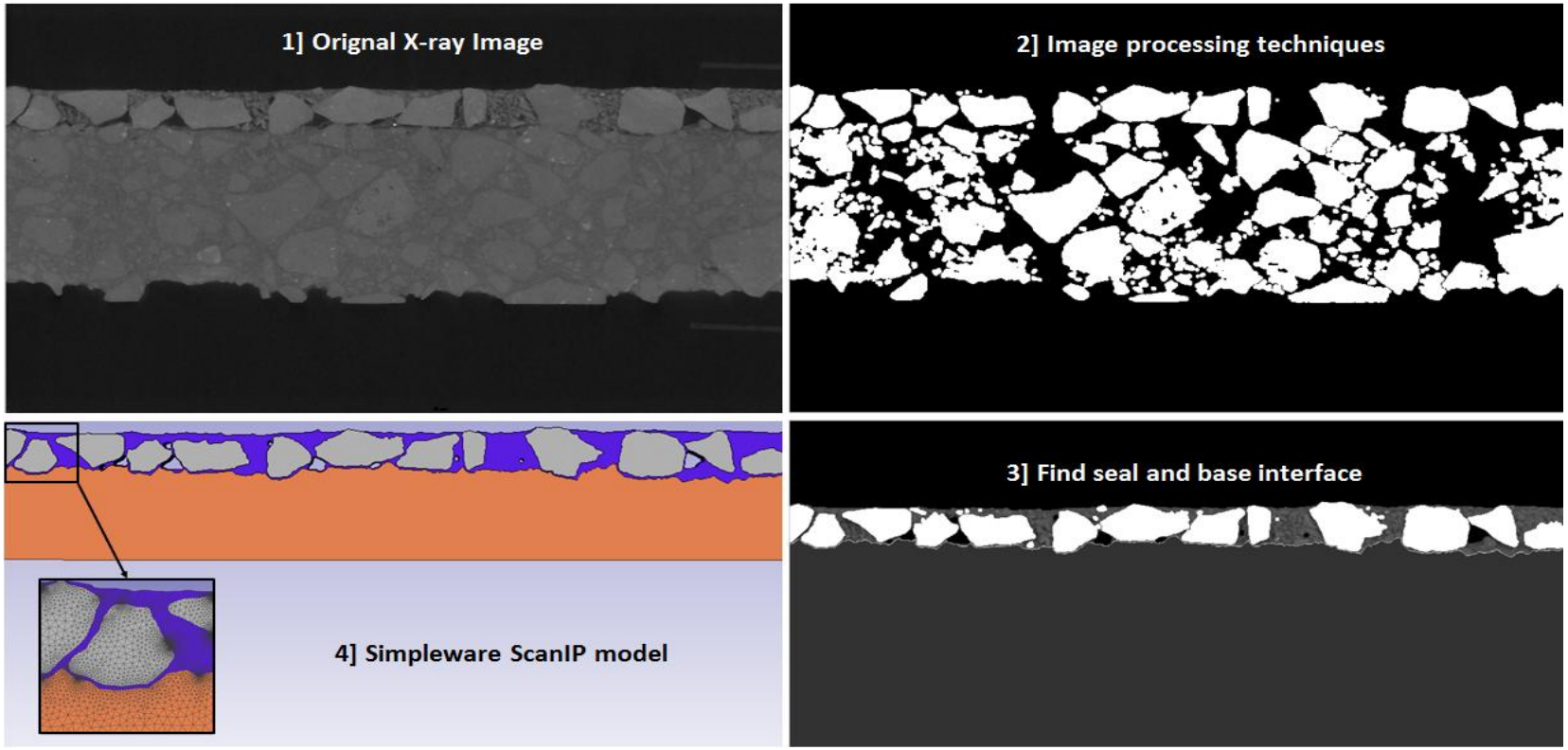


→ Applicable Research →

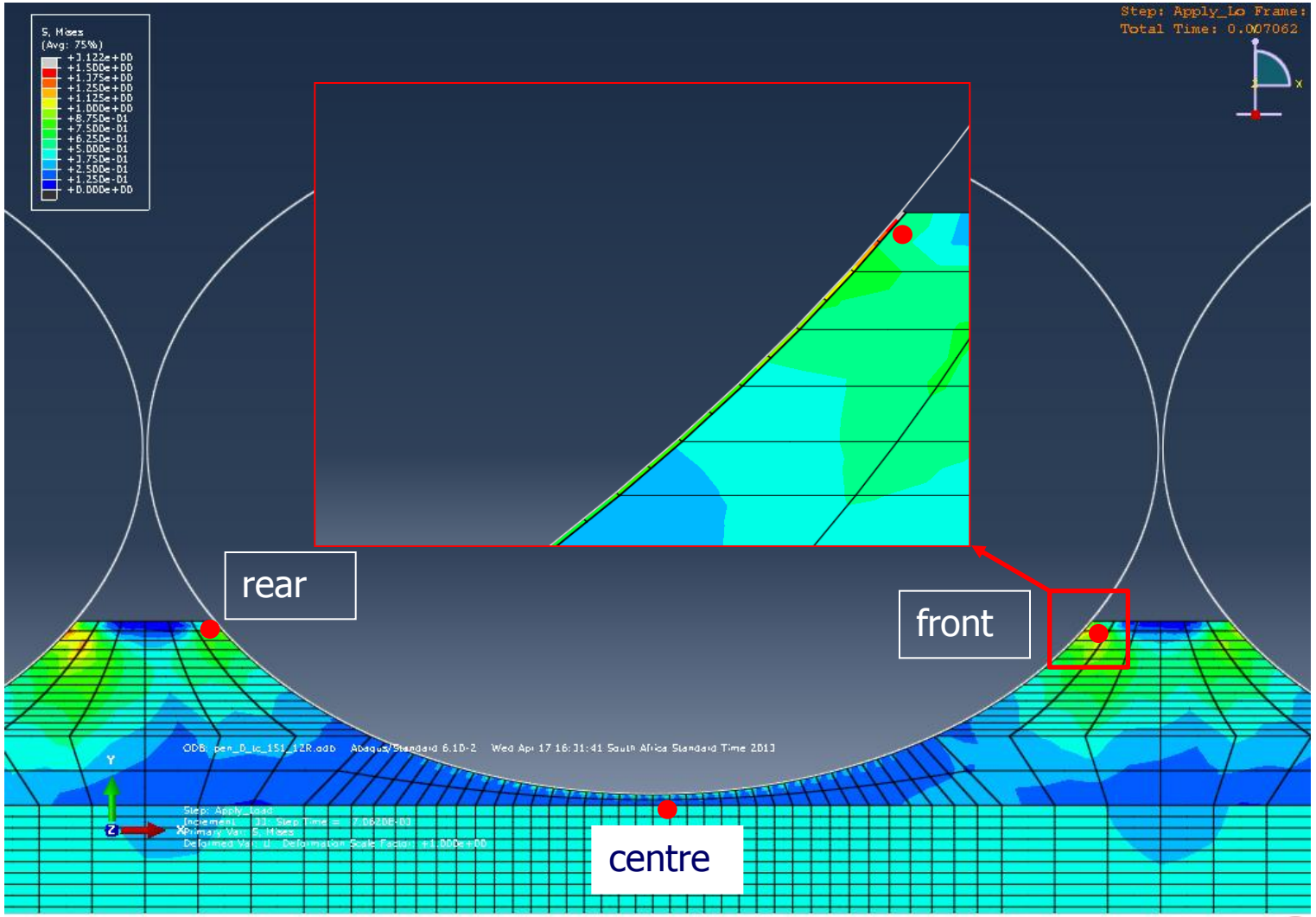


Mechanistic Seal Model

- X-ray 2D computer tomography model process



System development



Performance Model

- Performance measured in:
  - Adhesion failure [ravelling/stripping]
  - Cohesion failure [fatigue/cracking]
  - Embedment failure [punching/bleeding]
- Performance model variables overview

Component	→	Description		Number of combinations or variables
Traffic	→	Single wheel load	Wheel type, tyre load, tyre inflation pressure etc.	1242
Materials	→	Aggregate	Type, nominal size, ALD, spread rate etc.	81
		Binder	Type, response at temperature, app. rate etc.	180
		Fog Spray	Type, response at temperature, app. rate etc.	36
		Base	Base response char., construction embedment etc.	81
Model	→	Seal type	Single, Double & Cape	6
		Boundary Conditions	Radius of Curvature, max surface deflection etc.	16

Total Models: 5.069×10^{12}

Improved Damage Models for Bituminous Materials: Bituminous Materials

- Estimé Mukandila

Integration Between Different Components Of Seal Project

Input Material Model (DSR Data) [Estimé]

Response Output: master curves, Prony series	Adhesion output: Dissipated energy parameter: W_0, n	Cohesion output: Dissipated energy parameter: σ_0, n_0

Input Seal Model (Prony series, Constitutive material model, Environmental conditions, Traffic load model) [Johan]

Output: N_f function of binder application rate	For different types of tyre and given load

DSR to characterise binder and performance modelling

Calibration of seal model with site data [Gerrie]

Cracking initiation model (HDM)	Model Cumulative damage	Moisture ingress	Embedment, void and texture loss

Deliverable of material characterisation and modelling

Inception reference	Item	Deliverable	Comments
B3	Binder Characterisation (Response Model)	1 Master curve (Christensen formula	16 Equations per binder type (for 4 temp. and 4 binder conditions for each.)
		2 Prony series (G_0, α_i, τ_{ij}	16 prony series for each binder type
B6, B8	Cohesion (Fatigue Model)	W_0, n, $N_f=(W_0/W_i)^n$	Done at 0°C, 5°C, 10°C, 20°C (25°C)
B6, B8	Adhesion Model	σ_0, n_0, $N_f=(\sigma_{eq}/\sigma_0)^{n0}$	Done at 0°C, 5°C, 10°C, 20°C (25°C)

Apparatus and Accessories

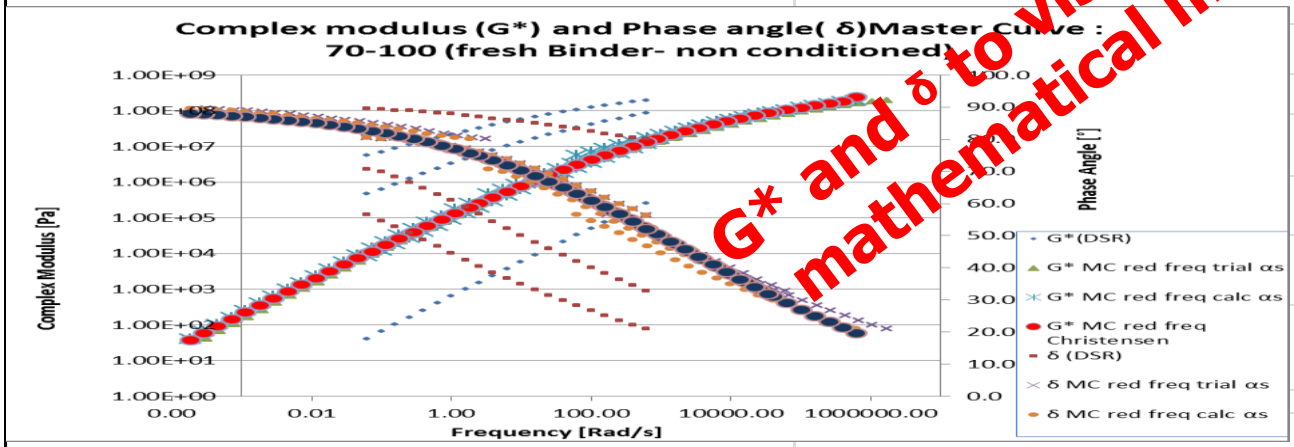
- Accessories

Binder Characterisation

Binder Characterisation (B3)

DSR
(Fresh, PAV, Recovered)

Master curve
ϰ
G*



G* and δ to visco-elastic mathematical models

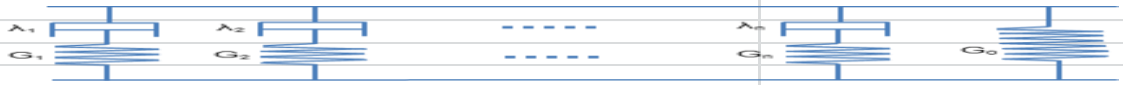
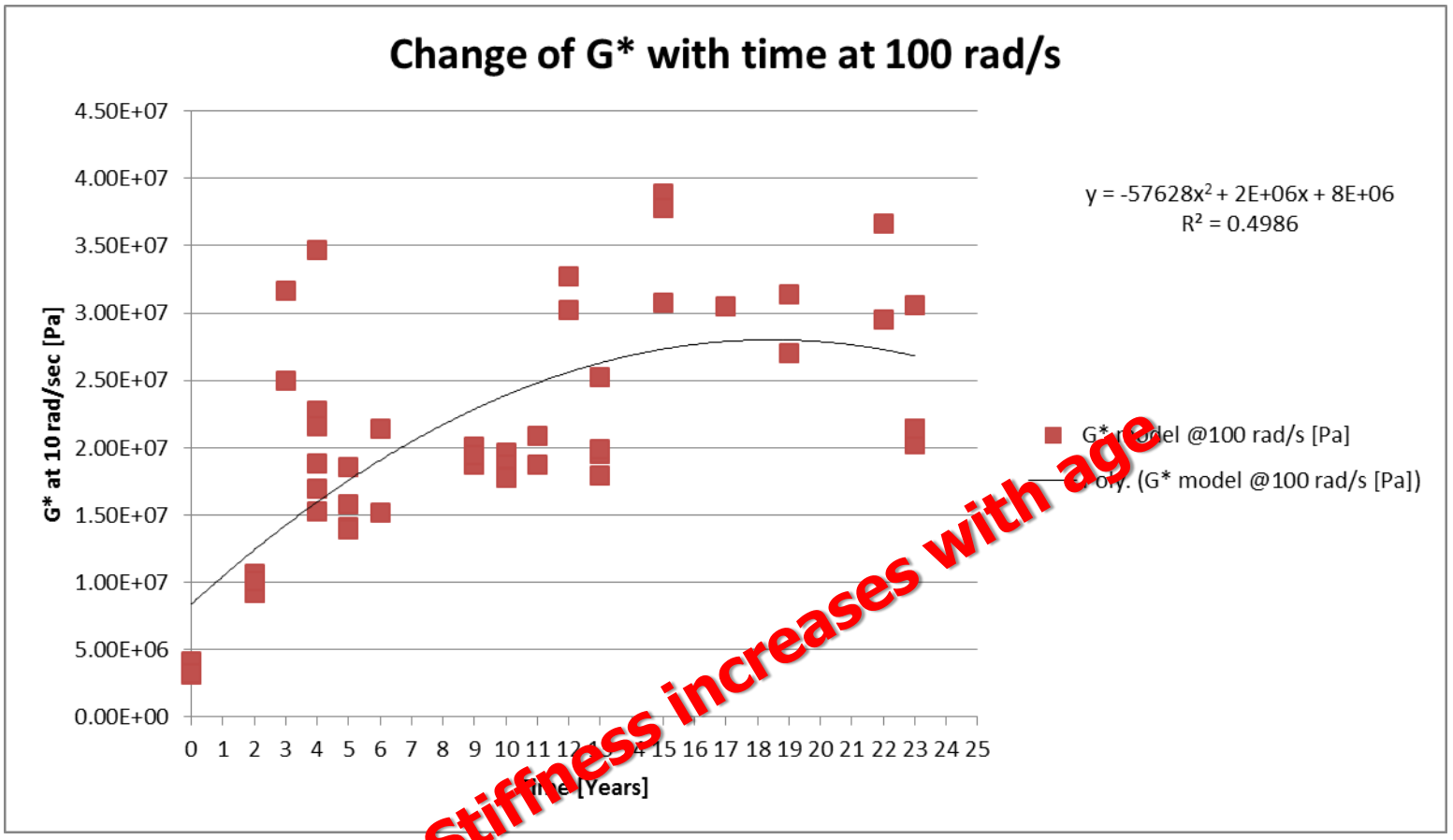


Figure 1.3: Prony series

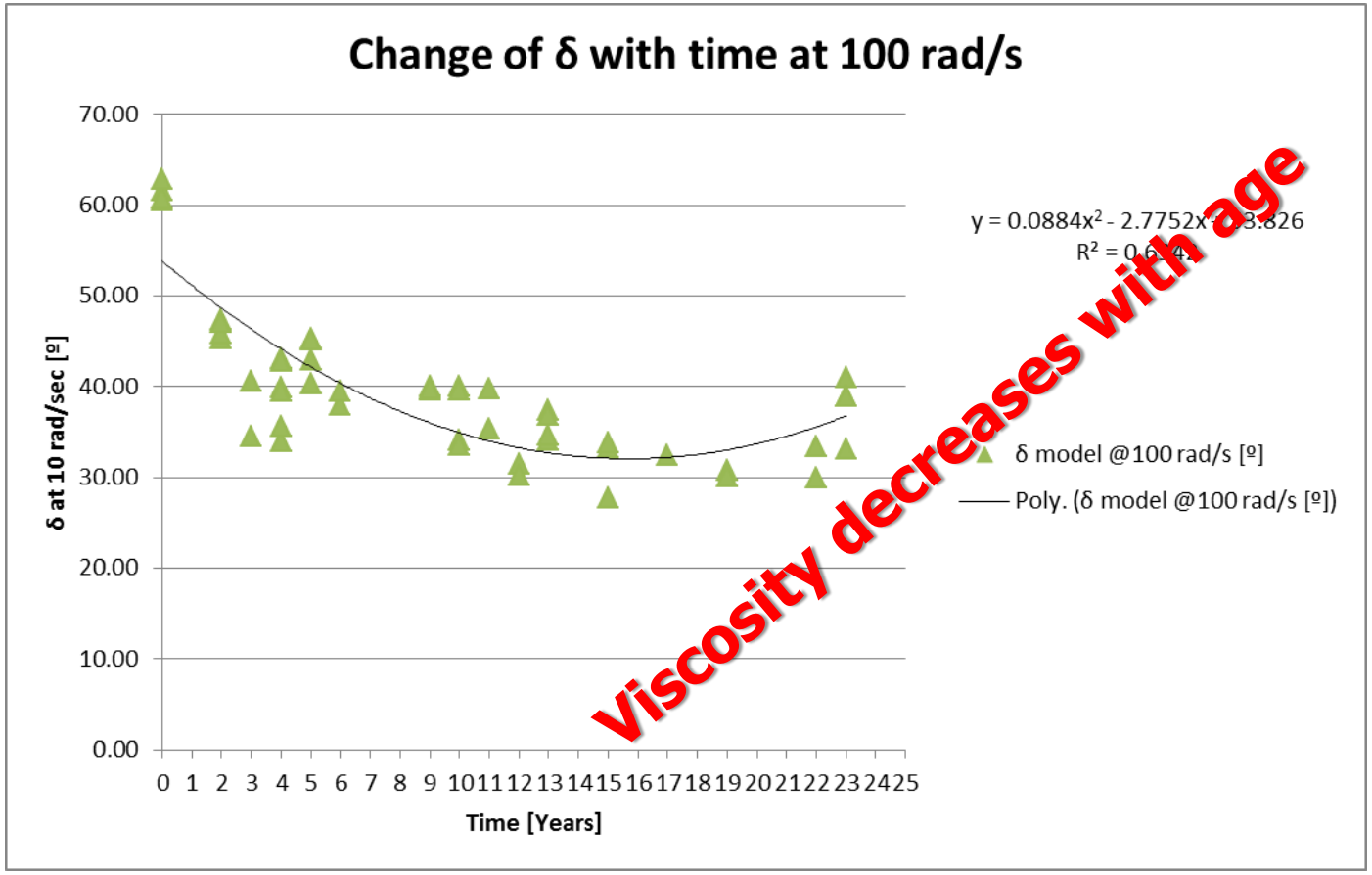
Current Progress on Bitumen charaterisation

- General aging trend using G*



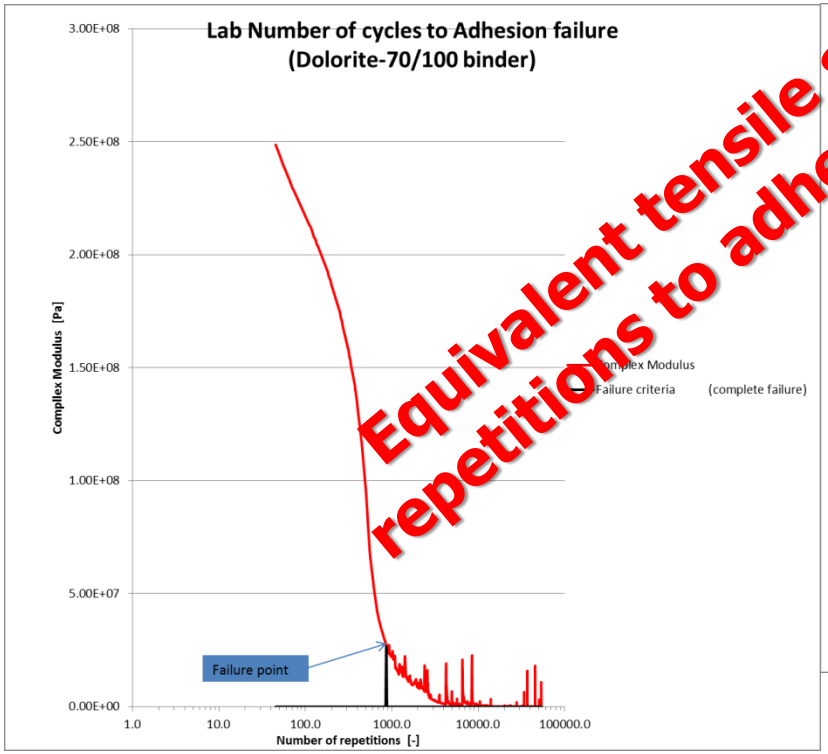
Bitumen Charaterisation

- General aging trend using δ

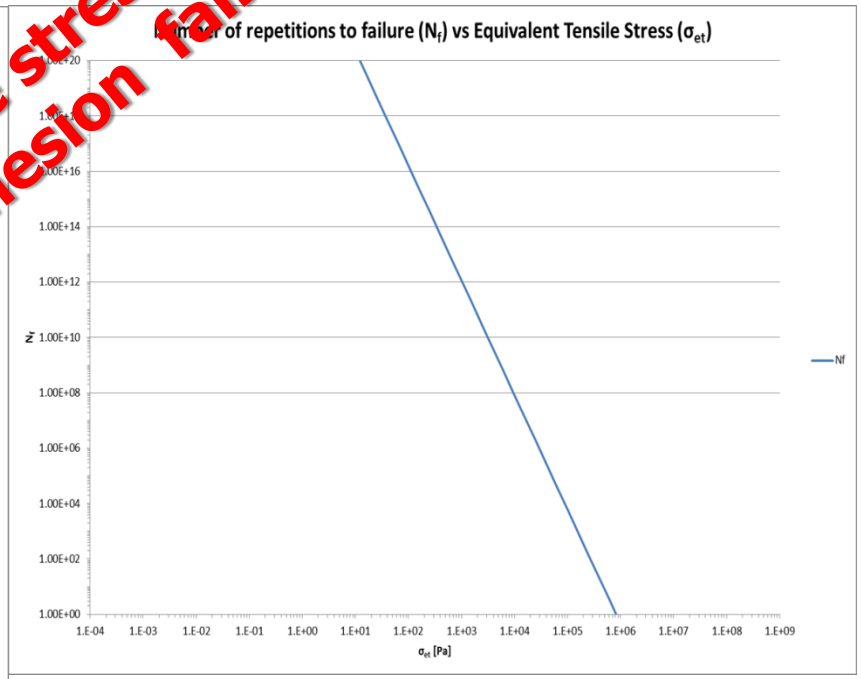


Adhesion model

- **Adhesion Model**

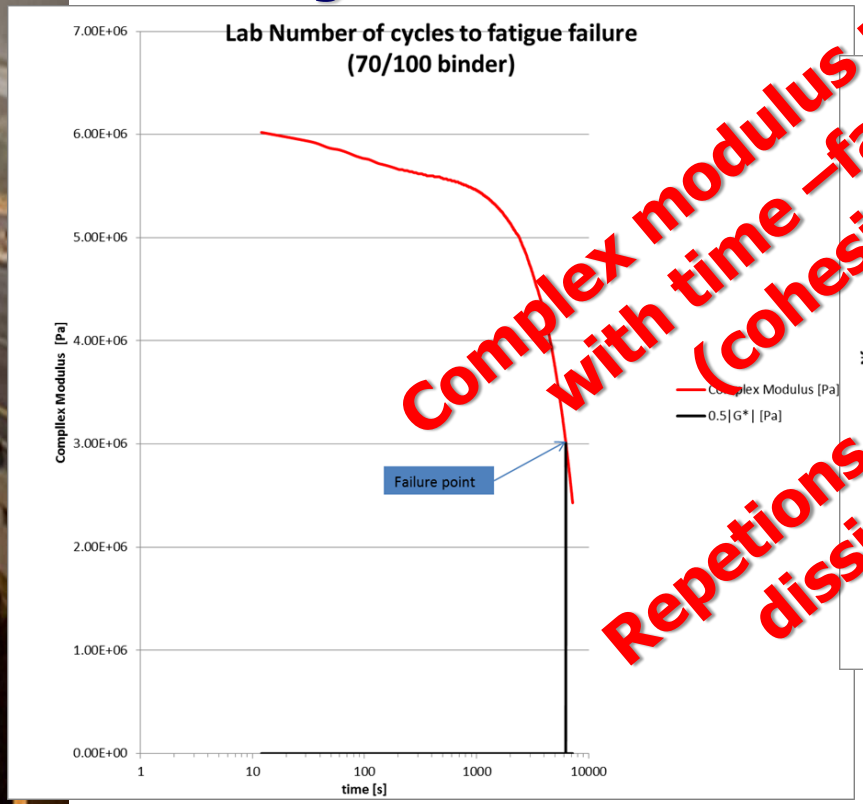


Equivalent tensile stress – repetitions to adhesion failure

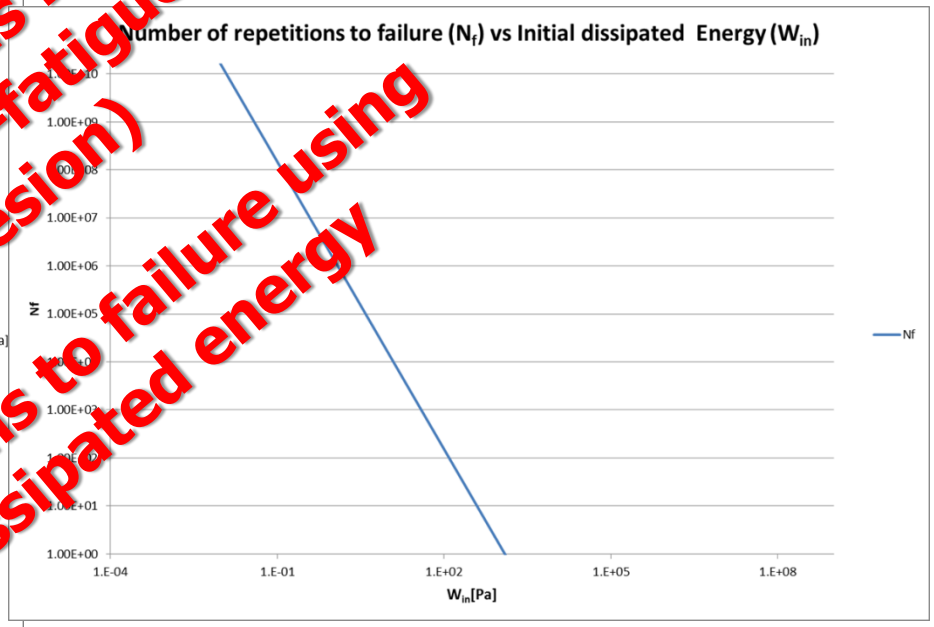


Cohesion model

- **Fatigue Model Cohesion**



Complex modulus reduces with time –fatigue (cohesion)



Repetions to failure using dissipated energy

Progress

	Task Title	Task Progress	T Milne	G van Zyl	M de Beer	A Visser	J Gerber	E Mukandile
A1	Inception Phase	100%	X					
B1	Investigate an appropriate mechanistic behavior model	80%					X	
B2-1	Tyre Loading (contact stresses)	100%	X					
B2-2		100%					X	
B2-3		100%						
B2-4		100%						
B3	Obtain/adapt materials behavioral, analysis and simulation equipment and laboratory equipment	60%						X
B4	Develop Behavioral Model (FEM)	75%						X
B4-1(i)							X	
B4-1(ii)							X	
B5	Develop the traffic loading input for the model						X	
B6	Model parameters (materials,yield limits) (lab testing)							X
B7	Performance Model(run model. Generate curves)						X	
B8	Mechanistic behavior model (mathematics simulati							X
C1	Field Study: Road section for surfaci			X				
C2	Field Verification of sites to i	90%		X				
C3	Laboratory testing of field samples	60%		X				
C4	Verify the model	25%		X				
D1	Colation,Integration, quarterly and final reports a t	5%				X		
E1	Project Management	60%	X	X				

70% complete
Big push to March 2014

Whats coming next?

- Full single seal system
  - Binder types and application
  - Base types
  - Traffic
  - Environment
  - Ageing
  - Aggregate types and application

Thank you